DEPARTMENT OF TERRESTRIAL MAGNETISM
J. A. Fleming, Director

Scientific Results of Cruise VII of the CARNEGIE during 1928-1929
under Command of Captain J. P. Ault

OCEANOGRAPHY – III

Ocean Atmospheric-Electric Results

O. W. TORRESON W. C. PARKINSON
O. H. GISH G. R. WAIT

CARNEGIE INSTITUTION OF WASHINGTON PUBLICATION 568
WASHINGTON, D. C.
1946

This book first issued June 15, 1946

PREFACE

Of the 110,000 nautical miles planned for the seventh cruise of the nonmagnetic ship Carnegie of the Carnegie Institution of Washington, nearly one-half had been completed on her arrival at Apia, November 28, 1929. The extensive program of observation in terrestrial magnetism, terrestrial electricity, chemical oceanography, physical oceanography, marine biology, and marine meteorology was being carried out in virtually every detail. Practical techniques and instrumental appliances for oceanographic work on a sailing vessel had been most successfully developed by Captain J. P. Ault, master and chief of the scientific personnel, and his colleagues. The high standards established under the energetic and resourceful leadership of Dr. Louis A. Bauer and his co-workers were maintained, and the achievements which had marked the previous work of the Carnegie extended.

But this cruise was tragically the last of the seven great adventures represented by the world cruises of the vessel. Early in the afternoon of November 29, 1929, while she was in the harbor at Apia completing the storage of 2000 gallons of gasoline, there was an explosion as a result of which Captain Ault and cabin boy Anthony Kolar lost their lives, five officers and seamen were injured, and the vessel with all her equipment was destroyed.

In 376 days at sea nearly 45,000 nautical miles had been covered (see map, p. iv). In addition to the extensive magnetic and atmospheric-electric observations, a great number of data and marine collections had been obtained in the fields of chemistry, physics, and biology, including bottom samples and depth determinations. These observations were made at 162 oceanographic stations at an average distance apart of 300 nautical miles. At each station, salinities and temperatures were obtained at depths of 0, 5, 25, 50, 75, 100, 200, 300, 400, 500, 700, 1000, 1500, etc., meters, down to the bottom or to a maximum of 6000 meters, and complete physical and chemical determinations were made. Biological samples to the number of 1014 were obtained both by net and by pump, usually at 0, 50, and 100 meters. Numerous physical and chemical data were obtained at the surface. Sonic depths were determined at 1500 points and bottom samples were obtained at 87 points. Since, in accordance with the established policy of the Department of Terrestrial Magnetism, all observational data and materials were forwarded regularly to Washington from each port of call, the records of only one observation were lost with the ship, namely, a depth determination on the short leg between Pago Pago and Apia.

The compilations of, and reports on, the scientific results obtained during this last cruise of the Carnegie are being published under the classifications Physical Oceanography, Chemical Oceanography, Meteorology, and Biology, in a series numbered, under each subject, I, II, and III, etc.

A general account of the expedition has been prepared and published by J. Harland Paul, ship's surgeon and observer, under the title The last cruise of the Carnegie, and contains a brief chapter on the previous cruises of the Carnegie, a description of the vessel and her equipment, and a full narrative of the cruise (Baltimore, Williams and Wilkins Company, 1932; xiii + 331 pages with 198 illustrations).

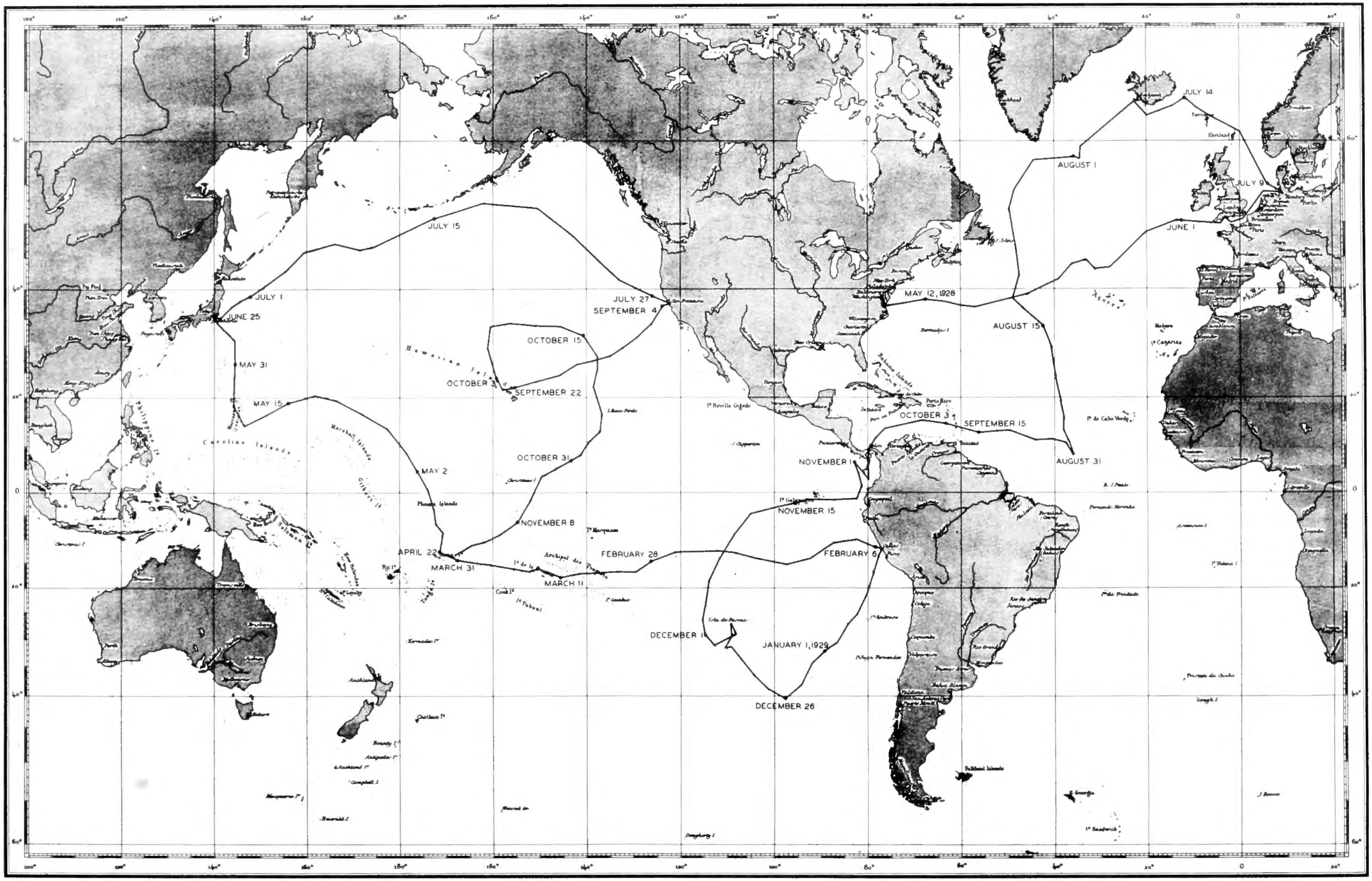
The preparations for, and the realization of, the program would have been impossible without the generous cooperation, expert advice, and contributions of special equipment and books received on all sides from interested organizations and investigators both in America and in Europe. Among these, the Carnegie Institution of Washington is indebted to the following: the United States Navy Department, including particularly its Hydrographic Office and Naval Research Laboratory; the Signal Corps and the Air Corps of the War Department; the National Museum, the Bureau of Fisheries, the Weather Bureau, the Coast Guard, and the Coast and Geodetic Survey; the Scripps Institution of Oceanography of the University of California; the Museum of Comparative Zoölogy of Harvard University; the School of Geography of Clark University; the American Radio Relay League; the Geophysical Institute, Bergen, Norway; the Marine Biological Association of the United Kingdom, Plymouth, England; the German Atlantic Expedition of the Meteor, Institut für Meereskunde, Berlin, Germany; the British Admiralty, London, England; the Carlsberg Laboratorium, Bureau International pour l'Exploration de la Mer, and Laboratoire Hydrographique, Copenhagen, Denmark; and many others. Dr. H. U. Sverdrup, now Director of the Scripps Institution of Oceanography of the University of California, at La Jolla, California, who was then a Research Associate of the Carnegie Institution of Washington at the Geophysical Institute at Bergen, Norway, was consulting oceanographer and physicist.

In summarizing an enterprise such as the magnetic, electric, and oceanographic surveys of the Carnegie and of her predecessor the Galilee, which covered a quarter of a century, and which required cooperative effort and unselfish interest on the part of many skilled scientists, it is impossible to allocate full and appropriate credit. Captain W. J. Peters laid the broad foundation of the work during the early cruises of both vessels, and Captain J. P. Ault, who had had the good fortune to serve under him, continued and developed that which Captain Peters had so well begun. The original plan of the work was envisioned by L. A. Bauer, the first Director of the Department of Terrestrial Magnetism, Carnegie Institution of Washington; the development of suitable methods and apparatus was the result of the painstaking efforts of his co-workers at Washington. Truly, as was stated by Captain Ault in an address during the commemorative exercises held on board the Carnegie in San Francisco, August 26, 1929, "The story of individual endeavor and enterprise, of invention and accomplishment, cannot be told."

The present volume is concerned with investigations during cruise VII on the electrical conditions of the lower atmosphere. In the introduction, O. H. Gish, Assistant Director of the Department of Terrestrial Magnetism, discusses the importance of studying these conditions over the oceans.

On previous cruises all the atmospheric-electric observations were made with eye-reading instruments. On cruise VII recording instruments were used for the first time for continuous measurements of the potential-gradient and the positive and negative conductivities. Eye-reading observations of the concentration of condensation nuclei, the concentration of small ions, the production of ions by penetrating radiations, and radioactive content of the air were also made daily. One section of the volume describes instruments and observational procedures.

Various conditions of weather, sea, and vessel must



Route of the Carnegie, May 1, 1928 to November 18, 1929 be considered in any analysis of observed atmospheric-electric data. Because of the importance in interpreting measurements, detailed notes were kept of weather conditions, including nearby clouds, variations in wind direction and velocity, changing conditions of mist or haze, and other related meteorological factors. One section gives an abstract of these notes, as entered in the ship's log by the sailing officers and of the notes on engine operation. Positions of the mainsail were recorded by the observer in charge of the atmospheric-electric work.

W. C. Parkinson, senior scientific officer, was in charge of the atmospheric-electric program throughout cruise VII. O. W. Torreson, executive officer, assisted in the observations and computations from May 1928 through July 1929 and S. E. Forbush, who replaced him, for the remainder of the cruise.

Reports of the work done during each leg of the cruise were mailed at every port of call. These were examined at Washington and comments submitted promptly to the observers on board. These reports and the suggestions are included here because of potential value in future operations at sea.

A systematized program of observation was followed insofar as possible. Over two hundred and fifty complete daily observations were made for each of the elements included in the program. Diurnal-variation series of twenty-four consecutive hourly sets of observations were scheduled to be made at weekly intervals and thirty-two complete or partial series were obtained. Several of the series could not be completed because instrumental difficulties developed or unfavorable weather conditions made observing impossible. Compilations of the daily observations, diurnal-variation series, and the automatically recorded data are given in four tables in sections V to VIII. The final section (IX) comprises eight short discussions of studies of the great number of observational data.

O. W. Torreson edited and compiled the material for publication. This volume is the twelfth of the series "Scientific results of cruise VII of the Carnegie during 1928-1929 under command of Captain J. P. Ault." It is the third of the Oceanographical Reports.

J. A. Fleming
Director, Department of Terrestrial Magnetism

CONTENTS

I. THE SIGNIFICANCE OF ATMOSPHERIC-ELECTRIC OBSERVATIONS AT SEA

Why investigate atmospheric electricity at sea? What can be accomplished there that could not be accomplished more easily ashore? These are questions which no doubt have arisen in the minds of all those who have been concerned in one way or another with such investigations. Certainly when facing the difficulties always attending such measurements but increased at sea by the high average humidity, the salt-laden air, and the rolling and pitching of the vessel, observers must have emphatically propounded questions of equivalent import.

The answers which may be given today to these questions contain new aspects which could not have been seen fifteen years ago, when the first intensive program of atmospheric-electric observations at sea was inaugurated on the Carnegie. These years have seen important advances in the science of atmospheric electricity, advances which, to a marked degree, were derived from the data obtained at sea, and which present the phenomena of atmospheric electricity in a new and improved perspective. The answers to our questions and the full significance of atmospheric-electric observations at sea will be seen best if viewed in this perspective. It may assist in this respect to review briefly some aspects of the science. It will be recalled that in so far as concerns atmospheric-electric phenomena, the earth may be considered a large electrically conducting sphere, charged with negative electricity and surrounded by an atmosphere which to a small degree conducts electricity because of the presence there of electric carriers, or ions--some positive and some negative. The positive ions are attracted to the earth and tend to neutralize its negative charge, while those of negative sign are repelled. Thus neither the charge of the earth nor the conductivity of the atmosphere could continue long without some source of replenishment for each of them. Calculations show that the charge would fall to one-tenth its initial value in twelve minutes if the conductivity as observed remained undiminished.

The sources of replenishment of the ions in the air are such ionizing agents as the radioactive matter of the earth and of the atmosphere, together with the penetrating radiation which includes cosmic radiation. The charge of the earth is maintained by some elusive, unknown factor, which we may call the supply current. To ascertain the origin and character of this supply current constitutes one of the most important objectives in present day atmospheric-electric investigations.

Although the earth's charge or its measure--the potential-gradient at the surface--and the conductivity of the air, are both on the average constant, yet interesting variations occur in both these features. The conductivity which depends both on the number of small ions and on their mobility will be affected by variations in these elements. The variations in the mobility of these ions, however, is of only minor importance. It is the number of ions (small mobile ions) which is the controlling factor in conductivity. This number is dependent both on the rate at which ions are formed and on their rate of decay or diminution. As already mentioned, the radiations from the radioactive matter in the earth and the atmosphere, together with the penetrating radiation, are the ion-producing agencies. Over land the radioactive matter of the earth and air is the predominating agency, while at sea the only agency known to be active is the penetrating radiation. Ionization produced by the latter cause is nearly constant everywhere, whereas that produced by radioactive matter varies considerably with both time and place. The radioactive matter in the air produces more than half the ions which arise from radioactive sources over land. It comes originally from the soil, and hence varies from place to place, depending on the content and porosity of the soil. It varies with time under the influence of changes in soil temperature, variations in barometric pressure, and depends on the direction, velocity, and turbulence of the wind.

Although ions probably are produced at the average rate of about ten pairs per cubic centimeter per second over land, and at the rate of only one and one-half to two per cubic centimeter per second over the oceans, yet the average number of ion-pairs in a cubic centimeter of air near the earth's surface is roughly 500, not only over land but also at sea. The population of small ions in the air is determined by their birth rate and their death rate, or the rate of formation and rate of diminution. It is apparent then that the rate of diminution over land is considerably greater than over sea.

The rate of diminution depends in part on the recombination which takes place between positive and negative small ions, and in part on the union of these small ions both with large, relatively immobile, ions and with certain electrically neutral particles or molecular complexes. These large ions and molecular complexes also serve as nuclei, or starters, in the condensation of water vapor. On this account they are called condensation nuclei. Everywhere in the lower kilometer of the atmosphere these nuclei occur in sufficient abundance to constitute the element which chiefly determines the rate of diminution of small ions. Their number and corresponding effect in decreasing the average life of small ions are much greater over land than at sea and are subject to large fluctuations which, especially in the vicinity of cities, often arise from man-made conditions.

The conductivity of the atmosphere thus affected has in turn an influence on the earth's charge and on its attendant electric force, or potential-gradient. Thus, for example, the low and fluctuating conductivity in the vicinity of cities gives rise to high and fluctuating values of the potential-gradient. The earth's charge, however, as measured by the potential-gradient varies from other causes. Thus, the electric charges generally connected with dust, smoke, fog, etc., and especially those intense charges which are developed in thunderstorms, all affect the potential-gradient directly. Effects arising from these causes will obviously vary in an irregular manner from place to place and from time to time, especially over land.

There is also another source of variation in the potential-gradient, to which attention is especially invited. From a study of the potential-gradient data obtained on cruises IV, V, and VI of the Carnegie, Mauchly was able to conclude that the regular change in this element during the day over the ocean proceeds on a universal schedule. Thus, for example, high values tend to occur everywhere at about 18 to 20 hours (6 to 8 p.m.) in Greenwich meridian time. Also, later he found evidence which supports the view that the same phenomenon occurs over land. Other effects such as have been mentioned already, however, and which are of very local origin, are there entangled with the general world-wide effect. Thus we see here evidence of a phenomenon world-wide in extent and simultaneous in occurrence, the manifestation of a factor which affects the entire earth at the same instant of time and which waxes and wanes in a regular manner throughout the day. This factor is likely the supply current. That it was possible to make a discovery of such far-reaching importance on the basis of the relatively small amount of data available at the time emphasizes not only the feasibility of measurements at sea but also the advantage of studying atmospheric-electric phenomena under the relatively simple conditions which prevail over the oceans. Under simple conditions fewer data are required in a given locality and with a moving observatory measurements at widely distributed localities may be obtained, a point of importance to the study of a world problem. On cruise VII, for the first time at sea, the potential-gradient measurements were made with a recorder instead of with eye-reading apparatus, and many days of record obtained.

In order to ascertain the effects of the various factors which determine the conductivity of the air at sea, measurements were made on cruise VII of both positive and negative conductivity, of ionic density, of the penetrating radiation, of the radioactive content of air at sea, and of the number of condensation nuclei. During the earlier part of the cruise the conductivity was measured by an eye-reading method, but beginning at San Francisco the apparatus which provided a continuous photographic record was used. The other measurements were obtained with eye-reading instruments. An additional instrument for measuring penetrating radiation and of a type different from that used on the Carnegie since 1915, including the present cruise, was put into use at Hamburg. The purpose of this was both to ascertain more definitely the absolute amount of ionization which is produced in the air by this source and to ascertain whether variations occur in this factor. In addition to the regular daily program of all these measurements, series extending throughout twenty-four consecutive hours were made as frequently as possible for the purpose of studying the diurnal variation.

Over 250 complete daily observations were obtained for each of the several elements included in the program. The diurnal-variation series, which were scheduled to be made at weekly intervals, were attempted on thirty-two occasions. Several of the series could not be completed because of the development of instrumental difficulties or unfavorable weather. Completed series ranged from sixteen in the case of nuclei concentration, to twenty-seven in the case of conductivity, with the series for small-ion concentration being completed on twenty occasions. It is also of considerable interest to note that satisfactory records of air potentials were obtained between August 7, 1928 and November 18, 1929, for 181 complete days, of which 160 days were free from negative potential, and that in the interval between San Francisco and Apia, Samoa, September 3 to November 18, 1929, complete and satisfactory records of conductivity were obtained for 58 days. Thus the recorders yielded satisfactory data at a rate which in the case of the potential-gradient was eight times, and in the case of the conductivity twelve times, the rate maintained when using eye-reading methods for diurnal-variation series.

The gratifying success of this program in great measure is owing to the interest of the Commander, J. P. Ault, to the enthusiasm, diligence, and skill of W. C. Parkinson, senior scientific officer, who was in charge of the atmospheric-electric work throughout the cruise, and to O. W. Torreson, executive officer from Washington to San Francisco, and S. E. Forbush, executive officer from San Francisco to Apia, who aside from their other duties assisted in various parts of this work.

II. INSTRUMENTS, OBSERVATIONAL PROCEDURE, AND CONSTANTS

Among the chief difficulties associated with atmospheric-electric work at sea is that of overcoming the effect of the ship's motion on the measuring instruments and of securing good insulation of the instruments. For satisfactory observing with the ship's motion, bifilar and unifilar electrometers were adopted on early cruises of the Carnegie (1) and their use was continued on cruise VII. Bifilar electrometers of Wulf's design, as modified by the Department of Terrestrial Magnetism, were used and unifilar electrometers of the Einthoven type as modified by Wulf. In both types of electrometers very fine fibers spun from quartz, made conducting by a very thin coating of gold or platinum, constitute the measuring elements. The fibers, of the thickness of fine spider-threads, are attached at their upper ends to the amber-insulated main terminal of the electrometer and at their lower ends to a bow or circle also made of a quartz fiber but not coated. The bow or circle maintains tension on the fiber system at all times. The amber and quartz mountings provide satisfactory insulation for the fibers.

In the bifilar instrument the two fibers are attached at the same point both at top and bottom. When the fibers are electrically charged they repel each other, and the resulting deflection can be read with a microscope suitably mounted in relation to the fibers and containing a graduated scale in the eyepiece. This type of instrument is useful where a sensitivity no greater than one-half to one division per volt is required. The fibers are mounted inside a housing consisting of an inner and an outer case. The inner case is insulated from the outer as well as from the fiber system, so that by raising or lowering its potential, by means of batteries, the readings of the instrument can be brought to any desired part of the scale in the eyepiece. The auxiliary potential on the inner case also permits the instrument to be used for any desired range of potential.

In the unifilar electrometer, instead of an inner case, two insulated metal plates are mounted, one on each side of the fiber, with their planes parallel to each other and to the quartz fiber. With the case of the instrument earthed, and the plates charged to say +100 volts and -100 volts respectively, or any other convenient amount, any charges communicated to the fiber will cause it to be deflected. The sensitivity of the electrometer may be altered either by changing the field between the plates or by changing the tension on the fiber. The latter may be accomplished by adjusting the position of the support of the bow or circle at the lower end of the fiber.

Batteries used for supplying potentials to the inner cases of bifilar electrometers or to the plates of unifilar instruments for the early part of cruise VII, were of the silver chloride type, in banks of 100 cells each, and giving approximately 100 volts potential, but for the greater part of the cruise commercial 45-volt "B" batteries gave very satisfactory service. Both types of batteries were protected as well as possible from the moist sea air and the spray by being installed in closed cabinets in the atmospheric-electric observing cabin, on shelves below deck, or in other closed compartments, suitable connecting wires being brought to the instruments from these locations.

The observing cabin on cruise VII was the same size and shape as on previous cruises and was located in the same place, although it was rebuilt just before cruise VII was begun. It stood between the mainmast and the after magnetic dome and was midway between the port and starboard rails. Thus it was not far forward of the quarter-deck (figs. 1, 2). The rebuilt cabin was equipped with convenient electric outlets for obtaining 110-volt direct current for lights and motors from the ship's power plant in the engine room. The cabin also contained shelves, storage compartments, and work tables or benches.

Within the cabin there were permanently mounted four atmospheric-electric instruments, together with numerous items of auxiliary equipment including control and calibrating apparatus. Along the port wall, in gimbals attached to the ceiling of the cabin, were disposed ion counter 1 (IC1), penetrating radiation apparatus 1 (PR1), and radioactive content apparatus 4 (RCA4). These pieces of apparatus were designed and constructed by the Department for use on cruises IV, V, and VI but were overhauled, improved in some respects, and put in good working condition before installation for cruise VII (figs. 3, 4, 5). Along the after and starboard walls were work tables and benches. At Hamburg, Germany, in July 1928, a portable penetrating radiation apparatus was added to the atmospheric-electric equipment, designated as Kolhörster apparatus 5503. When used for simultaneous observations with PR1, it was placed on a shelf in the atmospheric-electric cabin just beneath PR1 (fig. 6).

On the forward wall of the cabin was a shelf for the conductivity apparatus. The conductivity apparatus was new and arranged otherwise for cruise VII than for previous cruises. On previous cruises the tube through which the sample of air was drawn for the conductivity measurements had been located horizontally just above the roof of the cabin near the after end, with the electrometer located centrally below it within the cabin, supported in a gimbal mounted on the ceiling of the cabin. A large wooden box covered the tube when the apparatus was not in use. For cruise VII a vertical air-flow tube was adopted, standing at the port end of the shelf on the forward wall of the cabin and extending through the roof, and capped with a conical hood at a height of approximately one meter (figs. 7, 8). The new apparatus was designated 8A (CA8A), and was planned for continuous registration of conductivity. The recording equipment was not completed by May 1928, however, and only the air-flow tube and central cylinder and their appurtenances were installed at the beginning of the cruise. An eye-reading electrometer was utilized in place of the uncompleted recording equipment for measuring conductivity in the same manner as on previous cruises.

Figure 7 shows the eye-reading electrometer fastened to the shelf and making connection to the insulated central cylinder of the air-flow system through a small connecting tube. Below the shelf the vertical tube was connected to a horizontal duct running along the port wall, and at an aperture in the after wall at the end of the duct a motor-driven fan was mounted to draw the air through the air-flow system. The eye-reading electrometer was used for conductivity measurements from the beginning of cruise VII in May 1928, until the ship arrived at San Francisco at the end of July 1929. While in port at San Francisco, recording apparatus was installed and continuous records of conductivity were obtained for the three months September to November 1929--the remainder of the cruise. Positive and negative conductivity were recorded on alternate days, so approximately equal amounts of data were collected for each sign (fig. 9).

In addition to the measurements made in the observing cabin, of conductivity, ion content, penetrating radiation, and radioactive content, measurements of potential-gradient were made at the stern rail as on previous cruises. Eye-reading observations were made with potential-gradient apparatus 2 from the beginning of the cruise in May 1928, until September 16, 1928 (fig. 10). Continuous recording of the potential-gradient was begun on the stern rail July 7, 1928, after unsuccessful attempts to record at the top of the mainmast and on the roof of the atmospheric-electric observing cabin (fig. 11). The recording apparatus employed four ionium-coated collectors mounted at the tip of an insulated collector rod, the latter being attached to the fiber system of one of two recording electrometers designated Günther and Tegetmeyer 4946 or 4947 (fig. 12). Recording of potential-gradient with this apparatus was continued on the stern rail to the end of the cruise in November 1929. A considerable number of parallel observations of potential-gradient with eye-reading and recording equipment was obtained between July 7 and September 16.

Measurements of the concentration of condensation nuclei in the air were added to the program of atmospheric-electric observations for cruise VII. A small portable nuclei counter (figs. 13, 14) of the type devised by John Aitken in 1890 (2) was used, the measurements being made on the ship's bridge. Nuclei counter 4 was employed for the initial part of cruise VII, but difficulties with it, arising from accidents, required its replacement. It was used until arrival at Callao, Peru, January 14, 1929, but during the stay at Callao, counter 5 was obtained from the Department's Huancayo Magnetic Observatory at Huancayo, Peru, and was used for the remainder of the cruise.

From the above brief summary the following list of apparatus for the measurements of the atmospheric-electric elements on cruise VII may be made.

- Ion counter 1
- Penetrating radiation apparatus 1
- Penetrating radiation apparatus 5503 (from July 7, 1928)
- Radioactive content apparatus 4
- Conductivity apparatus 8A (eye-reading to July 28, 1929; recording from September 3, 1929 to to November 18, 1929)
- Potential-gradient apparatus 2 (to September 16, 1928)
- Potential-gradient recorder 4946 (from July 7, 1928 to November 18, 1929, except twelve days in August 1928 when 4947 was used)
- Nuclei counter 4 (to January 14, 1929, then counter 5 to November 18, 1929)

In the following paragraphs the various types of apparatus will be described in sufficient detail to give the reader a background of information to assist in evaluating for himself the data presented later and the discussions which complete the volume. Much of the descriptive material was presented by W. F. G. Swann in connection with his preliminary discussions of the results of cruise VI (3), but is repeated here for convenient reference.

Potential-Gradient Apparatus 2.--This apparatus is shown in use in figure 10. A brass tube was attached at one end to an axle so that it could rotate about that axle. The axle was mounted on supports fixed to a platform located at the mid-point of the stern rail, and the brass tube carried at its projecting end an umbrella-shaped conductor made of fine mesh bronze screen. The handle by which the tube was rotated was insulated from the rod and axle, and the latter was insulated from earth by sulphur rings at each end which were fixed in the axle supports. The axle was connected by a thin wire to the insulated fiber system of bifilar electrometer no. 28, used for this work exclusively. A contact was provided such that when the umbrella-shaped conductor was hanging downward over the stern at its lowest position the electrometer fibers were earthed. On rotating the conductor to some higher position as fixed by a stop, a deflection proportional to the potential-gradient was obtained on the electrometer. Insulation difficulties were minimized by this arrangement, since the leak occurring in the brief time required for turning the conductor from one position to the other would be very small. Further, the operation could be performed so quickly that a reading could be obtained at any desired position of tilt of the ship. The sensitivity of the apparatus was considerable, and it was not difficult to arrange to get full-scale deflection for normal values of potential-gradient. The brass tube and umbrella-shaped conductor could be put in place or removed very quickly, and when the apparatus was not in use these were removed and the electrometer and axle were covered by a weatherproof box. Auxiliary potentials for the inner case of the electrometer were supplied from batteries stored in a small laboratory forward of the quarter-deck, the connecting wires being brought beneath the deck to a marine plug located conveniently near the apparatus. With such an auxiliary potential, the range of the instrument could be adjusted to suit the occasion, and further, the sign of the prevailing potential-gradient could be determined readily by noting the direction of movement of the deflected fibers when a small change was made in the potential of known sign applied to the inner case.

Procedure for Observations with Apparatus 2

1. Uncover the electrometer and axle; attach the brass tube and the umbrella-shaped conductor.
2. Examine the electrometer and axle for excessive dampness of insulators or for any foreign material that may be bridging across insulators.
3. Test for insulation leak. To do this raise and lower the umbrella several times. Note the response of the fibers of the electrometer to each raising. If there is no response, the insulation breakdown is complete. If the fibers return immediately to zero reading, the leak is comparatively large. If the maximum deflection is maintained sufficiently long so that the fiber readings may be noted in an unhurried manner, the insulation is satisfactory. Poor or bad insulation must be remedied by drying or cleaning the insulators.
4. Having satisfactory insulation, apply to the inner case of the electrometer auxiliary potential of such magnitude as to bring the deflections of the fibers with the umbrella raised to a position on the scale most convenient for rapid reading.
5. With the fibers earthed (umbrella down) observe

the fiber deflections to obtain the value of the auxiliary potential applied to the inner case. Record the fiber readings on a suitable form. (Department form No. 102)

6. Commence observations of potential-gradient at such a time that twenty readings taken one minute apart will center on the average time of the observations of conductivity, ion content, and nuclei content which are being made simultaneously. Record the readings for the twenty observations on the form. Between the tenth and eleventh readings repeat item 5.

7. After the twentieth observation repeat item 5.

8. Record the position of mainsail and boom for the period of observation.

9. Record appropriate notes of weather conditions for the period.

10. Remove brass tube and umbrella; replace cover over electrometer and axle.

11. Calibrate the electrometer at least once each week or more often if necessary, always with the inner case earthed. With batteries brought on deck, apply potentials in suitable steps to cover the desired range of deflections on the scale of the electrometer. Record the deflections and the battery voltages as determined with a suitable voltmeter, on the calibration form. (Department form 153a)

It was necessary, of course, to determine the factor by which the potential measurements should be multiplied to reduce them to values representative of the potential-gradient over an open, flat surface undistorted by the presence of the ship. For the reduction factor determinations a shore station was chosen at each of those ports where there was comparatively flat open land, free from trees and other objects, as nearly as possible at the level of the surface of the sea, and not too distant from the ship's anchorage (fig. 15). At the stations a wire approximately twenty meters long, having sulphur insulators attached at each end, was stretched horizontally between two posts about one meter high. A metal disc coated with ionium preparation was attached at the mid-point of the wire and throughout the observations the height of this "collector" was maintained as closely as possible at one meter. The stretched wire was connected at one end to an electrometer, located at a distance of two or three meters, by means of a fine wire, and simultaneous eye readings were taken with this apparatus and with the apparatus on the ship. Readings usually were made at one-minute intervals for fifty minutes of each hour, for a period of several hours. During ten minutes of each hour, the collector was removed from the stretched wire and the insulation of the insulators supporting the stretched wire and of the electrometer was tested. Bifilar electrometers 25 and 26 were used on different occasions for the shore observations.

With potential-gradient recorders 4946 and 4947 available for reduction-factor determinations as well as the eye-reading apparatus, continuous recording both on the stern rail of the ship and at the shore stations could be arranged. During cruise VII five shore stations were established and at each one some work was done with the recording equipment, while a recorder was operating also on the stern rail on all occasions except the first. On two occasions continuous recording was maintained both on ship and shore for several days.

Positions of the mainsail and mainsail boom were noted during reduction-factor observations as the boom and sail extended astern far enough to contribute to distortion of the field.

Careful note was made of weather conditions during these observations as it was known from previous work that nearby clouds, variations in wind direction and velocity, and changing conditions of mist or haze could cause widely divergent values of potential-gradient at the two locations, thus making the measurements obtained in such circumstances unsuitable for determining the reduction factor.

Reduction factor determinations were made as follows:

1. May 5, 1928 . . . . . . Kitts Point, Maryland, U. S. A.
2. July 25, 1928 . . . . . . Reykjavik, Iceland
3. Sep. 28-29, 1928 . . . Bridgetown, Barbados, B. W. I.
4. Dec. 9-10, 1928. . . . Easter Island
5. Apr. 10-13, 1929 . . . Apia, Western Samoa

The results obtained at these five stations were not consistent with each other, and a study was made of the data in an effort to determine the relative reliability of the separate sets of material. A detailed report on this study will be given later. Briefly, sets 1, 3, and 5 appeared to have the greatest reliability, and on the basis of these three the data from the other two were adjusted to give compatible reduction factors.

Potential-Gradient Recording Apparatus.--Cruise VII was the first cruise of the *Carnegie* for which arrangements were made for continuous recording of the potential gradient. Initially it was planned that only eye-reading apparatus 2 would be used at the stern of the ship as on previous cruises, and that continuous recording apparatus would be used at the top of the mainmast. It was found, however, on the voyage from Norfolk, Virginia to Plymouth, England, May 10 to June 8, 1928, that recording at the masthead was not practical. (See progress reports, p. 31.) Recording on the roof of the atmospheric-electric observatory was tried then and also found to be impractical, so during the stay at Hamburg, Germany from June 22 to July 7, 1928, a platform for the recorder was built on the stern rail of the ship to starboard of the apparatus 2. On the platform was mounted the metal-sheathed weatherproof wooden box containing the recording equipment, and from the top of the box projected a metal rod at the tip of which was mounted a circular metal plate supporting, on its underside, four small metal discs coated with the radioactive material ionium.

During experiments with the apparatus at the masthead, a short vertical rod was used to support the collector plate. When the apparatus was installed on the stern rail, a bent collector-rod which projected out over the water directly astern was used at first. The collectors at the end of the bent rod were approximately one meter beyond the metal-sheathed box and in a horizontal plane approximately 75 cm above the top of the box. This arrangement is shown in figure 11, where the location of the recorder with respect to apparatus 2 may be noted also.

The bent collector rod was used from July 7, 1928, when the ship sailed from Hamburg, Germany, until November 5, 1929, eleven days after leaving Balboa, Canal Zone. After leaving Balboa, bad weather was encountered and during the next eleven days the bent rod was twisted out of place at frequent intervals and no useable records of potential-gradient were obtained. A vertical collector rod was installed on November 5, 1929, which was not as short as that used in the masthead experiments; it supported the collectors approximately 75 cm above the top of the box. This rod was used for the remainder of the cruise (fig. 16). For reduction of recorded volts to volts per meter for the two different collector rods, two standardizations were made with the bent rod and two with the vertical. These are discussed in detail in another part of this volume (pp. 127-132).

The Potential-Gradient Recorder.--The recorder, manufactured by Günther and Tegetmeyer, consisted of a bifilar electrometer of Wulf's design, a projection microscope, and a recording box with driving clock attached. (Two recorders were taken on the cruise, nos. 4946 and 4947; no. 4946 was used at the stern rail location throughout, except for twelve days in August 1928). The recorder, together with various items of control and operating equipment (except batteries), was contained in the weatherproof box, the front of which was removable to permit inspection, testing, and adjustment of the apparatus (fig. 12). The collector rod was supported in an amber insulator which was mounted in the tube projecting from the top of the box. Within the tube, above the amber insulator, was located an electric heating coil which served to keep the amber dry. The current in this coil, supplied by the ship's power plant, was regulated by a rheostat mounted in the wooden box. To protect the heating coil and amber insulator from rain and spray a metal "skirt" or cap was attached to the collector rod just above the end of the tube. Within the box, the inner end of the collector rod, projecting down from the amber insulator, made connection with the fibers of the electrometer.

The Electrometer.--The Wulf bifilar electrometer was equipped with an inner insulated case constructed in one piece. The inner case had a terminal which projected from one side of the outer case or housing, and the case was connected to the housing when the small threaded cap on the terminal was screwed against the housing. Care had to be taken to insure that this cap was not against the housing when an auxiliary potential was applied to the inner case, when the housing was grounded. A grounding terminal was located on the bottom of the housing. Each battery supplying the auxiliary potential was provided with a protective resistance in its circuit--10,000 ohms or more for each 100 volts.

The fibers of the electrometer were illuminated by a 110-volt lamp which was operated from the power plant of the ship. The desired degree of illumination was obtained by moving the lamp up or down or rotating it in its holder, or by adjusting a rheostat which was in the lamp circuit. On one side of the electrometer housing, under the microscope tube, there was an aperture covered by a screw cap. When the electrometer was in use, a glass tube or bulb half-filled with drying material such as phosphorus pentoxide was fitted at the aperture, mounted on a brass ferrule which replaced the screw cap. Another tube or bulb of drying material was mounted at the aperture in the side of the cap which protects the upper amber insulator of the electrometer. Both drying units are shown in figure 12.

The Projection Microscope.--To obtain a good photographic record, the projection microscope was adjusted as regards both focus of the fibers and symmetrical placing of the scale in the microscope in relation to the fiber positions. For focusing, a screw on the upper side of the microscope barrel could be loosened to adjust the position of the projecting lens; for symmetrical placing of the scale, the adjustment was accomplished by sliding the microscope mounting sidewise in its support on the side of the electrometer housing, after loosening a clamping screw.

The Recording Box and Driving Clock.--The driving clock was mounted on one side of the recording box (not seen in fig. 12), so connected as to rotate the lower of two wooden rollers within the box. Unexposed photographic paper was placed on the upper roller, and the clock-driven lower roller wound up the exposed paper during operation.

The back of the recording box was made to slide upward for insertion and removal of the photographic paper. To insert paper, the upper wooden roller was removed from the box by pulling out the upper knob which was on the side of the recording box opposite from the driving clock. The lower roller was removed by pulling out the lower knob, when the exposed paper was to be removed. Two cords, fastened in the recording box above the upper roller, rested against the photographic paper and were kept taut by a weight which they supported; the cords kept the paper in correct position during operation. The moving paper was exposed as it passed a slit on which was thrown the image of the electrometer fibers and the scale.

Photographic Paper.--Single weight matte enamel bromide paper was used. It was supplied in rolls of 150 cm length and 67 mm width, which was sufficient for a week's record and also allowed for a space between daily records of 5 cm. The average hourly rate at which the paper passed the slit when a week's record was allowed to accumulate on the lower drum was 5.92 mm. The first day required approximately 13.9 cm and the last day 14.5 cm.

Automatic Control of Time Marks.--The driving clock on the side of the recorder box was equipped with a contacting device which closed an electromagnet circuit once every hour for a period of two minutes, beginning one minute before the hour and ending one minute after. The electromagnet was mounted at an aperture on the side of the cap covering the top of the electrometer, and when actuated, its inner end attracted a flexible metal strip which was grounded and which moved sufficiently far to make contact with the post at the top of the electrometer fiber system and to ground it. The hourly time-marks not only controlled the time record but provided points for establishing a base line from which deflections of the fibers during regular recording could be measured.

Electrometer Calibration and Sensitivity.--For calibration of the potential-gradient recording apparatus, the collector rod was removed. A calibration was made each week, if weather conditions permitted. From batteries brought on deck, potentials in steps of twenty or thirty volts were applied between the grounded part of the apparatus and the insulated fiber system, and the deflections of the fibers noted for each value of voltage (fig. 17). The calibrations usually covered the range from 0 to about 300 volts. As calibration curves for electrometers of this type usually are not linear, particularly for the smaller deflections, it was arranged that during recording an auxiliary potential be used of such magnitude and sign that the deflections would usually be in that range of the scale having the best linearity. In this preferable range the sensitivity in divisions per volt was greater also, giving added reason for the use of the auxiliary potential. A value of auxiliary potential of 50 to 100 volts was usually used, and as the potential-gradient of the atmosphere is positive with respect to earth in fair weather, the sign of the auxiliary potential was negative. Calibration always was made with the auxiliary potential applied to the inner case, the value of the potential being approximately known and assumed to remain fairly constant. The sensitivity of the electrometer was maintained generally between 10 and 20 volts per scale division on the photographic paper, the tension of newly installed fibers being altered if preliminary calibrations showed that the desired sensitivity did not exist already.

Batteries and Auxiliary Potentials.--Auxiliary potentials were used on the inner case of the recording electrometer throughout the cruise. Initially, for the masthead experiments, the auxiliary potential batteries were kept on a shelf in the after galley, and connecting wires were brought up to a marine plug on the starboard rail directly above the galley. From the marine plug, flexible rubber-covered twin cables made the necessary connection to the apparatus. After September 16, 1928, auxiliary potentials were supplied from batteries housed in the small laboratory situated at the forward edge of the quarter-deck on the port side of the cabin companionway. Wires ran beneath the deck from this location to a marine plug on the stern rail. Prior to September 16, these batteries supplied auxiliary potentials to the eye-reading apparatus 2, but work with it was discontinued at that time. Serious breakdown of insulation in the marine plugs occurred from time to time during the cruise and caused short-circuiting and rapid deterioration of the batteries.

Insulation Leak.--Under sea conditions, the insulation of the amber mountings for the collector rod and for the fibers in the electrometer needed to be tested frequently--sometimes tests were made two or three times per day, but at least once each day when weather conditions permitted. With the upper part of the collector rod removed, a potential approximating the prevailing atmospheric potential was applied to the insulated system of the apparatus by a momentary contact. The deflection of the fibers then was immediately observed and, at the end of a period of four to eight minutes, was observed again. If these readings indicated that the leak exceeded one per cent per minute, the insulation needed to be improved. This rate of leakage was based on the condition that, during regular recording, four collectors were used on the collector rod. With fewer collectors the permissible rate would have been less. When insulation had to be improved, the amber insulators were cleaned by applying Putz Pomade with a piece of chamois, then later polishing them with a clean piece of chamois.

Meteorological Observations.--Weather conditions, of vital importance in the interpretation of the atmospheric-electric measurements, were carefully recorded while at sea by the meteorologist for his own records and by the ship's officers in the ship's log. The meteorological records have been published in Volume I of this series (4), and the ship's log appears both in that volume and in a later section of this one (pp. 47-64).

Sail Positions and Engine.--Other conditions at sea which affected the measurements, and which had to be recorded, were the position of the mainsail and the mainsail boom (fig. 18), and the operation of the "main" engine. The boom of the mainsail could be swung into three positions and the sail itself could be either "set" or "furled." In the ship's record, set and furled were designated as "up" and "down," respectively, and the following notations were adopted, for brevity, to indicate the various arrangements:

MUBS = mainsail up, boom swung out to starboard
MUBP = mainsail up, boom swung out to port
MDBPC = mainsail down, boom lowered into port crutch
MDBS = mainsail down, boom swung out to starboard
MDBP = mainsail down, boom swung out to port

Variations in the amount to which the boom was swung out to starboard or port naturally occurred but, except when the ship was "close-hauled" (and such occasions were recorded) the variations in position were not considered great enough to affect the measurements. The last two arrangements noted above were met with only rarely, and in any case the standardization observations which were made indicated that the sail up or down was of little importance as compared with the position of the boom. The presence of the quarter-deck awning (figs. 18, 19) also was shown, by the standardization observations, to have no appreciable effect on the measurements of potential-gradient, no doubt because the awning was behind the crutch which was in a dominant position with respect to the apparatus.

The operation of the main engine was required to drive the ship in calm weather. The main engine exhaust was located at the stern and the effect of the atmospheric pollution produced by the exhaust usually was marked enough to be obvious even in the most casual inspection of the potential measurements. The operation of the main engine thus made records for certain hours and even whole days of such doubtful value as to make it necessary to discard them.

Control Program for Potential-Gradient Recorder

Daily

8:00 - 9:00 A.M. Local Mean Time (LMT)

1. Note positions of electrometer fibers through viewing window. Correct illumination if not satisfactory. Focus fibers if necessary.
2. Note whether driving clock is running.
3. Ground the fibers and note position: position indicates whether or not auxiliary is applied to inner case.
4. Test hourly zero contact by manual closing of hourly contact circuit.
5. Change drying material on electrometer if necessary.
6. Remove collectors and make leak test for approximately five minutes, noting movement of fibers through viewing window during this interval. If leak exceeds one per cent per minute (rate based on use of four collectors during regular recording), improve the insulation.
7. On a "Daily Record" form record times of above observations and results obtained.

Greenwich Mean Noon (or Midnight)

1. Advance photographic paper 5 cm.
2. Note position of electrometer fibers through viewing window.
3. Make appropriate notes on daily record.

5:00 -6:00 P.M. LMT

Repeat items 1 to 7 under 8:00 - 9:00 A.M. above.

Weekly

1. Calibrate recorder over voltage range of zero to approximately 300 volts, then allow to record for fifteen minutes.
2. Roll balance of photographic paper onto bottom roller in recorder box.

3. Remove recorder from wooden box on stern rail, take to darkroom and remove the week's roll of photographic paper and install new roll.
4. Wind driving clock and set to correct Greenwich Time.
5. Replace recorder in box on stern rail.
6. Make notes of above operations on daily record form.

Conductivity Apparatus 8A.--The method employed on cruise VII for the visual measurement of the conductivity of the air was the same in principle as that used on previous cruises although the arrangement of apparatus was somewhat different. The method is that devised by Gerdien (5). In this method air is drawn by a fan through the space between two concentric cylinders, the central member of which is charged and connected to the insulated fiber system of an electrometer. The theory of the instrument shows that as long as the velocity of the air stream is large enough to insure that the central cylinder cannot collect from the air all the ions attracted toward it as the air passes through, the rate of loss of charge by that cylinder is independent of the air velocity and dependent only on the potential applied and on the conductivity contributed by the ions of sign opposite to the charge on the cylinder.

The outer tube of the air-flow system has been shown in figures 7 and 8. Air was drawn into the intake of the air-flow tube on the roof of the observing cabin. It passed around a small cylinder which was supported in an amber insulator concentrically within the air-flow tube, and at a height convenient for attachment of an eye-reading electrometer or a recording apparatus located on the shelf in the cabin. A difference of potential was maintained between the small cylinder and the air-flow tube by means of a battery, the battery being carefully protected against the sea air by being kept in a suitable cabinet or compartment. In the upper part of the air-flow tube, above the small central cylinder, two concentric cylinders were installed, the innermost being connected directly to the air-flow tube and the other one insulated from both. A high potential could be applied across the cylinders whenever desired, to "sweep" out of the air stream all the ions entering the tube, a procedure which was used both with eye-reading and recording apparatus. With eye-reading apparatus, the sweeping potential was applied when tests were made of insulation leak, and with recording apparatus it was applied for a few minutes once each hour to establish a base line from which the deflections during regular recording could be measured.

The procedure on cruise VII, as on previous cruises, for eye-reading measurements of conductivity consisted essentially in observing the rate of discharge of the central cylinder and the attached electrometer when charged to an average potential, V'. In determining the rate of discharge it was convenient to observe the time, τ, required for the fiber (only one fiber is observed in this work) to move over a specified number of scale divisions, θ, corresponding to a change in potential, δV. The symbols used here are those used on a form supplied for recording the observations (Department form 101), and the potential is expressed in volts. The capacitance, C_1, of the central cylinder, the electrometer and the connections of electrometer to central cylinder, and also the capacitance, C_2, of that part of the insulated system exposed to the air flow, enter the determination of conductivity. Both values of capacitance must be measured rather than computed; otherwise inaccuracy is introduced in the conductivity determination (6). The formula for the conductivity is as follows:

$$\lambda = \frac{\delta V}{V'} \frac{C_1}{4\pi C_2} (\tau_m{}^{-1} - t_m{}^{-1})$$

where t_m^{-1} is obtained from leak tests as explained hereafter.

Procedure for Eye-Reading Conductivity Measurements on Cruise VII

1. Preliminary
   (a) Ascertain that the bifilar electrometer and batteries are in proper working condition. Desirable electrometer sensitivity is about two volts per division.
   (b) Start fan motor and apply the sweeping potential.
   (c) Calibrate the electrometer over the range to be covered in the observations, using for this purpose a Weston voltmeter connected in parallel with it. Two points near the limits of the range will be adequate.
2. Initial leak test
   (a) Apply to the central cylinder and electrometer system a potential slightly higher than that desired at the beginning of the conductivity observations proper.
   (b) Observe leak in scale divisions for a definite interval of time, say 180 seconds. Record time-duration of leak test (on form 101 opposite Δt_1). Observe and record position of fiber at the beginning and at the end of the leak test and enter on form after θ_1.
3. Conductivity observations
   (a) Remove sweeping potential one or two minutes before starting observations.
   (b) Select the number of scale divisions, θ, over which the electrometer shall discharge, say four divisions, and charge the apparatus as in 2(a).
   (c) Observe the time at which the fiber reaches the beginning and the end of the four-division range and record the times on form 101; the time interval in seconds is τ. Recharge the fiber and repeat this operation three times or more to obtain several values of τ.
4. Final leak test
   (a) Apply the sweeping potential and begin the leak test when the fiber reaches a position approximately as far below the scale range used in 3(c) as it was above the scale range at the end of the initial leak test. Complete the test as in 2(b), recording Δt_2 and θ_2.
5. Computation of conductivity
   (a) Compute the several values of τ, take the reciprocal of each, and obtain the average, which is $\tau_m{}^{-1}$, in 10^{-4} units.
   (b) Compute $t_1{}^{-1}$ from the formula $t_1{}^{-1} = \theta_1/\theta\,(\Delta t_1)$ and $t_2{}^{-1}$ from a similar formula, expressing the values in 10^{-4} units. Average the two values for $t_m{}^{-1}$.
   (c) The value of capacitance of C_1 is 14.9 cm and that of C_2 is 6.14 cm; consequently $C_1/4\pi C_2 = 0.193$.
   (d) From the calibration made in 1(c), determine the voltages V_1 and V_2 for the scale readings at the beginning and end of the four-division range used in observing conductivity. From these, $\delta V = V_1 - V_2$ and $V' = (V_1 + V_2)/2$.
   (e) Compute conductivity from the working formula $\lambda = 0.193(\delta V/V')(\tau_m{}^{-1} - t_m{}^{-1})$.

In accordance with the above procedure, observations were made daily on cruise VII until July 28, 1929, except when bad weather or other cruise programs prevented. Each day three separate determinations of conductivity would be made; on one day the first and third sets would be measurements of positive conductivity and the second set of negative, while on the following day the first and third sets would be negative and the second positive. Each set would require fifteen minutes or longer, depending on the magnitude of the conductivity. The sets were so spaced and the actual manipulations of apparatus were so arranged that the same observer could also make measurements of ion content, penetrating radiation, and nuclei content centering very closely on the average of the beginning and ending times of the conductivity observations.

Conductivity Recording Apparatus.--At San Francisco, in August 1929, the eye-reading electrometer was removed from the conductivity apparatus and a very satisfactory recording apparatus, designed and constructed by the Department staff for observations at sea, was installed (figs. 9, 20, 21). The shelf on the forward wall of the observing cabin had originally been planned for mounting the recording equipment, and the installation was readily accomplished. For recording it was planned that the charge acquired by the central cylinder from the air stream in the air-flow tube should be allowed to leak continuously through a very high resistance of about 10^{12} ohms. With such high resistance, although the current would be extremely small, the voltage drop would be appreciable, of the order of a volt or two. With one side of the high resistance to the fiber of a sensitive unifilar electrometer and the other side to the electrometer case, a voltage drop of one or two volts would produce appreciable deflections of the fiber, and variations in the voltage drop due to variations in conductivity would cause measurable variations in the fiber deflection.

Figure 9 shows that recorder as it appeared in use. The electrometer, the high resistance, and other parts that might be detrimentally affected by moist and salt-laden air were enclosed in the metal box seen at the left. Calcium chloride was placed in this box to absorb any moisture which might slowly gain entrance. In figure 20 one side of the box is removed to show the electrometer and in figure 21 the opposite side is removed to show the high resistance unit. The high resistance unit was a radioactive cell of the Bronson type as modified by Swann and Mauchly (7), and consisted essentially of a cylindrical metal chamber about 20 cm in diameter and 20 cm high in which the air was made very slightly conducting by the presence of a small amount of ionium salt.

From the metal box a lightproof tube extended to the recording mechanism at the right in figure 9. Two fittings on the lightproof tube supported glass containers in which drying material was placed. A viewing hood attached to the tube permitted the observer to view the position of the electrometer fiber at any time. The recording mechanism included a driving clock, a metal cylinder or drum rotated by the clock, and a lightproof cylindrical container in which the rotating drum was enclosed. Where the lightproof tube joined the cylindrical container a horizontal slit was provided through which the image of the electrometer fiber was thrown onto the photographic paper on the rotating drum. This slit could be opened or closed by a simple manual manipulation. The drum was made to rotate once in twenty-five hours, so that the photographic paper on the drum would represent one day of recording of conductivity. Each daily record was 30 cm long and 9.5 cm wide. Each hourly interval was 8.3 mm long. The scale in the eyepiece of the electrometer was focused on the photographic paper, giving a background of lines 3.0 mm apart parallel to the long dimension of the paper against which to measure the fiber deflection.

To obtain deflections representing zero conductivity from which to measure the deflections obtained in regular recording, the sweeping potential mentioned earlier was applied for a few minutes once each hour to the cylinders in the upper part of the air-flow tube. The potential was applied automatically by a contact device fitted to the driving clock.

Above the lightproof tube and recorder mechanism was mounted the calibration apparatus by which values of conductivity could be established for different deflections of the electrometer fiber. It consisted of a variable cylindrical condenser, one element of which was made to move by a motor at a steady rate, to give a uniform change in capacitance with time, dk/dt. Across the two elements of the condenser was applied a potential, V. Thus, in place of the unknown current flowing through the high resistance during conductivity measurements, a known current Vdk/dt was supplied by the calibration apparatus. Different values of potential across the condenser gave different values of current and different deflections of the fiber. The wiring diagram of the apparatus is shown in figure 22.

During the three months September to November 1929, when the recording apparatus was in use, the "operating potential" applied between the central cylinder and the air-flow tube was maintained at 185 volts, except for the brief period September 5 to 11, when various values ranging from 93 to 231 volts were used at various times. With the rate of air flow in the tube approximately 400 cm per second, and an operating potential of 185 volts, ions were being drawn from a region in the air-flow tube bounded by a cylindrical surface of about 4 cm radius, which is only half of the radius of the air-flow tube. Observations for determining the sensitivity of the electrometer were made at approximately weekly intervals by applying values of 1.0, 2.0, and 3.0 volts, from a potentiometer, between the fiber and case. A sensitivity of approximately 1.3 scale divisions (4 mm) per volt was consistently maintained. Calibrations of the entire apparatus by means of the variable "calibrating condenser" were made almost daily while at sea during September 1929, and in October and November were made every two or three days. Calibrations for positive and negative conductivity were made on alternate occasions. The calibrations showed that for negative conductivity the adjustment of the high resistance cell gave a constant scale value of 2.1×10^{-5} esu per scale division. For positive conductivity the calibrations were not linear, giving greater scale values for the smaller deflections. Typical values were 3.7×10^{-5} esu for 1.3 divisions and 3.2×10^{-5} esu for 4.5 to 5.0 divisions. The positive scale values were thus more than 50 per cent greater than for the negative conductivity, the difference being related to the adjustment of the high resistance cell and the direction of passage of current through it.

Ion Counter 1.--Ion counter 1 (IC1) used on cruises IV, V, and VI, after being overhauled, provided with an electric motor instead of the troublesome spring-driven motor used previously, and put in good repair, was installed for cruise VII. A description of the apparatus, the procedure for making measurements, and the method of computing ion content was given by Swann in 1917 (8). Some details of both apparatus and observational procedure, however, can be described to advantage at this time. The apparatus differed from the design of Ebert in one major respect; namely, it was designed so that the "charging" method instead of the "discharging" method could be used. In the Ebert apparatus a stream of air is drawn by a fan through a cylindrical condenser, the inner cylinder of which is connected to an electrometer and charged to a potential sufficiently great to insure that all small ions (mobility greater than 1.0 cm per second per volt per cm) are removed from the air stream passing by it. Ions of sign opposite to that of the charge on the inner cylinder will be collected by that cylinder, discharging the cylinder with time.

In the charging method the air is drawn through a cylindrical type condenser, the outer cylinder of which is maintained at a constant potential while the inner cylinder is, at the outset of an observation, near to earth potential. Ions which are well within this condenser and of the same sign as the potential on the outer cylinder are driven toward the inner cylinder. When the apparatus is used as an ion counter, all ions of mobility greater than a certain value reach this cylinder and impart a charge to it, hence the designation "charging method." The increment of charge thus acquired from a known volume of air is measured and used in the calculation of ionic density. Ions which at any instant are located outside or even some distance within the mouth of the condenser, however, are subjected to a field which opposes their entrance unless special provision is made when designing the condenser to shield them from an opposing field.

Swann (9), who devised this type of counter, was cognizant of this potential source of error. He states "this difficulty is one which shows itself very materially in practice, as appeared when experiments were made to test it . . . I finally adopted (the shielding cup) which entirely overcomes the difficulty." The effectiveness of this device has been verified by tests made on several occasions in more recent years.

A more detailed description than that given by Swann of the novel features of the type of ion counter used in the Department of Terrestrial Magnetism is given in that which follows. Some improvements which were made when conditioning the instrument for use on the Carnegie during cruise VII are included.

This type of counter differs from the well-known Ebert only in the form of condenser and in that a single-fiber electrometer is used. It will suffice here to describe only the condenser. The details are shown in figure 23. It consists of an outer brass cylinder (1) with its attached cap (9) and intake-port (10) which is covered with a suitable cowl (not shown), an inner cylinder (2), and a central electrode or collector which is made up of the brass rod (4), the struts (7), and the cylindrical brass shield (3). The lower end of the outer cylinder fits into the cap of the electrometer and connects with the tube that leads to the air-flow meter and the air-flow fan and is thus in electrical contact with all the "earthed" parts of the system. The inner cylinder is insulated from the outer cylinder by two tight-fitting ebonite rings (5), which, together with the binding-post (6), also serve to support it. This cylinder is maintained at a constant potential of from 20 to 100 volts by means of a battery attached at the binding-post (6). The lower end of the central rod (4) fits into the post of the electrometer and thus connects with the sensitive element. Three brass struts (7) (radial arms also have been used) support the thin-walled brass shield (3) from the central rod and connect these parts electrically. The shield (3) is maintained in a central position by an amber ring (8). An annular disc (11) is placed below this insulator to shield it from the intense field of the condenser-element (2) and thus avoids effects from induced creeping charges. The shield (3) is designed to intercept those electrical fields which, without it, would drive some of the ions to "earthed" parts of the condenser. Thus, for example, the field which without (3) would extend between the upper part of the inner cylinder (2) and the lower part of the intake-port (10) and cap (9) would also drive some ions to these last-mentioned parts and thereby decrease the number collected by the central electrode. The number of ions determined under these conditions accordingly would be too small.

The relative merits of this type of ion counter and the usual Ebert type for conditions encountered on the Carnegie at sea are as follows: (1) An increment of charge may be measured with a given precision in about one-twentieth the time required for the Ebert, provided that in both methods the conductance across the prime insulators is small and nearly constant. (2) Defective insulation is both a less common and a less serious source of error than with the Ebert method. (3) With the charging method one can at once distinguish corrections arising from insulation-leak from those arising from a conduction current. (4) With the charging method more auxiliary equipment is needed than with the Ebert method, but this disadvantage is not serious and is greatly outweighed by the advantages enumerated.

Ion counter 1 was mounted in the atmospheric-electric cabin near the conductivity apparatus (fig. 3). It was held in a gimbal supported from the ceiling, and the air-flow tube projected approximately one-quarter meter through a roof aperture (fig. 8). A funnel was fitted at the intake which could be turned into the wind and thus eliminate possibility of aspiration up the air-flow tube in moderate and heavy winds. A domed metal cap or hood covered the roof aperture and air-flow tube when the apparatus was not in use. The potential applied across the cylinders of the condenser on cruise VII, was 60 volts from May 1, 1928 to July 28, 1929, and 90 volts thereafter.

The unifilar electrometer was adjusted for a sensitivity of approximately ten divisions per volt. The air-flow fan was driven by an electric motor operated from the ship's power plant, and the volume of air passed through the apparatus during a period of observation was determined by an anemometer calibrated by the United States Bureau of Standards in March 1928, just before cruise VII began. The same anemometer was used on cruise VI and was calibrated by the Bureau October 6, 1919, before that cruise began and again on February 24, 1923, sixteen months after it ended. The correction factors for converting anemometer readings to liters per second obtained on these three occasions were: for 1919, 1.08; for 1923, 1.05; for 1928, 1.02, over a range of 1.4 to 2.0 liters per second. The factor for cruise VII, namely 1.02, was thus in reasonable agreement with the values for the previous cruise. That it varied little, if any, from the value of 1.02 during the nineteen months of cruise VII seems likely, judging from the small change indicated for the twenty-five months of cruise VI.

Procedure for Observation of Ion Content

1. Preliminary
   (a) Ascertain that the electrometer, batteries, and electrical circuit are in working order.
   (b) Apply plate potentials to the electrometer and start the air-flow motor ten or fifteen minutes before observations are to commence.
   (c) Select the range of scale divisions, say five or ten, over which the electrometer shall discharge during the observations, centering this range on the scale division representing the earthed position of the fiber; determine the potential in volts to which the selected range corresponds. Record the range as θ and the voltage δV on a suitable form (Department form 101).
2. Leak test or test of residual ion content with air flow stopped
   (a) Stop air-flow motor and discharge central cylinder and fiber.
   (b) For a selected period of say 100 seconds, observe the fiber position at beginning and end of period.
   (c) Record on form 101 the time interval of the test in seconds as Δt_1, and the scale readings of the fiber at beginning and end as θ_1.
3. Ion content observations
   (a) Start air-flow motor; keep it running throughout this part of the work.
   (b) Charge the central cylinder to a potential sufficient to bring the fiber to a position slightly beyond the beginning of the selected scale range.
   (c) Note anemometer reading as fiber passes the beginning of the selected range and again as it passes the end, and record on form 101, under M. Record watch time T_1 of first anemometer reading.
   (d) Repeat (a) to (c) to obtain as many sets as desired, usually three or more. Record watch time T_2 for last anemometer reading.
4. Leak test, etc.
   (a) Repeat test of section 2 above, recording the observations as Δt_2 and θ_2 on the form.
5. Repeat preliminary calibration
   (a) Redetermine the potential, V, for the selected range θ used during observations of ion content.

Procedure for Computing Ion Content and Mobility

1. From the anemometer readings observed under 3(c), obtain ΔM in seconds and multiply this by the conversion factor for the anemometer, 1.02×10^3, to obtain W, the number of cc per second of air passed through the apparatus during the voltage drop δV. For convenience in computation, obtain the reciprocal W^{-1}, in 10^{-7} units. Obtain W^{-1} for each set of observations under 3(d) also, and take the mean W_m^{-1}.
2. From T_1 and T_2 and the corresponding anemometer readings obtained under 3(c) and 3(d) determine the total number of seconds during which the air was drawn through the apparatus and the number of liters drawn through. From this compute the time p for one cc to pass through. (For the particular fan, motor, and air-flow system used on cruise VII the value of p was between 0.6 and 0.7×10^{-4} as the rate of air flow varied between 1.7 and 1.4 liters per second.)
3. From the value selected for Δt_1 and Δt_2 under 2(b) and the value of θ selected under 1(c), together with the observed values of θ_1 and θ_2 obtained under 2(c) and 4(a), compute values of t^{-1} and t^{-2}, in 10^{-3} units from the formula $t_1^{-1} = \theta_1/\theta(\Delta t_1)$ and $t_2^{-1} = \theta_2/\theta(\Delta t_2)$. Take the mean t_m^{-1} of the two values and multiply by the value of p just obtained, and record as w_m^{-1}, in 10^{-7} units.
4. The formula for computing ion content, n_+ or n_-, depending on the sign of the potential applied to the central cylinder, is

$$n = \frac{C\,\delta V}{300e}\,(W_m^{-1} - w_m^{-1})$$

where C is the measured capacitance of the apparatus, and for ion counter 1 was found to be 24.2 cm. Determinations of capacitance indicate the value to be correct to within plus or minus two per cent. If the value 24.2 cm is used, then

$$C/300e = 16.8 \times 10^7$$

and the working formula becomes

$$n = 16.8\,\delta V(W_m^{-1} - w_m^{-1})$$

where the exponental terms 10^7 and 10^{-7} cancel out.
5. Confusion may arise on occasion as to the sign of the correction w_m^{-1}. This may be clarified as follows.
   (a) If the travel of the fiber during the leak observation is in the same direction as during the observation of ion content, then

$$n = 16.8\,\delta V[W_m^{-1} - (+w_m^{-1})]$$

   (b) If the travel during the leak observation is opposite in direction to that during observation of ion content, then

$$n = 16.8\,\delta V[W_m^{-1} - (-w_m^{-1})]$$

   (c) These rules apply whether positive or negative ion content is being measured.

Ion counter 1 was installed near the conductivity apparatus to facilitate simultaneous observations with both types of apparatus. Form 101 was used to record both ion content and conductivity as long as eye-reading instruments were used for both. Observations were so adjusted that both types of measurement covered as nearly as possible the same period of time, and the data therefore can be regarded as taken simultaneously.

From simultaneous data of ion content and conductivity the specific mobility of the ions can be determined by means of the formula

$$\text{mobility, } v, = \lambda/300ne$$

where v is expressed as cm per second per volt per cm. Computed values of mobility were derived for all simultaneous sets of observations of ion content and conductivity and are tabulated later in this volume (pp. 66-112).

Aitken Nuclei Counters.--More than fifty years ago John Aitken devised an instrument for counting the number of particles in the atmosphere which act as centers or nuclei for condensation of moisture (2). A considerable body of observational evidence has been gathered since that time, showing that the number of these particles present in any locality affects the electrical condition of the atmosphere there. Certainly when they are numerous, the potential gradient of the atmosphere is greater and the conductivity less than when they are few. The particles acquire and lose charge through combining with small ions and with each other, and on any given occasion some will be charged positively, some negatively, and others will be uncharged. It is a matter of considerable importance to determine what part these particles play in the ion equilibrium of the atmosphere.

Aitken called the particles "dust" particles and his instrument the dust counter, but, since his particles are not dust particles as we now know them, to avoid confusion they are called condensation nuclei and his small, portable counter the Aitken pocket nuclei counter. Figure 13 is a view of the Aitken pocket nuclei counter and details are shown in the drawings in figure 24. A shallow circular receiver, R, connects through a three-way cock, K, with a piston chamber, P, when the cock is set as shown. The cock, K, when turned 90°, connects the receiver to the outer air, while at the same time the piston chamber is, by a separate orifice, also connected to the outer air. The volume of the receiver is a few cubic centimeters and the piston chamber about one-third that of the receiver when the piston is down at full stroke. Hence the air in the receiver may be expanded about 30 per cent by a full piston stroke.

The air in the receiver is kept saturated by a moistened disc of blotting paper, mounted on a loose disc within the receiver. When the counter is shaken, the disc mixes the air. In the bottom of the receiver is a glass window divided into millimeter squares for a counting stage, and on the receiver cover is mounted an eyepiece, M. Light is directed into the receiver by an adjustable mirror mounted below the receiver on the piston tube and so designed as to give black background illumination. To move the piston the operator uses the knurled collar which slides on the tube, G. When the piston is pulled down sharply, moisture in the receiver will condense on the nuclei present and make the latter readily visible through the low power eyepiece as they fall on the counting stage. It is always assumed that nuclei once deposited are never returned to the air and recounted, and the functioning of the counter indicates that such an assumption is justified.

On the side of the tube, G, are markings of 1/5, 1/10, 1/20, and 1/50 which are used when introducing different proportions of impure air into the counter for testing. Aitken arranged the markings to be so placed on the tube that when the knurled collar is set with its bottom edge coincident with one of them, impure air is introduced in such quantity that when it is mixed with the pure air in the receiver and expanded by a full piston stroke, there will be in the receiver that proportion of impure air specified by the marking. An equation for this was given by Wait (10) in connection with his study of several counters made after Aitken's design, as follows. If V_r is the volume of the receiver, V_x the volume of the piston tube with the piston down at full stroke, and V_s the volume of the piston tube above the piston head for any marking 1/S, then $[(V_r + V_x)/V_r]\cdot[(V_r + V_s)/V_s] = S$. Aitken also arranged the height of the receiver above the counting stage to be one cm, and by counting particles falling on a mm square his sampling was made from a volume of 0.01 cc in the receiver, necessitating introduction of a factor K = 100 to obtain particles per cubic centimeter.

Seven instruments of the Aitken design made in Germany and the United States were found by Wait to have dimensions different from those of the original Aitken instrument and also to have the markings on the tube, G, improperly placed. In particular, the height above the counting stage was not one cm, thus affecting the factor, K. The two instruments used on cruise VII (counters 4 and 5) were of this group and for these the product SK, instead of being 500 for 1/5 setting, 1000 for 1/10, and so on, had values as follows.

Setting	Product SK	
	Counter 4	Counter 5
1/5	710	695
1/10	1300	1260
1/20	2520	2440
1/50	6000	5900

The use of the counter involves several systematic operations including initially clearing all nuclei from the receiver, next introducing a certain proportion of outside air, then mixing the air thoroughly, and finally expanding it enough times to insure the deposit of all nuclei from the air, at the same time counting all the droplets that fall on a chosen square in all the expansions.

To clear all nuclei from the receiver, the cock, A, is closed and cock, K, set as shown in figures 13 and 24, after which repeated strokes of the piston are made until no more particles fall on the counting stage. Sometimes the repeated strokes of the piston will build up pressure in the receiver, apparently because on the downstroke of the piston small quantities of air somehow enter through interstices too small to admit nuclei as well, and this pressure must be relieved or the subsequent nuclei measurements will be erroneous. Therefore, after the several strokes to clear the receiver have been made, the piston is left at its highest position and the cock, K, turned so as to connect the receiver with the outside air, to equalize the pressure inside and out. The cock, K, then is promptly restored to its initial position. Then the piston is set to one of the settings on tube, G, and the cock, K, turned 90°, permitting outside air to enter the receiver to equalize the pressure inside and outside. At the same turning of the cock, the piston chamber is connected to the outside air and next it is exhausted into the outside air by bringing the piston to its highest position. The cock, K, then is restored to its first position, connecting the receiver with the piston chamber. The counter now is shaken to stir the air in the receiver, the mirror adjusted for the best illumination of the counting stage, and the piston smartly pulled down for its full stroke. With the expansion thus produced, droplets will appear and fall to the stage, where the number falling on a given square must be counted. The counting must be done very quickly as the droplets evaporate in a few seconds.

The piston is then returned to its highest position, after which a second expansion is made. The droplets in general will be fewer on this expansion, and by the fifth or sixth expansion only one or none at all may fall if the counter is not leaking. Usually no particles are left to fall after the fifth or sixth expansion.

For a satisfactory set of observations ten repetitions of the above manipulations are generally made.

If for a given setting of the piston more than ten droplets are deposited on the chosen square on the first expansion, the observation should be discarded, the receiver cleared of nuclei, and a new setting of the piston, representing a smaller proportion of polluted air, should be adopted for the particular occasion. To count more than ten particles before some of them evaporate is very difficult, and the piston setting should always be such as to keep the number deposited at any one expansion at some value smaller than ten per square millimeter.

On cruise VII the practice was adhered to of taking ten successive determinations of nuclei content as one set of observations. Such a set required between ten and fifteen minutes for completion. The sets were made to coincide with the mid-point in time of the conductivity and ion-content measurements, thus making the various types of data simultaneous. Early in the cruise it was found that the nuclei were not numerous over the ocean and the observing program was modified by counting the particles falling on four squares instead of only on one square. The constants used in connection with various settings on the piston tube were therefore only one-fourth the values given in the preceding table.

A suitable form (designated number 157) was provided for recording the nuclei counts. On the form space was provided for weather notes relating to wind direction and velocity, visibility, presence of fog, mist, or haze, and other items which might be pertinent to the nuclei concentration in the atmosphere.

Penetrating Radiation Apparatus PR1 and Kolhörster 5503.--The measurement of the penetrating radiation consists essentially in determining the rate of formation of ions in the air of a closed chamber. This is much the same in principle as measuring the number of ions with an ion counter. All the ions of one sign are swept to an electrode (or central system), near the center of the ionization chamber, by a suitable electric field. Thus, in apparatus of the type of PR1, the central system (including the central electrode, the fiber, and other connected parts) gradually acquires charge, and in an instrument of the Kolhörster type it loses a charge. The time (τ) required for the central system to suffer a change of potential (δV), indicated by a change in fiber position (θ) is noted. Then the charge in electrostatic units acquired per second is $C\delta V\tau^{-1}/300$, where C is the capacitance of the entire central system, δV is expressed in volts and τ in seconds (the symbols here used are the same as on Department form 104). The charge acquired per second divided by the charge (e) of a simple ion gives the number of ions collected by the central electrode per second and this in turn divided by the volume (U) of the ionization chamber yields the number of pairs of ions (R) formed per second in one cubic centimeter of the air contained in the chamber. Thus

$$R = C\delta V\tau^{-1}/300\ Ue$$

Chief Features of Penetrating Radiation Apparatus 1.--A cylindrical chamber approximately 29 cm in diameter and 34 cm high, was made from copper sheet approximately 0.1 cm in thickness. It was thoroughly cleaned and filled with dry filtered air. Mounted on suitable supports, it was insulated from earth and, being connected with one of the plates of a unifilar electrometer, was maintained at a potential of about 100 volts (fig. 4). Concentric within the lower two-thirds of the cylinder was a rod, or central electrode, which was connected with the electrometer fiber and with the inner element of a small condenser, the latter being mounted on the side of the electrometer cap. The other element of this condenser, the outer cylinder, was insulated from earth and connected with that electrometer plate which was not connected with the ionization chamber. The potential on this outer cylinder therefore was equal in magnitude but opposite in sign to that on the ionization chamber, provided all insulation on the lines connecting with the batteries was adequate. The capacitance of the so-called balancing condenser could be varied by small amounts by means of the adjusting screw at the end of the outer cylinder, but for greater changes it was necessary to remove the outer cylinder and screw the inner cylinder in or out as required. The balancing condenser was correctly set at the laboratory in Washington and instructions were to avoid changing it, if possible, as the adjustment would be a tedious operation. The purpose of the condenser was to annul inductive effects that, without it, would occur from very small variations in the battery potential and would falsify the measurements.

All the prime insulators of the central system were surrounded by earthed guard-rings and, since the potential of that system differed very little from zero, the loss of charge over these insulators could not be large. Furthermore, the observations were so arranged that the average potential of the central system was zero (e.g., an initial potential of +1 and a final potential of -1) so that the loss and gain would nearly balance.

Two drying tubes were attached to the ionization chamber. The drying material was metallic sodium which lasted for long periods provided air was not admitted to the chamber. During use, the sodium would change to sodium hydroxide on absorbing moisture, and the latter was itself a fairly good drying agent and could be left until droplets of the liquid solution appeared in the tubes.

The constants of PR1 were: capacitance, C, 12.8 cm; volume, U, 21,600 cc. These, together with the value for the charge of a simple ion ($e = 4.77 \times 10^{-10}$), were used in the equation given above and, when combined, gave as the working formula for this instrument

$$R = 4140\ \delta V\tau^{-1}$$

Special Notes Regarding Care and Adjustment of PR1.--When a change of dryer became necessary, the change was made in such a way as to minimize the chance of an interchange of air between the chamber and the outside. The procedure was that one of the spare drying tubes would be filled with fresh sodium before the change and so would be ready to screw into place as soon as the exhausted tube was removed.

The insulators on the battery lines were those which required most attention. To be satisfactory the insulation resistance on each battery line needed to be about 10^9 ohms. Tests to determine whether or not this requirement was fulfilled were made in accordance with instructions. Other insulators which were carefully watched for leak were those on the ionization chamber and the outside insulator on the balancing condenser.

Adjustments of the electrometer were necessary at times, both to obtain the desired sensitivity and to obtain about the same sensitivity on either side of zero. If the latter conditions were not approximately maintained, the loss and gain of charge by leakage across the prime insulators did not balance. Whenever adjustments of the electrometer were made, it was necessary that both the ionization chamber and the balancing condenser be disconnected from the electrometer plates and earthed. After completion of the adjustments, the zero-positions were noted for both settings of the battery reversing switch. With these zero-positions in mind, the ionization chamber and the balancing condenser were connected to their respective electrometer plates and the positions again noted. If these were changed, defective insulation on the battery lines was regarded as the most likely cause. Differences in the zero-positions, however, of about 10 per cent were tolerated in practice.

If the differences were greater, and insulation difficulties were found not to be the cause, adjustment of the balancing condenser became necessary. Instructions for this operation were supplied in some detail. Adjustment was not expected to be needed unless there had been a creep of the adjusting screws or an unbalancing caused by thermal expansion. If the outer cylinder were to be removed for any reason, care was to be taken that the adjustment of the inner cylinder was not changed and, on replacing the outer cylinder, particular note was to be taken that it was firmly seated against the shoulder of the rubber insulator supporting it. In any adjustment of the balancing condenser, the fine-adjustment screw (exposed at the end of the condenser) was to be tried first. If this did not provide sufficient change, the outer cylinder was to be removed, and the inner cylinder screwed very slightly inward or outward until the final adjustment was within the range of the fine adjustment. Only a few degrees turn of the inner cylinder would be necessary to produce a large difference in the fine adjustment.

With the electrometer adjusted for equal sensitivity on either side of the position taken by the fiber when the battery switch was open, and with adequate insulation on the battery lines, the correct adjustment of the balancing condenser was that for which equal deflections to either side were obtained for the two positions of the battery reversing switch. These deflections usually were small; for a sensitivity of ten divisions per volt they were only a fraction of one division. On cruise VII no major adjustment of the balancing condenser was necessary; the use of the fine-adjustment screw was sufficient on the few occasions when adjustment was required.

Chief Features of the Kolhörster Penetrating Radiation Apparatus 5503.--This instrument consisted of an ionization chamber of about four liters volume, at the center of which was placed the electrometer system consisting of two loops made from metal-coated quartz fibers (fig. 6). These were viewed with a microscope and acted in much the same way as the fibers of the bifilar electrometers. The calibrating procedure was essentially the same as for the bifilar electrometers. The electrometer system was charged either for calibrating or for measuring the penetrating radiation by means of a contact-arm located inside the chamber and connected with an insulated outside binding post. This contactor was operated from the outside by a magnetic device. The contactor was earthed (i.e., was in contact with the walls of the chamber) when in the position for observations. On this account the battery was not applied except when the contactor was set in the position for charging the central system. The procedure for observation with this instrument was:

(a) Charge the system to a potential giving nearly a full scale deflection and allow it to stand a few minutes until the charge becomes distributed over the insulators of the central system
(b) Note the positions of the fibers, and the time
(c) About one hour later again note fiber positions and the time of doing so

The equation given earlier for calculation of R also applied for this instrument, δV being the change in potential represented by the change, θ, in fiber positions during the observed time interval, τ, expressed in seconds. The capacitance, C, was given by Kolhörster as 0.374 cm and the volume, U, was 4130 cc, making the working formula

$$R = 630\, \delta V \tau^{-1}$$

(See discussion of changes in C on page 15).

Comparative Measurements.--Simultaneous measurements with two instruments so different in type as the PR1 and the Kolhörster were expected to be of more value than a much larger mass of data obtained with a single instrument, on the basis of the following considerations. The total measured ionization in any penetrating radiation apparatus is produced by at least two distinct agencies. One of these agencies either is radioactive matter in the material from which the ionization chamber is made or is the natural radioactivity of that material itself. The part of the ionization arising from that source may be termed the residual ionization. The rest of the ionization is produced by the penetrating radiation which passes through the walls of the ionization chamber and by its secondary radiation. In an air-tight vessel the residual ionization may be considered constant. It is that which would be observed if the penetrating radiation were cut off by surrounding the chamber with a sufficient thickness of absorbing material. The Kolhörster instrument was so designed that the residual ionization could be determined by immersing it in a sufficient depth of water. Dr. Kolhörster determined the residual ionization of his instrument, giving the value as 1.3 ion-pairs per cc per second. The residual ionization for PR1, however, could not be determined by immersion, and it was hoped that a satisfactory estimate for it could be arrived at from comparative measurements with the two instruments.

Another uncertainty in the measurement of penetrating radiation, apart from that caused by residual ionization, arises from the fact that the number of ions produced in the chamber is not the same as would be produced in an equal volume of air. The intensities of the rays are reduced somewhat by absorption in the walls of the chamber and the surrounding structures, but in spite of this the ionization in such a chamber usually is considerably more than in free air, owing to secondary radiations excited in the walls of the chamber. In order to ascertain the ratio of the observed ionization to that which would be produced in free air by the same agency, the so-called Eve's constant for the instrument is determined. The determination of this constant for PR1 was made on the Carnegie at Newport News in May 1928. The result, however, fell short of what was desired since it was impracticable to include the effect of masts, rigging, etc. It was hoped that a fairly close estimate of the latter effect could be obtained at sea by obtaining observations with the Kolhörster instrument alternately in the atmospheric-electric house and somewhere on the quarter-deck well to the stern of the ship where the largest clear expanse about the zenith could be seen. The ratio of mean values of R obtained at these locations (i.e., R_o/R_i, in which R_o represents quarter-deck measurements and R_i the indoor measurements) would then be a "reduction factor" for eliminating the effect of the ship's gear from the measurements made with the Kolhörster apparatus in the atmospheric-electric house. With this factor, and a series of comparative measurements with PR1 and the

Kolhörster, a factor for the former could be found. The number of such series that would be required would depend on how consistent the Kolhörster results were for the indoor and outdoor positions. A minimum of four series was planned, each of about four hours duration, for the early part of cruise VII, two of these to be with all sails furled, if possible, and two with all sails set. Definite results from these might obviate further tests.

During the regular daily observations and during diurnal-variation runs, the Kolhörster instrument was to be placed at a convenient position in the atmospheric-electric house, preferably between the ion counter and PR1. It was desired particularly that simultaneous observations be obtained with PR1 and Kolhörster 5503 during diurnal-variation observations.

In accordance with the suggestions of the foregoing paragraphs, simultaneous measurements were made with PR1 and 5503 from July 9 to 19, 1928, between Hamburg and Reykjavik, and again after leaving Reykjavik from July 28 to August 18. From these results an attempt was made to determine the residual ionization of PR1, but the scatter of the data for apparatus 5503 was so great as to prevent getting a satisfactory value. The data for the period August 10 to 18 were not used in this investigation, as it was noted that after August 9 a radical change in the measurements with apparatus 5503 occurred, much higher values of ionization being obtained with it after that date without correspondingly higher values for PR1. In the progress reports of the next section (pp. 31-45), difficulties with apparatus 5503 are discussed; continued difficulties culminated in abandonment of the program contemplated for this instrument and the return of the apparatus to Washington for repair when the ship arrived at Canal Zone in October 1928.

The repaired apparatus was returned to the ship at Tahiti in March 1929. The repairs included the replacement of the broken "charging arm" and replacement of the fibers and fiber mounting of the electrometer element. These changes altered the capacitance to 0.348 cm in comparison with 0.374 cm as given by Kolhörster. Both these figures subsequently were corrected when information was received that a correction factor of 1.243 should be applied, the new values being 0.433 and 0.465 cm, respectively.

After March 20, 1929, simultaneous measurements with PR1 and 5503 were again made, but the scatter of data obtained with 5503 again prevented determination of the residual ionization of PR1. In general, the operation of apparatus 5503 was unsatisfactory throughout cruise VII, and the data are being omitted from this publication. Unfortunately, this apparatus, as also all other instruments and pieces of apparatus, was lost with the ship on November 29, 1929, and therefore no attempt could be made later, in the laboratory, to find the causes for the unsatisfactory performance.

Penetrating radiation apparatus 1 thus was left without an established value for the residual ionization. Measurements were made regularly, however, throughout cruise VII with this apparatus, the average value for 368 daily measurements being 2.8 pairs of ions per cubic centimeter per second, not corrected for residual. Each daily measurement required between one and two hours and the period of observation was arranged to coincide with the period required for conductivity and ion content measurements.

Attempts were made on thirty-two occasions to make diurnal-variation observations of penetrating radiation with PR1; twenty-six series of twenty-four hours each were completed and six left incomplete. So much scatter was found among the hourly measurements composing these series, that the publication of this material as representative of the diurnal variation of penetrating radiation (or cosmic rays) is scarcely warranted. Furthermore, so much has been done since 1929 by other investigators toward establishing the character and magnitude of diurnal variation of cosmic rays that little need now exists for the data of cruise VII. Accordingly, this material will not be presented.

Mauchly (11), discussing the daily measurements of penetrating radiation made with PR1 on cruises IV and VI, gave the average values, not corrected for residual, as 3.2 pairs for cruise IV and 3.8 pairs for cruise VI. These means were obtained for observations on 296 and 316 days, respectively. On the matter of residual ionization he said ".....this probably does not much exceed two pairs per cubic centimeter per second, since it is not uncommon to observe a total ionization of the order of two and one-half pairs per cubic centimeter per second, with several extreme cases going even below two pairs." In one of the progress reports of the next section (p. 33), the suggestion is made that lack of a roof aperture over the penetrating radiation apparatus, such as had been used on previous cruises, might be responsible for the lower value of ionization (2.8 pairs) observed on cruise VII. This seems unlikely, however, because at sea the penetrating radiation is largely, if not entirely, cosmic rays and the presence or absence of the roof above the apparatus should make little difference. A more likely explanation might be that the lower value of cruise VII was the more accurate value, owing to greater reliability of the apparatus as a result of improvements incorporated just prior to the start of the cruise. The balancing condenser, in particular, was improved considerably.

Mauchly's value of two pairs per cubic centimeter per second for the residual ionization of PR1 seems somewhat too high for the cruise VII data. A more appropriate value would seem to be about 1.5 pairs, thus leaving the balance of 1.3 pairs as the average ionization by cosmic rays. The scatter of the observed values from the average of 2.8 pairs per cc per second may be indicated by stating that 60 per cent of the values fall between 2.6 and 3.0, 90 per cent between 2.4 and 3.2, and 95 per cent between 2.2 and 3.4 pairs per cc per second. The individual values will be tabulated in a later section in which the daily observations of the several atmospheric-electric elements will be presented.

Radioactive Content of the Atmosphere.--Apparatus for the measurement of the radioactive content of the atmosphere was installed on the *Carnegie* before the beginning of cruise VII, but successful measurements were not obtained with it until the last two months of the cruise because of persistent insulation failure on one of the three major items of equipment. The apparatus used on cruise VII, as on previous cruises, consisted of a collecting apparatus, a high potential generator, and an ionization chamber with electrometer attached. The high potential generator was the equipment on which adequate insulation could not be maintained, until the instrument was remodeled.

The method employed for measuring the radioactive content of the atmosphere consists in drawing air between two concentric cylinders of a collecting apparatus, the central cylinder of which is charged negatively to such a high potential (by the high potential generator), that all the active carriers entering the outer cylinder are brought to the central cylinder. The saturation current produced in the ionization chamber by the active deposit collected on the central cylinder in a given time is then measured. This, combined with a knowledge of the air flow during the collection of the deposit, permits the amount of active material per cubic meter of the air to be estimated, if one assumes a knowledge of the nature of the deposit, which latter can be obtained from the form of the decay curve.

The Carnegie apparatus was designated radioactive content apparatus 4. The ionization chamber was the same as used on previous cruises, but it was overhauled and put in good working condition before cruise VII began. The high potential generator of previous cruises was taken along on cruise VII and in addition a unit incorporating new and improved features was supplied. Both these were superseded in September 1929 by a still further improved generator unit, and this final unit was the one with which successful measurements of radioactive content were obtained.

The collecting apparatus consisted of an air-flow tube and a central collecting system. The air-flow tube was a copper cylinder 64 cm long and about 20 cm in diameter, with an anemometer at one end and a fan at the other. The fan was driven by an electric motor operated from the ship's power plant. The central system consisted of an insulated wooden cylinder 12 cm long and 12 cm in diameter, supported by a rod passing through its axis and insulated from it by sulphur. When the collecting apparatus was in use, the surface of the wooden cylinder was covered with a sheet of copper foil, held on by rubber bands, and it was on this foil that the deposit was collected. Earthed metal caps, attached to the central rod, covered the top and bottom ends of the central cylinder without touching it, to insure that the negative charge, and consequently the active deposit, would be confined to the copper foil.

The collecting apparatus, high potential generator, and accessories, were mounted together as a portable unit which could be moved to suitable positions for collecting. The collecting apparatus was operated on the bridge in such a position as to be exposed to the prevailing wind. For charging the central cylinder of the collecting apparatus a potential of about 2000 volts was required to be supplied by the high potential generator. A form of Kelvin water dropper was used on earlier cruises as the high potential generator. In the simplest form of water dropper, a jet of water issues from the nozzle of a water tank, the droplets falling through an insulated metal cylinder mounted below the tank. The cylinder is connected with one terminal of a battery of, say, 100 volts, the other terminal of which is earthed. Below the cylinder is mounted a funnel or container which becomes charged by the droplets falling into it, and in practice the potential of the funnel or container rises until the rate of electrical leakage over the supporting insulators equals the rate of supply of electricity by the drops. The original Carnegie water dropper had, instead of one cylinder and one jet of water, a group of seven smaller cylinders each with a separate jet, and the effect of the multiple jets was shown to be additive, so that the efficiency of the apparatus accordingly was enhanced (12).

The other type of high potential generator provided at the beginning of cruise VII had, instead of several jets from which water issued under force of gravity, a single nozzle (atomizer) from which water was forced by compressed air, thus giving a fine spray of innumerable very small droplets. These droplets, as in the earlier apparatus, passed through a charged insulated cylinder and then communicated their charges to an insulated funnel or container below the cylinder. This type of generator was found very efficient under laboratory conditions. Under sea conditions, however, with rolling and pitching of the ship, the spray contrived to reach the insulation of the funnel or container and further modification was necessary.

The final modified form of generator was supplied at San Francisco in August 1929 (fig. 25). On this unit the insulation for the cylindrical container to which the droplets gave up their charge was at the upper end of three supporting posts, within an upper compartment into which no water was sprayed. Drying material in this compartment assisted in keeping the insulators dry. In the figure the generator unit is shown removed from its outer case. The connections for water hose and air hose are readily seen at the top of the unit. One of two black binding-posts on the top plate makes connection with the charged metal cylinder through which the water is sprayed; the other is an earth connection. A third binding-post on the top plate has a metal hood protecting the insulating material, and this post makes connection with the container collecting the charge.

The ionization chamber of the radioactive content apparatus has been shown in figure 5. The chamber was a cylindrical copper container about 12 cm in diameter and about 25 cm long. The insulated central system of the ionization apparatus was a long thin rod, and it was attached to the fiber system of a unifilar electrometer. The sensitivity of the electrometer was adjusted to between 5 and 10 divisions per volt. When the copper foil was removed from the collecting apparatus, it was formed into a cylinder with the active surface inward, and placed as a lining against the inner wall of the ionization chamber. Installed this way, the foil did not contribute to capacitance of the apparatus. The height of the chamber was made about twice that of the foil cylinder, so that the latter would cover only the middle part of the chamber wall; in this way it was arranged that none of the α particles would strike the top or bottom of the chamber. Thus, although the range of some of the α particles would be cut short by their traversing, for example, a short chord of the cylinder, the average reduction of range brought about in this way would be a definite and calculable function of the radius of the cylinder and of the true range of the α particles. It would be independent of the distribution of the active material on the foil--a point of some importance, since the distribution of active deposit on the foil would not be uniform.

In the measurements with the ionization chamber, the method of allowing for insulation-leak was exactly analogous to that adopted in the case of the eye-reading conductivity apparatus, except that no test could be made after a measurement because the whole internal surface of the ionization chamber would be likely to be covered with the disintegration products of the material originally collected. The observations were recorded on a suitable form (Department form 103). The symbol, η, used on this form represents the number of pairs of ions produced per second in the ionization chamber, because of active material which would be deposited on the collecting cylinder in an air flow of 1 cc per second. η is recorded on the form for various periods of time after the completion of the deposition, and serves as a preliminary quantity for use in subsequent determination of the radium-emanation content. This determination, which necessitates a careful analysis of the curve obtained by plotting η against time, was carried out at Washington rather than on ship.

The value of η is computed from the formula

$$\eta = C\delta V(\tau^{-1} - t^{-1})/300We$$

where C is the capacitance of the apparatus; δV is the voltage change corresponding to the change in deflection of the electrometer fiber over a selected range, θ, of scale divisions; τ is the time in seconds for the fibers to move over the selected range, θ; t is the leakage correction based on a leak-test made before the copper foil is introduced into the ionization chamber and derived as explained on page 8 under computation of conductivity; e is the electronic charge; and W is the number of cubic centimeters per second of air drawn past the collecting cylinder during the period of collection of active deposit.

For cruise VII the capacitance, C, was taken as 8.9 cm for radioactive content apparatus 4, as compared with 8.7 cm used for cruise VI. Twenty measurements of radioactive content were obtained on as many days, during the period between September 22 and November 18, 1929. The observational procedure was such that the copper foil was exposed in the collecting apparatus for 3600 seconds, during which time air was flowing past the foil at the rate of approximately 130 liters per second. The high potential generator maintained the foil within the range of 1500 to 3000 volts, negative with respect to the air-flow tube, for each collecting period, with the most frequently obtained potentials lying in the range between 2000 and 2500 volts.

After transfer of the foil from the collecting apparatus to the ionization chamber, observations with the latter were made over a period of two to three hours, during which time five or six, and occasionally more, sets of measurements were made of the ionization produced by the active deposit. From these several sets of data the form of the decay curve could be obtained.

Owing to a late beginning of the observations of radioactive content on cruise VII and the sudden ending of the cruise, only twenty measurements were obtained, as has been mentioned earlier. One measurement was made September 22, 1929, and the remaining between October 8 and November 18, 1929, all in the Pacific Ocean. To assemble these into groups of about ten for the purpose of drawing an average decay curve for each group, as was done for the data from cruises IV, V, and VI, would yield only two or three determinations of emanation content. This number is small compared with the thirty-two derived values of emanation content for the Pacific Ocean obtained from 271 measurements made with apparatus 4 on cruises IV, V, and VI. Furthermore, the measurements over all oceans on these cruises totaled 497, and the derived values of emanation content totaled 63. These have been tabulated and discussed by Swann (13) and Mauchly (14). The two or three values to be derived from cruise VII measurements have been considered, therefore, to be too few to warrant the lengthy and involved analysis which would be required to obtain them, and too few to add significantly to the information obtained from the work of previous cruises. The data from this part of the program of cruise VII accordingly are being omitted from the present publication.

LITERATURE LIST

1. Bauer, L. A., W. J. Peters, J. A. Fleming, J. P. Ault, and W. F. G. Swann. 1917. Ocean magnetic observations 1905-1916 and reports on special researches. Researches of the Department of Terrestrial Magnetism. Carnegie Inst. Wash. Pub. No. 175, vol. 3, pp. 378-392.

   Ault, J. P., S. J. Mauchly, W. J. Peters, L. A. Bauer, J. A. Fleming. 1926. Ocean magnetic and electric observations, 1915-1921. Researches of the Department of Terrestrial Magnetism. Carnegie Inst. Wash. Pub. No. 175, vol. 5, pp. 201-209.
2. Collected Scientific Papers of John Aitken. 1923. Cambridge University Press. pp. 236-246.
3. Bauer, L. A., W. J. Peters, J. A. Fleming, J. P. Ault, and W. F. G. Swann. 1917. Ocean magnetic observations 1905-1916 and reports on special researches. Researches of the Department of Terrestrial Magnetism. Carnegie Inst. Wash. Pub. No. 175, vol. 3, pp. 380-401.
4. Jacobs, W. C., and C. Clark. 1943. Meteorological results of cruise VII of the Carnegie, 1928-1929. Sci. res. of cruise VII of the Carnegie during 1928-1929 under command of Captain J. P. Ault. Meteor.-I. Carnegie Inst. Wash. Pub. No. 544. 168 pp., 62 figs.
5. Gerdien, H. von. 1905. Die Absolute Messung der Specifischen Leitfähigkeit und der Dichte des Verticalen Leitungsstromes in der Atmosphäre. Jour. Terr. Mag., vol. 10, pp. 69-71.
6. Swann, W. F. G. 1914. The theory of electrical dispersion into the free atmosphere, with a discussion of the theory of the Gerdien conductivity apparatus, and of the theory of the collection of radioactive deposit by a charged conductor. Jour. Terr. Mag., vol. 19, pp. 81-88.
7. Swann, W. F. G., and S. J. Mauchly. 1917. On the conduction of electricity through an ionized gas, more particularly in its relation to Bronson resistances. Jour. Terr. Mag., vol. 22, pp. 1-21.
8. Bauer, L. A., W. J. Peters, J. A. Fleming, J. P. Ault, and W. F. G. Swann. 1917. Ocean magnetic observations 1905-1916 and reports on special researches. Researches of the Department of Terrestrial Magnetism. Carnegie Inst. Wash. Pub. No. 175, vol. 3, pp. 386-389.
9. Swann, W. F. G. 1914. On certain new atmospheric-electric instruments and methods. Jour. Terr. Mag., vol. 19, pp. 171-176.
10. Wait, G. R. 1932. The Aitken pocket nuclei-counter. Beitr. Geophysik, vol. 37, pp. 429-439.
11. Ault, J. P., S. J. Mauchly, W. J. Peters, L. A. Bauer, J. A. Fleming. 1926. Ocean magnetic and electric observations, 1915-1921. Researches of the Department of Terrestrial Magnetism. Carnegie Inst. Wash. Pub. No. 175, vol. 5, pp. 421-423.
12. Bauer, L. A., W. J. Peters, J. A. Fleming, J. P. Ault, and W. F. G. Swann. 1917. Ocean magnetic observations 1905-1916 and reports on special researches. Researches of the Department of Terrestrial Magnetism. Carnegie Inst. Wash. Pub. No. 175, vol. 3, pp. 390-393.
13. Bauer, L. A., W. J. Peters, J. A. Fleming, J. P. Ault, and W. F. G. Swann. ibid., pp. 413-416.
14. Ault, J. P., S. J. Mauchly, W. J. Peters, L. A. Bauer, J. A. Fleming. 1926. Ocean magnetic and electric observations, 1915-1921. Researches of the Department of Terrestrial Magnetism. Carnegie Inst. Wash. Pub. No. 175., vol. 5, pp. 416-421.

FIGURES 1 - 25

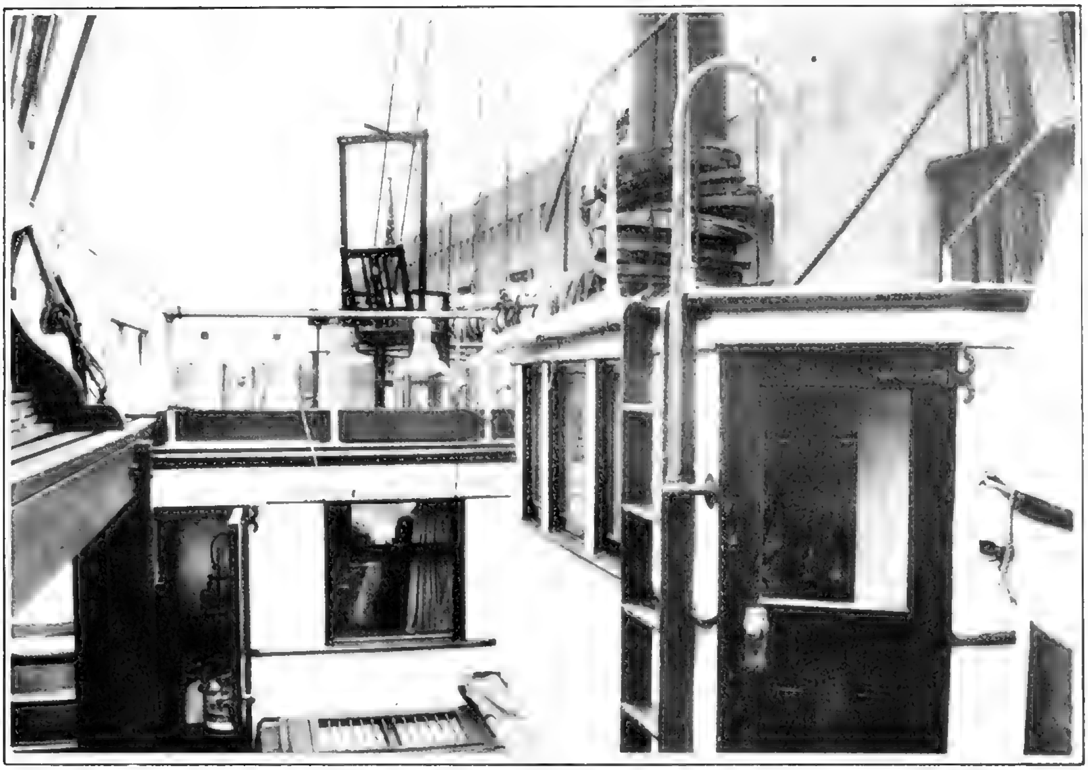


Fig. 1. Atmospheric-electric cabin at right, showing starboard wall and entrance

Fig. 2

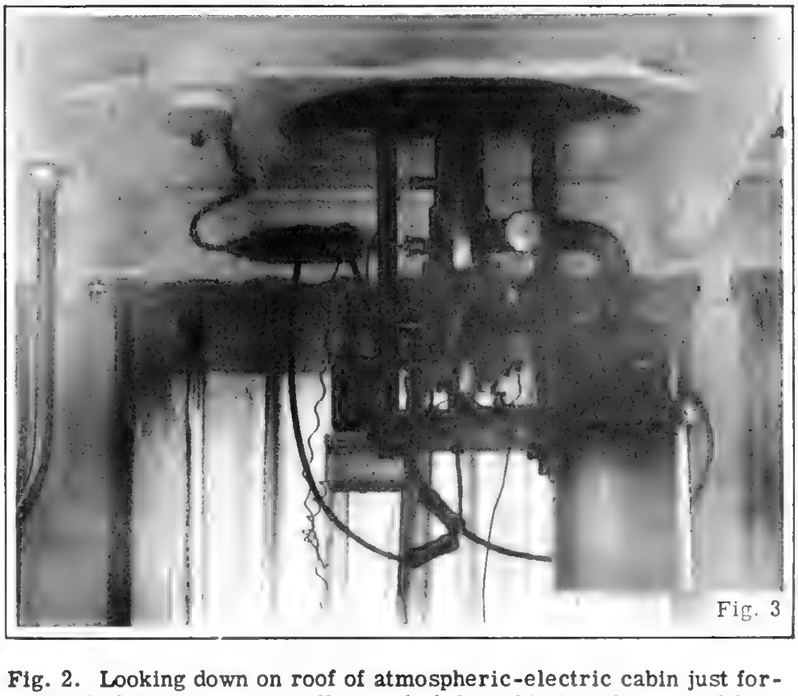


Fig. 3

Fig. 2. Looking down on roof of atmospheric-electric cabin just forward of the mainmast. Forward of the cabin is a dome used for magnetic measurements, and forward of the dome is the bridge. At the stern rail may be noted both eye-reading and recording apparatus for potential-gradient measurements

Fig. 3. Ion counter DTM No. 1 (IC1) for measurement of small-ion content of the atmosphere. The apparatus projects through the roof and is uncovered during use

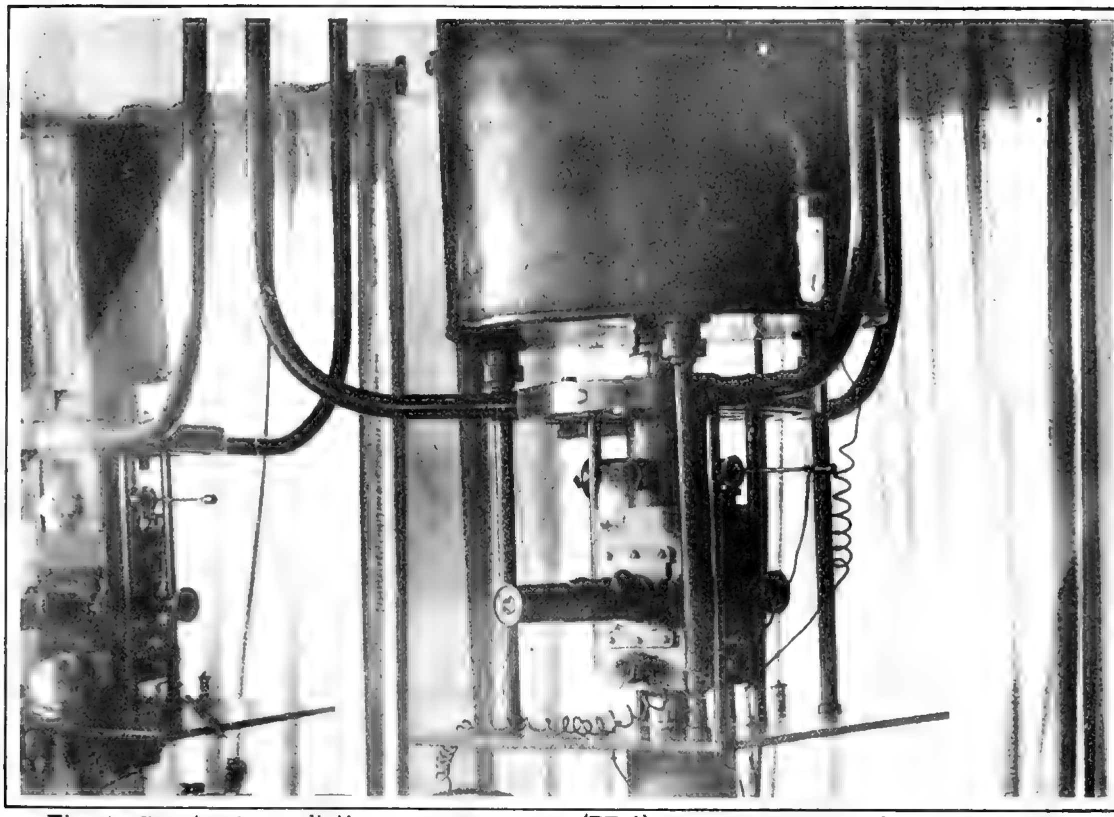


Fig. 4. Penetrating radiation apparatus No. 1 (PR 1) for measurement of ionization due to cosmic rays and other penetrating radiations

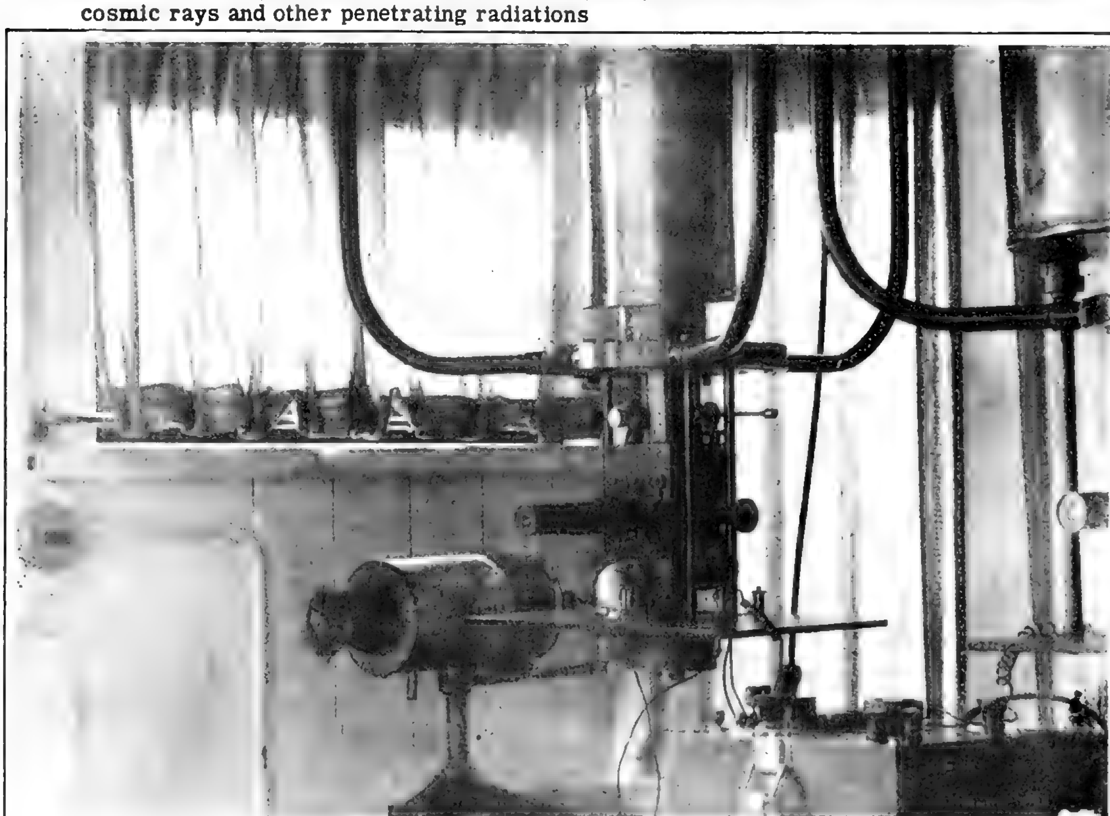


Fig. 5. Ionization apparatus of radioactive-content apparatus No. 4 (RCA4). Copper foil with a deposit of radioactive material is placed in this apparatus and the resulting ionization measured

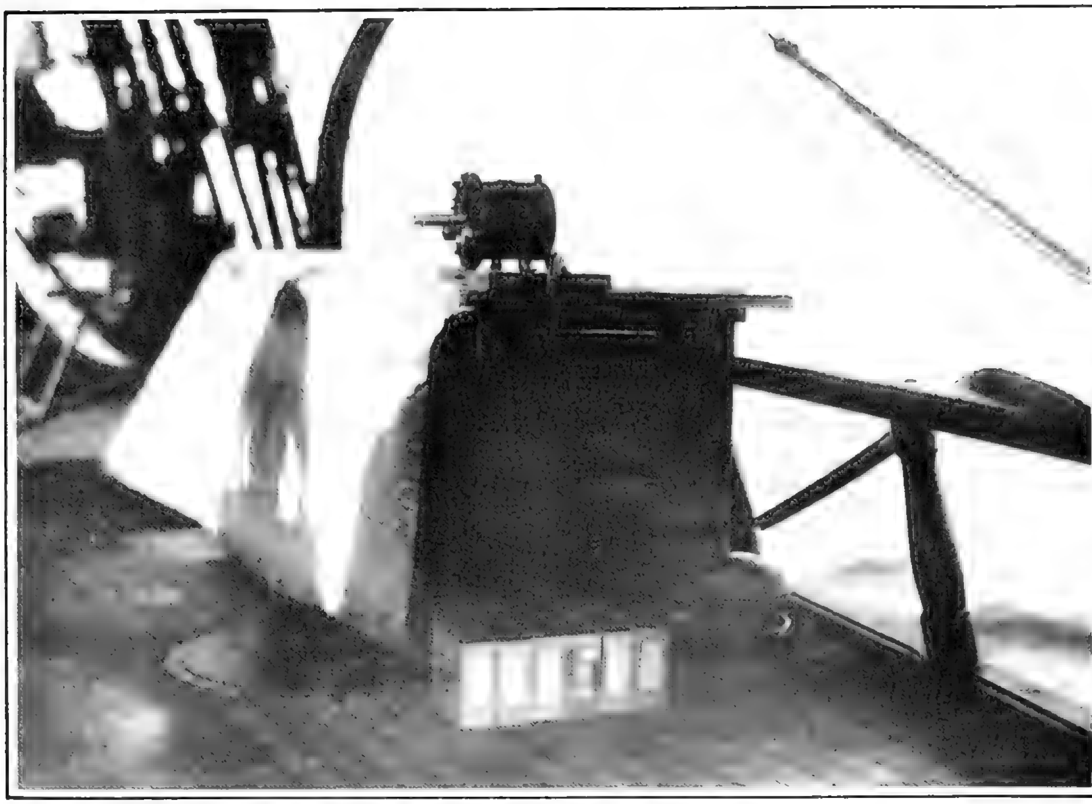


Fig. 6. Kolhörster penetrating radiation apparatus No. 5503 in use on quarter-deck for special tests. Generally used adjacent to PR 1 in atmospheric-electric cabin

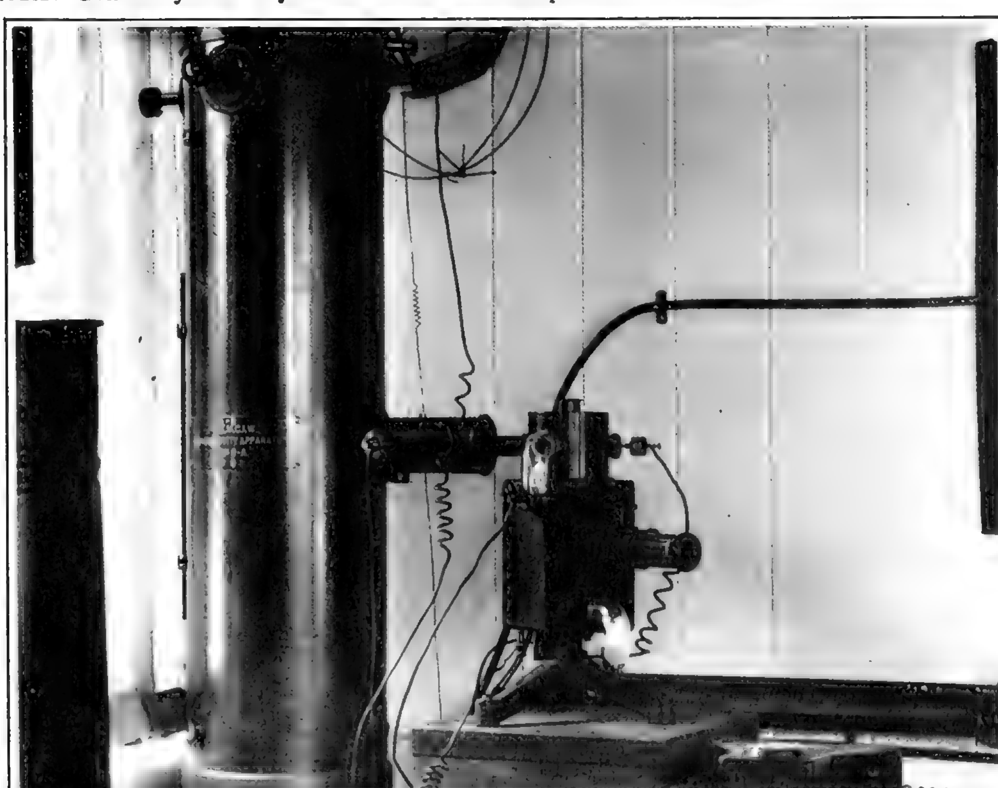


Fig. 7. Conductivity apparatus No. 8A (CA8A), showing vertical air-flow tube and the eye-reading electrometer which was used until September 1929

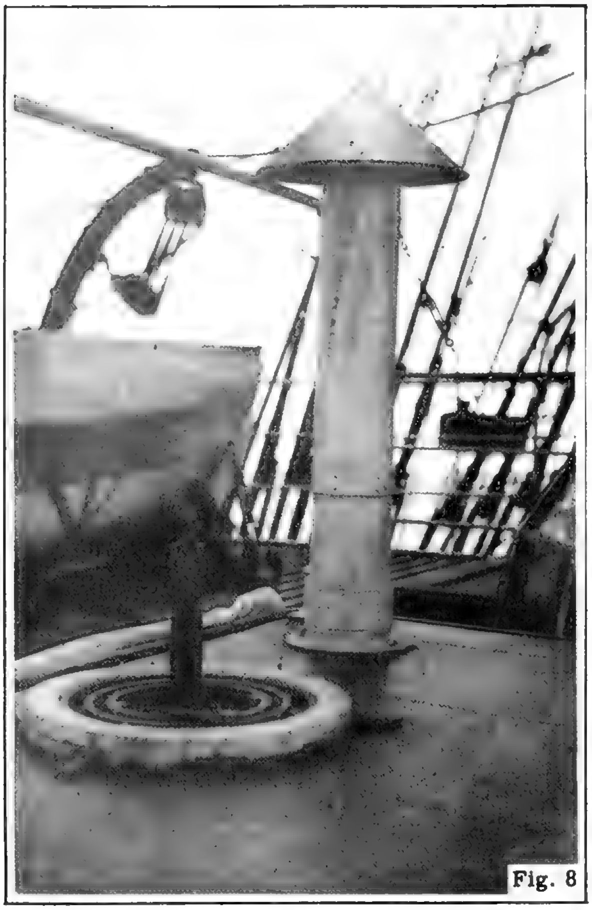


Fig. 8

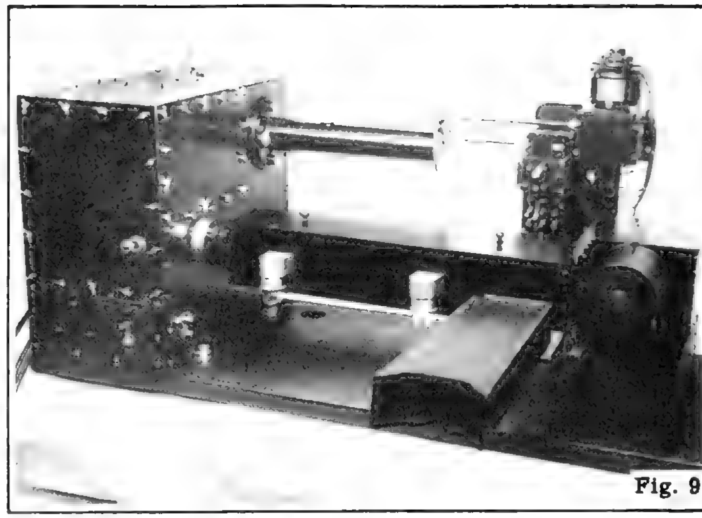


Fig. 9

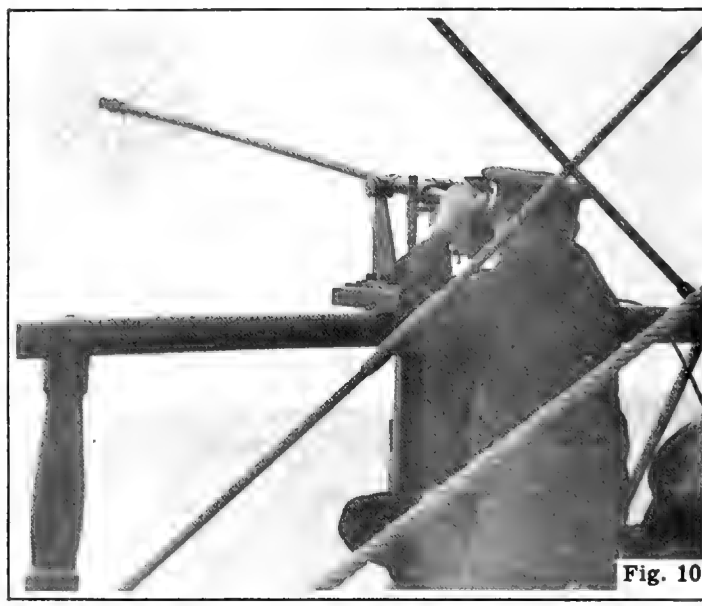


Fig. 10

Fig. 11

Fig. 8. Air-flow tubes of ion counter (small tube) and conductivity apparatus (large tube) on roof of atmospheric-electric cabin

Fig. 9. Conductivity recording apparatus installed at San Francisco in August 1929, and used at sea September through November, 1929

Fig. 10. Potential-gradient apparatus No. 2 (PGA2) with umbrella-shaped conductor, used for eye-reading observations until September 16, 1928

Fig. 11. Potential-gradient recording apparatus installed on stern rail to starboard of eye-reading apparatus PGA2. Note form and position of collector rod; this was used from July 7, 1928 to November 5, 1928

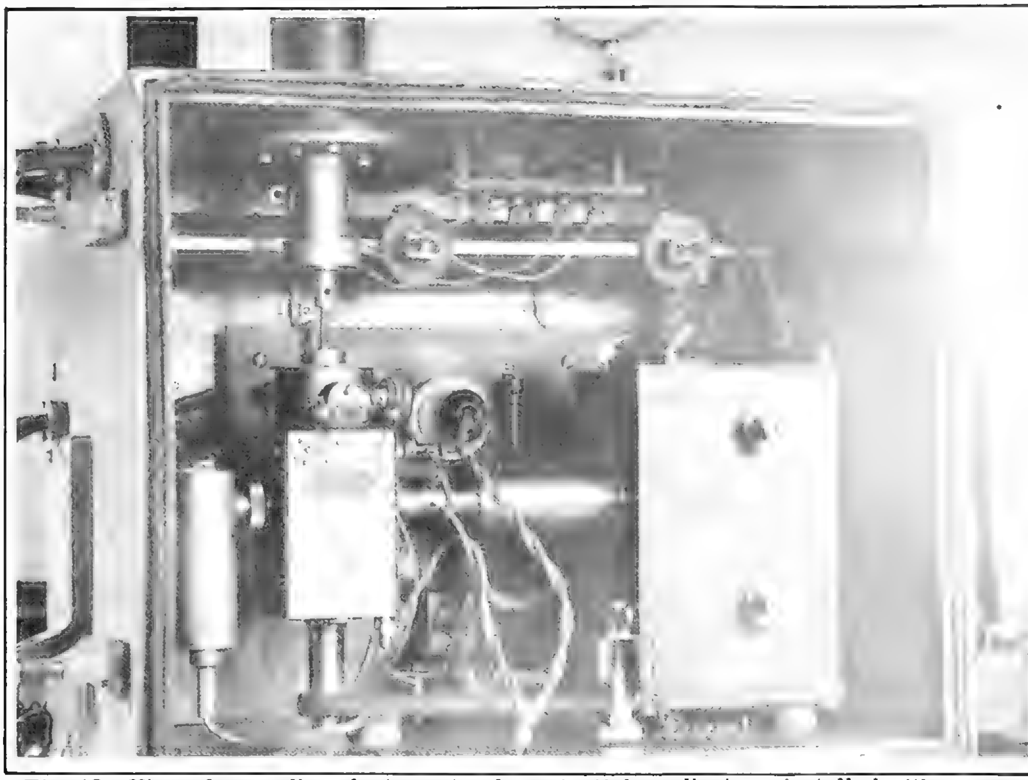


Fig. 12. View of recording electrometer for potential-gradient, as installed with accessories in weatherproof box for mounting on stern rail

Fig. 13. Aitken nuclei counter, used to determine the number of condensation nuclei per cubic centimeter in the atmosphere

Fig. 14. W. C. Parkinson operating the Aitken nuclei counter on the bridge

Fig. 15. Potential-gradient reduction-factor station on Watson's Island, Apia, Samoa, April 1929

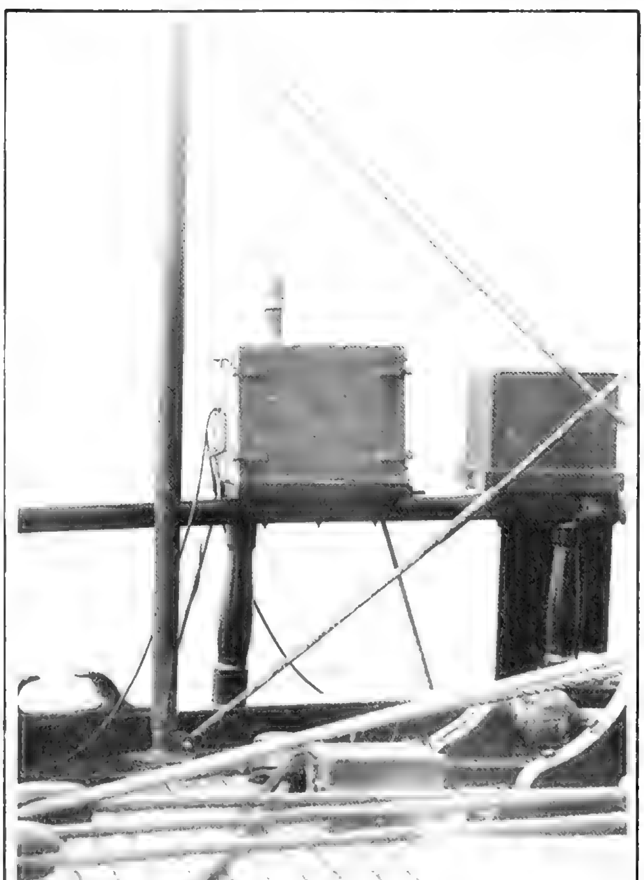


Fig. 16. View of short vertical collector rod on potential-gradient recording apparatus substituted for bent rod (fig. 11) on November 5, 1928

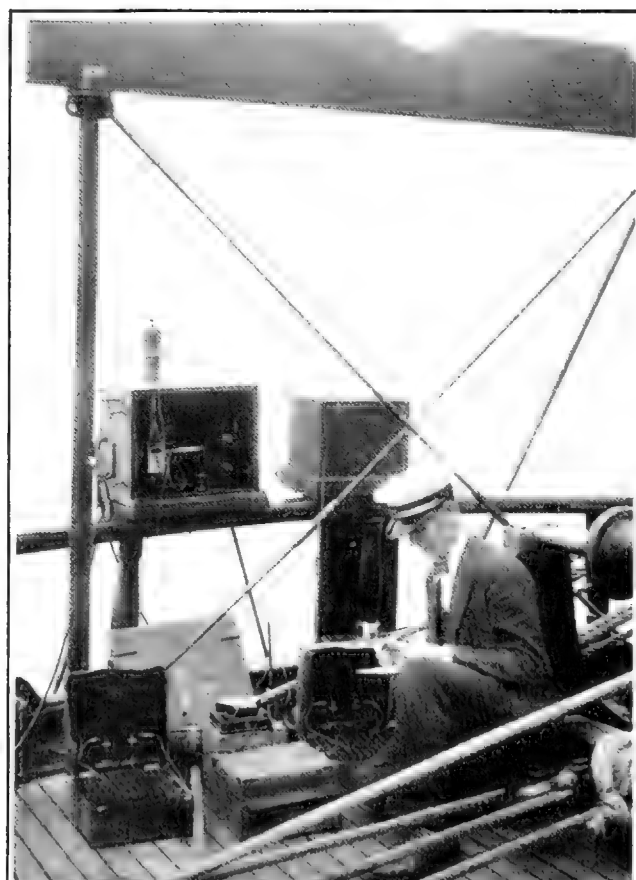


Fig. 17. Calibrating the potential-gradient recording apparatus, an operation performed once each week unless bad weather prevented.

Fig. 18. View of potential-gradient recorder and eye-reading apparatus on stern rail of ship. Note how the boom crutch dominates the location, and shields the apparatus from distortion of the earth's field arising from the installation or removal of the quarter-deck awning. The mainsail is up with boom to starboard, a position designated as MUBS in this volume

Fig. 19. View of potential-gradient apparatus from quarter-deck with awning up. Note the small boat on davits at the port rail, probably contributing somewhat to the distortion of the earth's field at the stern of the ship

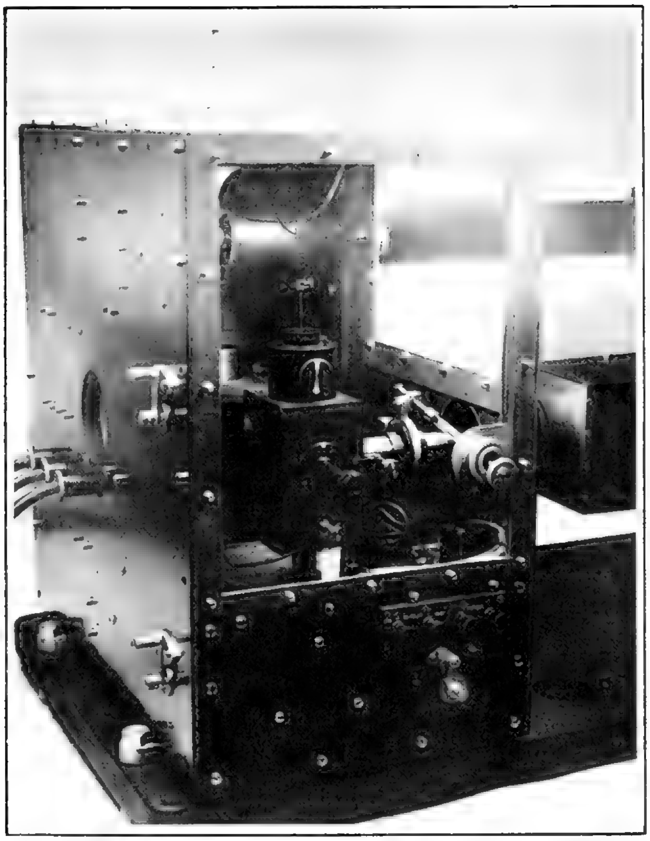


Fig. 20. View of unifilar electrometer of recording conductivity apparatus CA8A

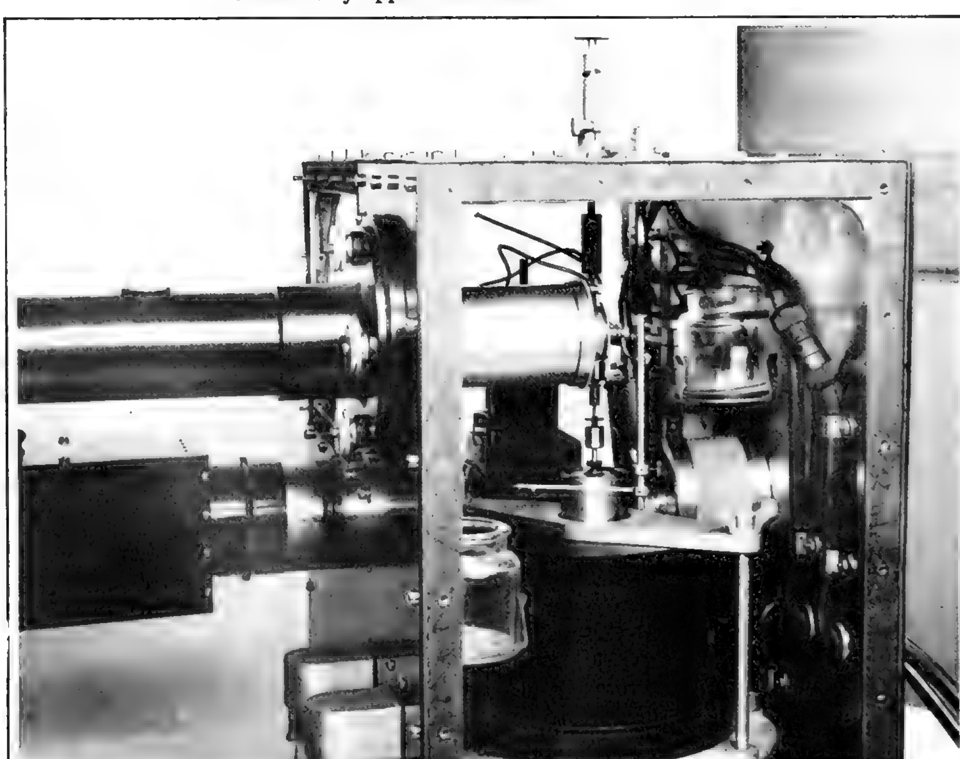


Fig. 21. View of high resistance ionium cell of recording conductivity apparatus

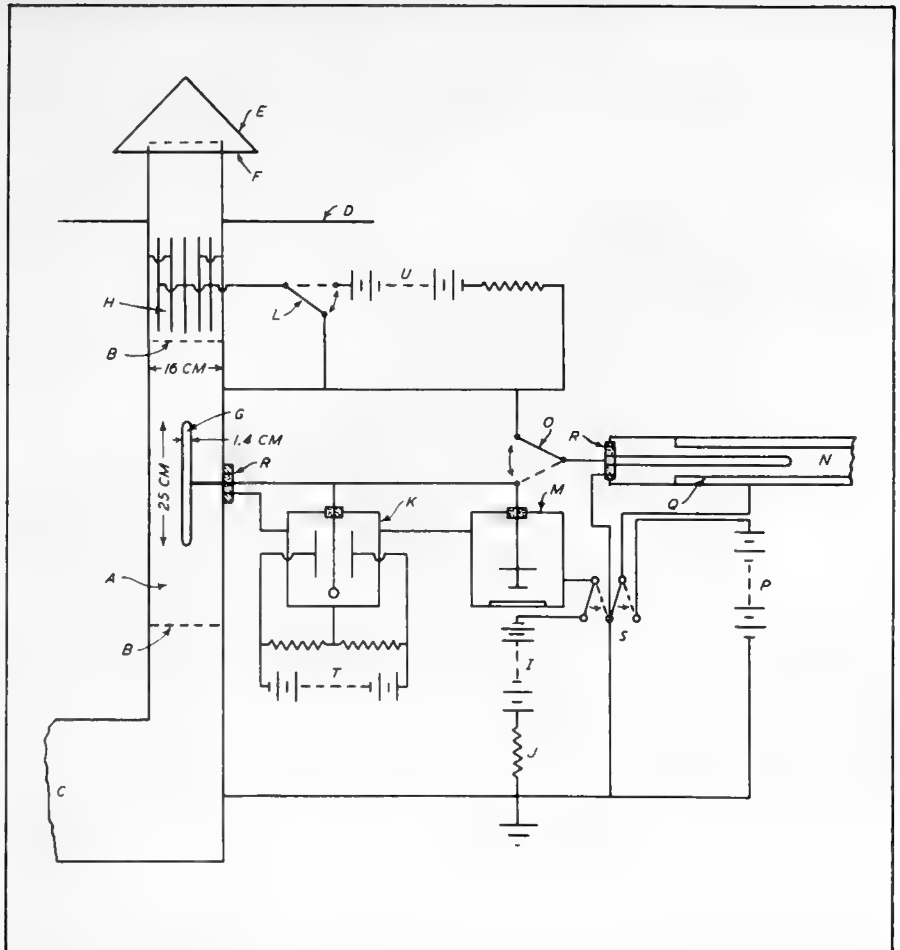


Fig. 22. Schematic diagram of Gerdien conductivity apparatus with unifilar electrometer, high resistance cell, and variable calibrating condenser. A, vertical cylindrical air-flow tube; B, screens to prevent entry of foreign particles; C, duct from air-flow tube to fan; D, roof line of cabin; E, conical hood; F, air intake; G, central cylinder; H, concentric tubes across which sweeping potential, U, is applied by switch L; I, operating potential; J, protective resistor; K, unifilar electrometer; M, high resistance radioactive cell; N, variable calibrating condenser; O, switch for connecting central member of calibrating condenser to radioactive cell for calibration; P, calibrating potential; Q, movable cylinder of calibrating condenser; R, guard rings; S, double pole, double throw switch to remove operating potential and apply calibrating potential for calibration; T, plate potential. Ambers are shown in dotted cross-section. Note: Switches O and S are thrown into positions of broken lines in order to calibrate

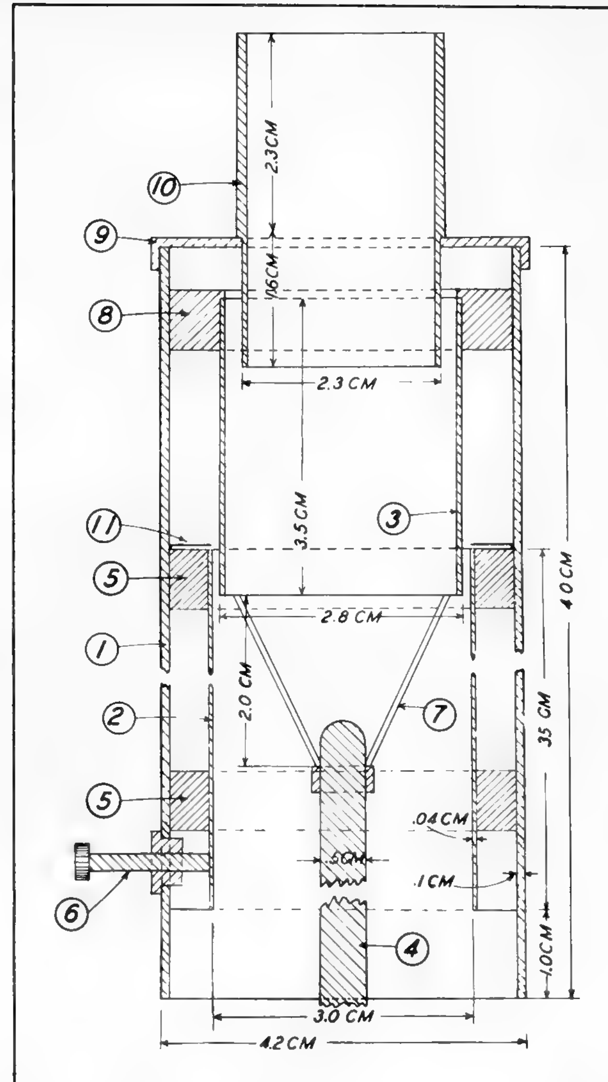


Fig. 23. Design of shielding "cup" at intake of ion counter devised to avoid error in ion measurements when the "charging" method of operation is used. 1, outer brass cylinder; 2, inner cylinder of condenser; 3, cylindrical shield or cup; 4, central rod; 5, ebonite insulating rings; 6, binding-post; 7, brass struts; 8, amber insulating ring; 9, cap; 10, intake aperture; 11, annular shielding disc

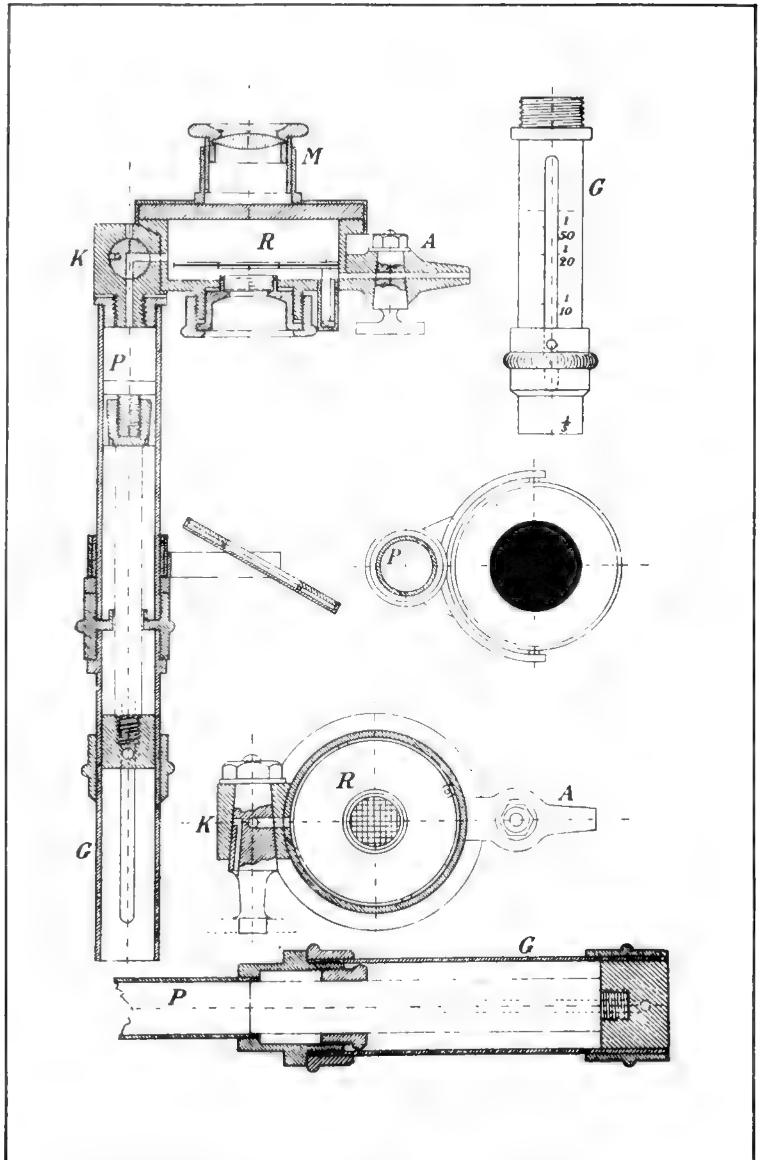


Fig. 24. Detail drawing of Aitken nuclei counter

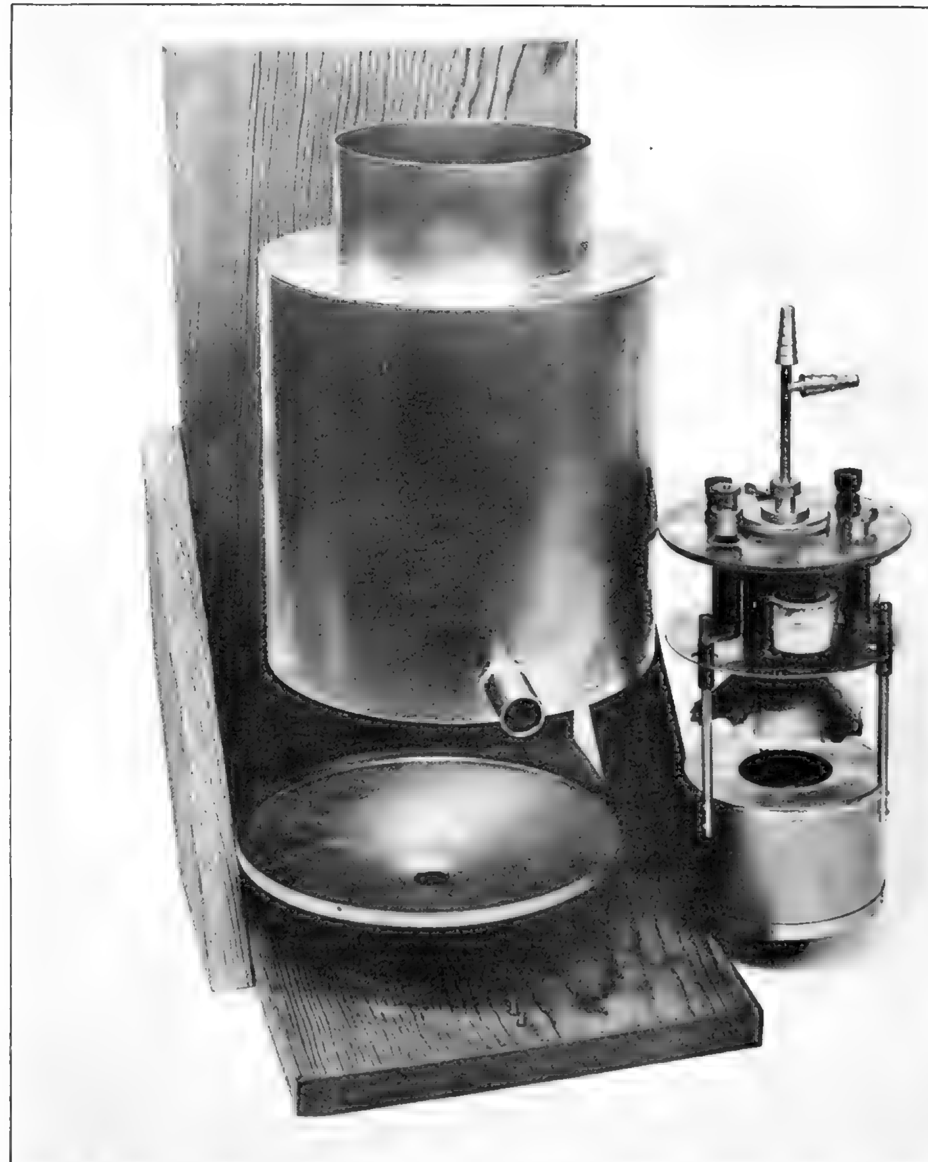


Fig. 25. High potential generator for radioactive content apparatus No. 4 shown removed from metal housing

III. REPORTS ON ATMOSPHERIC-ELECTRIC WORK OF CRUISE VII, 1928-1929, PREPARED ON BOARD SHIP

NEWPORT NEWS, VIRGINIA TO PLYMOUTH, ENGLAND, MAY 10 TO JUNE 8, 1928

After leaving Newport News on May 10 the first few days were occupied in acquiring some degree of facility in observing during the ship's motion. The conductivity and penetrating radiation apparatuses have presented no great difficulties but the ion counter has been found to be extremely sensitive to rolling and the fiber therefore hardly ever at rest. It might be considered advisable to increase its stability by having an additional weight below the electrometer platform which could be removed when the gimbals are clamped, thus preventing undue wear on the pivots.

A systematic daily program of observation similar to that carried out on previous cruises has not been arranged, for the following reasons. During the oceanographic work the potential-gradient at the stern cannot be observed, because the engine is running and nets are being towed; also, with the ship hove to, the rolling is excessive and we have not been able to work with the ion counter at these times. When the magnetic work is being done, the conductivity motor possibly may cause disturbances in the field in the after dome. The oceanographic work and, to a lesser degree the magnetic work, are controlled by sea conditions and it has happened on one occasion so far that the oceanographic work has been done in the morning and the magnetic work in the afternoon of the same day, leaving no part of the day free for atmospheric-electric work. It is proposed to make tests to determine the effect, if any, of the conductivity motor on the magnetic work in the after dome and a regular schedule of atmospheric-electric observations will be carried out as often as conditions permit.

Recording Potential-Gradient Apparatus.--Continuous recording of potential-gradient at the masthead has had to be discontinued. For the first few days, while the mainsail was to port, the recorder box remained fairly steady and one good 24-hour trace was obtained; the fibers, however, were at a low sensitivity (about 60 volts per division). When the mainsail was put to starboard, the recorder-box guide cables slackened, owing to the play in the masthead and the box was in continuous motion through an angle of about 45° astern of the masthead. The traces obtained during this period were quite illegible. There is no way of preventing this play of the masthead because of the elasticity in the hemp rigging. There were difficulties in raising and lowering the box past the sail when the mainsail was to starboard also. Then it was thought that a satisfactory diurnal-variation curve might be obtained on the roof of the atmospheric-electric house, in spite of the probable low field due to the proximity of the mainmast and staysails. An experimental trace, however, showed that the field was too weak to produce a curve from which the diurnal variation might safely be derived. Next it is planned to try mounting the box on the stern rail, near potential gradient apparatus 2, though it is feared that the daily running of the engine will produce serious gaps in the records.

Radioactive Content Apparatus.--On several occasions during the few periods of good weather we have had, we have experimented with the collector of this apparatus but have been unable, so far, to maintain a potential of 1500 to 2000 volts for more than five minutes. For a time it seemed that it was an advantage to have the door closed rather than open, but in the end the insulation always broke down after a few moments had elapsed. We have been unable so far, therefore, to obtain any observations of radioactive content, but experiment with the collector will be continued as soon as possible.

Diurnal-Variation Observations.--Persistent bad weather has prevented diurnal-variation observations of any of the atmospheric-electric elements.

Nuclei Concentration.--Since May 21 practically daily observation has been made with the nuclei counter 4. No difficulties have been encountered.

Battery Replacements.--Fifteen cell replacements have been made in battery 14689 and the use of the battery on June 7 for calibration of potential gradient apparatus 2 indicated some more bad cells. All other batteries have maintained high potentials.

Attention might be called to the consistently low values that were obtained for ionic content and conductivity, particularly the latter. No reason for this fact is apparent, except unusually stormy weather conditions.

HAMBURG, GERMANY TO REYKJAVIK, ICELAND, JULY 7 TO 20, 1928

General.--Observations of all the atmospheric-electric elements, with the exception of radioactive content, have been made whenever conditions permitted. Lack of time and adverse weather have prevented any attempt to get the radioactive content apparatus into working order. It is hoped that something may be done with this when more temperate latitudes are reached. During the stay in Hamburg additional shelf space was provided in the atmospheric-electric observatory for the storage of batteries and miscellaneous equipment.

Potential Gradient Recorder.--At Hamburg a staging was built on the stern rail, to starboard of the potential-gradient apparatus 2, and the recorder was mounted thereon. The collector rod was remodeled so as to allow the disc collectors to project over the stern. So far some very good traces have been obtained with this arrangement. Because head winds required frequent running of the main engine, some of the records do not represent normal air conditions. Appropriate record, of course, will be kept of the times of starting and stoping the main engine, for proper interpretation of the traces. It was hoped that the traces obtained up to date might have been transmitted before leaving Iceland but the ship and shore observations have made this impossible. It is felt, however, that the present location of the instrument is the only feasible one on the ship and it is confidently anticipated that some reliable diurnal-variation data will be obtained.

Penetrating Radiation.--As previously reported, Dr. Kolhörster delivered his penetrating radiation instrument (Günther and Tegetmeyer No. 5503) in Hamburg and, as will be seen from the records transmitted, daily intercomparisons between this instrument and penetrating radiation apparatus 1 have been made. There are some difficulties in the use of an instrument of this type, rigidly mounted on a rolling ship, and having coarse fibers widely separated which are in constant and irregular motion. It is necessary to use a large initial potential (over 300 volts), and the time interval for each observation must be at least one hour. It would be an advantage to have the initial voltage the same for each observation, no doubt, but with the magnetic contact-device now in use, it has been found impossible so far to reproduce a deflection with the same number of cells. The "zero" position of the fibers has moved about 15 divisions (full scale deflection is about 160 divisions) to one side of the center and there seems no ready way of bringing it back to the center. For the computation of the values of R the calibration curve supplied by Dr. Kolhörster has been used, but with the change of zero it is doubtful whether it still holds. It is intended to recalibrate the instrument before leaving Reykjavik.

Potential-Gradient Apparatus 2.--During the damp weather encountered since leaving Hamburg, trouble has been experienced with the sulphur insulators supporting the collector-system, and since arriving at Reykjavik these have been recast. It would be a convenience if one or two spare sets of these insulators, with the screw holes made, could be supplied, as it is impossible to recast the sulphur while the ship is in motion and dry insulators could be mounted easily when necessary. The shield protecting the hard rubber connection of the handle of the umbrella-shaped conductor or collector was accidentally dropped overboard and a replacement of this is requested as soon as possible. Frequent necessity for using the main engine has decreased the number of opportunities for making potential-gradient observations. Reduction-factor observations on ship and shore, using both recorders and eye-reading instruments have been made at Reykjavik but the final analysis of the results has not been completed.

Silver Chloride Batteries.--Some of the batteries are beginning to show signs of rapid deterioration. Number 14832 has had two replacements; no. 14689, which had fifteen cells replaced during May, has had the remaining eighty-five renewed; and no. 14870 needs entire renewal. With the new penetrating radiation apparatus, requiring 300 volts for its use, it seems necessary that six entirely new batteries should be supplied at Balboa. The 45-volt Burgess batteries can be used for some purposes, of course, but they are not convenient where intermediate voltages are required.

Acknowledgment is made of the memorandum of July 7, 1928 dealing with the penetrating radiation measurements. The comparison observations had been made before receipt of this memorandum but the observations follow closely along the lines suggested. Advantage will be taken of any opportunity to make measurements on an exposed part of the quarter-deck to determine the shielding effect of the atmospheric-electric observatory, and other parts of the ship's superstructure. Dr. Kolhörster had informed us that the residual ionization of the chamber of his instrument is equal to 1.3 ions per cc per sec.

It is intended to make diurnal-variation observations at least once per week from now on, of as many of the atmospheric-electric elements as the weather permits.

Comments

Some Preliminary Deductions from Data up to July 19, 1928.--The penetrating radiation observations received from the Carnegie thus far show characteristics much like those obtained on previous cruises and the comparisons between penetrating radiation apparatus 1 and Günther and Tegetmeyer No. 5503 indicate that these two instruments on the whole give consistent values. The observations obtained July 19, 1928 are the only ones seriously out of harmony with the general trend.

A rough estimate from these data of the ratio of Eve's constant for penetrating radiation apparatus 1 to that for Günther and Tegetmeyer No. 5503, gives 0.9 ± 0.1, and the residual ionization for penetrating radiation apparatus 1, taking that for Günther and Tegetmeyer No. 5503 as 1.3 ions per cc per sec as given by Kolhörster, is 1.9 ± 0.1 ions per cc per sec. This last is surprisingly close to that estimated by Mauchly.[1] These values are only tentative; the final values must be deduced by a statistical study of a more extensive mass of data.

Using the value for Eve's constant determined at Newport News (namely 5.0×10^9) and assuming the square law for recombination, we find that the mean number of ions in a cc of air during the period July 9 to 19 is by calculation 725, whereas the mean of observations is 547. Although the calculated value is about 30 per cent too great, it is considerably closer than other calculations in which the present controls are lacking. The discrepancy here may be in part because the value of Eve's constant is too small since the effect of masts, rigging, etc., is not included, and in part because nuclei increase the rate of recombination and thus reduce the total number to be found at any time. An estimate of the former factor can be obtained by the method indicated under "Comparative measurements" of penetrating radiation (p. 14) and a control for the latter may be derived from nuclei-count observations.

The Desirability of Simultaneous Nuclei Count, Ion Count, and Penetrating Radiation Observations probably has not been stressed sufficiently heretofore. These three elements are needed to determine definitely whether the penetrating radiation is the sole and adequate ion-producing agent over the oceans. This is one of the most important unsolved problems in atmospheric electricity.

The Difficulties with Günther and Tegetmeyer Radiation Apparatus No. 5503 which were mentioned in the observer's report probably will necessitate opening the chamber in order to examine and adjust the troublesome parts. If the defects are such that this instrument is not usable, it should be opened and the attempt made to adjust the contact finger so that it makes more positive contact. The electrometer element should be examined also to ascertain the cause of the zero shift and erratic behavior reported and should be adjusted if possible. If satisfactory adjustment is obtained, the chamber should be sealed again and used as before. Possibly the points at which the quartz support is attached to metal may be the real source of difficulty as the cement may have loosened or broken away. DeKhotinsky cement (possibly

[1]Researches of the Department of Terrestrial Magnetism, vol. 5. 1926.

the soft grade) and perhaps, more conveniently, shellac and alcohol may be used for recementing. The shellac should be thoroughly dry and all excess of alcohol removed before the instrument is reassembled. Naturally every care must be used to avoid salt particles being inclosed in the chamber and the air inclosed must be as dry as possible. Even though the residual ionization will doubtless have changed, this can be measured later. The other instrument to be supplied by Günther and Tegetmeyer will be sent as soon as possible to replace 5503, which should then be returned to Washington unless otherwise directed.

REYKJAVIK, ICELAND TO BARBADOS, B. W. I., JULY 27 TO SEPTEMBER 16, 1928

General.--Observations of the atmospheric-electric elements have been made practically daily throughout this leg of the cruise. Low values of ionic content and conductivity were obtained until reaching 13° north latitude on August 27. From August 27 to September 3 the values obtained were higher than normal and as the westerly course to Barbados was begun the values gradually became normal. On six occasions complete 24-hour diurnal-variation runs were obtained and on three other days diurnal-variation observations were begun but had to be discontinued because of bad weather.

Potential-Gradient Recorder.--Various difficulties have been encountered in obtaining good scalable traces. The chief difficulty has been the instability of the fibers of the electrometer. Part of this (and the greater part) is electrical, but there is some mechanical shifting of the fibers with the pitch and roll of the ship and, at times of light wind, with flapping of the mainsail and movement of the boom. An effort to reduce the electrical activity of the fibers was made by removing three of the four ionium discs from the collector system. With this arrangement, however, the electrometer deflection took several minutes to come up to its normal value after each hourly zero and so the discs were replaced. Various sensitivities have been tried and the one now being used (about 25 volts per division for each fiber) seems the most suitable. An inspection of the spare sets of fibers supplied showed that there were some on which the gold sputtering had flaked badly. When one box was opened, all three fiber systems were found broken. One set of fibers was broken by an observer when he mounted them in the recorder, during considerable motion of the ship, in place of a set of which the fibers were too fine to use at the required sensitivity. For these reasons, a request was made that more fibers be sent to Balboa. It appears that thicker fibers should be supplied as they will give a more satisfactory trace in addition to the fact that the added inertia will tend to damp out some of the larger fluctuations. Control observations with potential-gradient apparatus 2 have been made almost daily but it will be seen from the traces that, owing to the raising and lowering of the umbrella, the trace during the observation assumes a character different from that preceding and following. For this reason it seems hardly worth while to try to standardize the recorder by observations at the stern but rather to do it by land comparisons, using another recorder on shore over a period of several days, as we plan to do at Barbados. Another source of trouble which occasioned some loss of trace was the loosening of the objective lens inside the tube connecting the electrometer to the recording-paper housing. This lens fits against a spiral spring in the inner case of the electrometer and, presumably from some continuous motion, it worked loose, thus throwing the trace out of focus. Several attempts to refocus by the ordinary method were made before the real cause of the trouble was discovered. After the lens was replaced it would remain in position only for about two days. Finally, on September 10, the lens mounting was fixed in the tube with shellac and no further trouble has been experienced up to date.

Potential-Gradient Apparatus 2.--The sulphur insulators for this have had to be recast since leaving Reykjavik, thus reducing insulation difficulties, but considerable trouble has been experienced with the hard rubber insulator near the handle of the rod supporting the umbrella-shaped conductor. It seems necessary to have this unscrewed about one-half turn before it acts as an insulator. A brass cover was made for this insulator and was found quite effective in use.

Penetrating Radiation Apparatus Günther and Tegetmeyer 5503.--Inspection of the values of R obtained after about August 9 and also the attempted calibration of August 19 show that the deflection of the fibers is not representative of the applied voltages. The cause is not definitely known but the fact can be ascribed only to some defect in the fiber system itself. It has been the practice, during the magnetic observations in the after dome, to remove the penetrating radiation instrument to the photographic dark room, but the greatest care has been exercised in the removal at all times and it is certain that the instrument has suffered no sudden jar. When in the atmospheric-electric house, the instrument is secured by a leather strap to the port bench, between the radioactive-content electrometer and penetrating radiation apparatus 1. It is hoped that some satisfactory remedy can be suggested for the difficulty here mentioned as the comparisons between this instrument and the older one were proving to be quite good.

Penetrating Radiation Apparatus 1.--This instrument has performed very well and some instructive diurnal-variation curves have been obtained. In this connection attention is drawn to the form now being used for this work. The old form is not very suitable for continued observation and it is suggested that some forms might be supplied to obviate the work of ruling them up here. It will be noticed that the values in general are lower than those obtained on previous cruises. This change possibly may be owing to the fact that formerly a part of the roof over the chamber was removed during observation. This seems a good proof of the desirability of a second instrument such as the Kolhörster, with which observations could be made out-of-doors as suggested in Mr. Gish's memorandum of July 7, which was acknowledged in our last report. It was necessary to renew the sodium in the drying tubes on September 13, the operation being performed with as little exposure of the orifices as possible, as suggested in Mr. Gish's memorandum.

Radioactive Content Apparatus.--Several attempts have been made to maintain a high potential on the collecting system but with the same negative results as previously reported. There has been too great pressure of work in other lines to warrant further effort to obtain results with this instrument.

Silver Chloride Batteries.--Two more batteries have developed bad cells and the great pressure of current work has prevented replacements. It is intended, however, to make these replacements before leaving Barbados.

Comments

Difficulties with Potential-Gradient Recorder.--Mr. Parkinson's conclusions regarding these seem plausible. We would suggest, however, that fibers as fine as are admissible as regards sensitivity and size of image should reduce disturbances of mechanical origin unless these disturbances are really caused through vibration of the invar rods and the lower support for the fibers. Whenever the electrometer is opened for any cause the invar rods and inner case should be inspected so as to assure that all parts are rigidly fastened. As indicated in the report, however, it is likely that the chief sources of instability are electrical disturbances which may arise from movements of the mainsail or the boom or may be caused by space charges carried from spray by gusts of wind. Disturbances arising in this way probably will act on the recorder chiefly by induction and, if so, removing three of the four collectors would not result in much greater stability. If the capacitance to earth of the shielded part of the collector system were increased, however, the inductive effects would be reduced, and the effective collector activity would be correspondingly reduced even with the four collectors in use. Hence such a device would be effective whether the disturbances result from induction or from actual collection of charge. This scheme should have another advantage over reducing the number of collectors, namely, that the falsifying effect of insulation leak, as we see it, is not increased even though the system may have so much added capacitance that it takes five or ten minutes to charge from zero to air potential.

Although it has been possible to give this difficulty only brief consideration, it seems likely that an attachment which will correct it can be made up in the shop and sent to the Carnegie for installation.

Even with the recorder as operating during the period August 10 to September 17, many diurnal-variation data are being obtained which, on preliminary inspection, seem valuable and at the rate of accumulation during that period will soon outnumber the series obtained on all previous cruises. The form in which these data are tabulated seems very convenient.

Radioactive Content Collector.--If this cannot be made to function when the atomizer is used, the parts of the old water dropper which are on the Carnegie should be tried. In our opinion the spray from the atomizer fouls the insulation under conditions aboard the Carnegie although in the laboratory it worked beautifully.

Silver Chloride Batteries.--The experience with the silver chloride batteries apparently is not much different from our experience here. The lack of any report about the "B" batteries suggests that they continue in good condition.

BARBADOS, B. W. I., TO BALBOA, CANAL ZONE, OCTOBER 1 TO 11, 1928

General.--Observations have been made daily and in as complete form as the generally variable weather conditions would permit. A diurnal-variation run was begun on October 8 but bad weather and a large leakage in the ion counter prevented its completion. The special leak tests of the ion counter suggested in Dr. Wait's memorandum of September 11 were made on October 9 and will be found among the records being transmitted from this port.

Potential-Gradient Recorder.--This instrument has operated continuously. The records, however, are somewhat broken up by squalls. Reduction-factor observations were made at Bridgetown, Barbados and in spite of indifferent weather conditions eighteen hourly values are available for comparison. These give in the mean a reduction factor for the ship recorder to volts per meter of 0.70. This is in good agreement with the value as determined at Reykjavik, which was determined indirectly, by use of the reduction factor for potential-gradient apparatus 2 as determined at Kitt's Point. It will be noticed from the summary of the observations at Bridgetown that the position of the boom, rather than that of the mainsail, appears to be the dominating factor, but the different values are so close as to warrant using, as a preliminary reduction factor, the value of 0.70 and the scaled values are being converted to volts per meter on this basis. The new fibers received at Barbados have not been used so far but it is planned to insert one set of them while docked here.

Kolhörster Penetrating Radiation Apparatus.--On October 1, 1928, after overdeflecting the fibers many times, according to the advice of Dr. Kolhörster, using 500 volts ±, and getting no satisfactory results, we opened the instrument. It was found that the contactor arm had been displaced to the wrong side of the contact pin of the electrometer system. This condition confirmed previous impressions that the contactor arm did not touch the case, as it should do, when away from the contact pin. The varying deflections thus were the result of the varying effect of the field between the charged contactor arm and the fibers, depending on changes in the position of the arm, this position naturally changing with the roll of the ship. When the instrument was reassembled again, a calibration was made which gave a satisfactory curve, although the sensitivity had decreased slightly. On October 2 and 3 observations were made which gave results which were comparable with those obtained with penetrating radiation apparatus 1. On October 4, when about to begin an observation, we found that the contactor arm had crossed to the wrong side of the contact pin again. It should be mentioned that, during the magnetic work on October 4, the instrument was moved from the atmospheric-electric observatory to the biological laboratory. The utmost care was exercised in doing this and the instrument, wrapped in a soft cloth, was not moved during the time it was in the biological laboratory. On October 4 the instrument was reopened. In trying to bend the contactor arm so as to lessen the danger of its flying past the contact pin, we found that the arm was loose from the amber insulator. This insulator also holds the phosphor-bronze connector from the outside terminal. This loosening probably was caused by the heat softening the substance which was used as an adherent. The contactor arm was removed with a view to fastening it to the insulator again. During these operations one of the fibers became loose, at one end, from the vertical strip to which it was held with shellac. In view of the difficulty of making the necessary repairs in a satisfactory manner on board ship, the advisability of having dry air in the apparatus when again assembled and sealed up, and of making some changes mentioned below, it is recommended that the instrument, with its accessories, be returned to Washington from Balboa. Tests made with the instrument while it was open showed how easy it was for the contactor arm to pass to the wrong side of the contact pin and it is recommended that this pin be made longer and also with an upper extension so that the contactor arm cannot slide over it as perhaps it does now. Also, if possible, the substance used for fastening the various parts together, such as the contactor arm to the amber insulator, should have a higher melting point. There has been no means of telling the temperature inside the chamber but the attached thermometer frequently registers 40° C, which is the limit of its scale.

Silver Chloride Batteries.--It is planned to test all cells here and make up as many complete batteries as the stock of spare cells on hand will cover. It will be necessary to purchase some Burgess batteries here.

Comments

Potential-Gradient Recorder.--The reduction factors obtained at Bridgetown for the potential-gradient recorder are very consistent indeed. It was rather expected that the factors for "boom to port" and for "boom to starboard" would differ more than was found, but it was not surprising to learn that values for "mainsail up" differed inappreciably from those obtained with "mainsail down." Apparently no observations were made with the boom over the crutch. Will it be possible at all times to avoid that position when potential-gradient is being recorded?

Penetrating Radiation Apparatus No. 5503.--The description of defects in penetrating radiation apparatus Günther and Tegetmeyer 5503 as given by Mr. Parkinson has been helpful in determining the methods of reconditioning this apparatus. It is expected that this will be repaired and tested in time to be placed again on the *Carnegie* at Callao. The duplicate instrument did not arrive in time to send to Balboa and in view of Mr. Parkinson's surmise that the cementing material used by the makers softens at the temperatures reached on the *Carnegie* it has seemed better to repair No. 5503 in such a way as to avoid such a source of failure and return it to the *Carnegie* rather than to send the duplicate instrument and run the risk of a repetition of this type of failure.

A Further Comparison of Penetrating Radiation Measurements with penetrating radiation apparatus 1 and Günther and Tegetmeyer No. 5503 indicates that the latter instrument began to act abnormally on July 19, 1928. Most of the measurements after that date yield values of R which are so near the residual ionization for this instrument (No. 5503), as reported by Dr. Kolhörster, that they obviously are in error. From Mr. Parkinson's diagnosis of the ailment, it appears that the change in capacitance due to the proximity of the charging arm may be sufficient to account for the change in the relation between the values of R obtained with the two instruments. This appears especially likely when it is noted that an increase in capacitance of 0.3 cm would account for the difference.

The Performance of Penetrating Radiation Apparatus 1 according to this examination apparently was very good until some time early in August 1928. After that, however, departures in the relations between values obtained with the two instruments occur and in such direction as to indicate that the values from penetrating radiation apparatus 1 are too small, in fact, sometimes less than the value of residual ionization which was deduced from the earlier and more consistent data. Since the observations are taken so that loss and gain due to defective insulation on the central system should just balance, this possible explanation seems excluded. Other instrumental factors which may diminish the charging rate of the electrometer are: progressive changes in the insulation of the battery circuits or a changing battery e.m.f. The latter should have no effect, however, provided the insulation on the battery circuits is adequate and the balancing condenser is in proper adjustment. If, however, the capacitance of the balancing condenser has in some way increased, that fact alone would account for the diminished values of R. Another possibility is that the residual ionization of penetrating radiation apparatus 1 has changed, but this seems unlikely. These various possibilities are mentioned in the hope that they will suggest tests or observations that may disclose the cause of this diminution of R, provided it is of instrumental origin.

If notes describing such tests and observations are entered in the operating records, they will be helpful in making analyses as well as in appraising the data. Even a brief indication of such matters as, e.g., the times when the insulators were cleaned, the drier was renewed, various adjustments were made with some details as to their nature, at times may be of considerable value if for no other reason than allaying a doubt as to the value of a group of data.

BALBOA, CANAL ZONE TO CALLAO, PERU, OCTOBER 25, 1928 TO JANUARY 14, 1929

General.--With the exception of October 27, and of the seven days during which the vessel was anchored off Easter Island, observations of the atmospheric-electric elements have been made daily throughout the period covered by this report. Some interesting effects of local meteorological conditions were noted during this period. Among these may be mentioned (a) the effect of rain on conductivity, October 28, and (b) the effect of fog on ion concentration and conductivity, December 22. Weather conditions, apart from the period October 26 to November 4, have been generally favorable. Eight complete 24-hour diurnal-variation runs have been made.

Potential-Gradient Recorder.--The sloping collector rod which had been installed at Hamburg was still in use during the week following departure from Balboa, but in the rough weather encountered, the rod began to be twisted round by the wind and by the excessive rolling of the ship. On two occasions the rod came apart at the soldered joint near the lower angle and it became obvious that it would be dangerous to continue to use a collector rod of this type as it is impossible to anchor it without the introduction of another insulator and, therefore, another possible source of leakage. An attempt was made to hold the rod in place with wires stretched from insulators attached to the handles of the recorder box but it was found impracticable to put sufficient tension on the wires without deforming the rod. It will be remembered that the apparatus originally was designed for use with a vertical collector rod where lateral motion of the collector was of no importance, so this type of rod was reverted to on November 5. This change, of course, made a considerable change in the reduction factor and thus made necessary an alteration in the sensitivity of the fibers. Subsequent traces, however, gave promise that a good representation of the diurnal variation of the air potential could be obtained and that, with adequate shore control, reliable absolute values could be deduced.

During the three days, December 9 to 11, at Easter Island, intercomparisons were made between the recorder on the ship and the spare recorder mounted at the shore station. In spite of very indifferent weather conditions and an unfortunate fogging of the shore trace during some of the daylight hours, fair provisional reduction factors for the three boom positions were obtained, as follows:

Mainsail up, boom starboard	1.61
Mainsail up, boom port	1.25
Mainsail down, boom over port crutch . .	2.48

Between November 5, 1928 and January 14, 1929, fifty complete days' traces were secured and there is only one day, December 15, for which no value of potential-gradient is available. On this day, it should be noted, no eye observations would have been possible.

Careful attention has been given at all times to the elimination of leak; tests are made daily, sometimes more than once. Calibrations are made as nearly as possible weekly and the curves obtained are in remarkably good agreement.

Owing to the excessive heat generated by the burning lamp inside the metal-covered box, the glass window has been removed. During rough weather, when spray is likely to enter through the hole thus made, a plug is temporarily inserted.

Appropriate record has been kept of the positions of the mainsail and boom and also the times of operation of the main engine.

A disastrous series of mishaps with fibers for the recorder occurred on November 16. The fibers in use were dismounted as they were obviously flaked. In attempting to fit a new system, three pairs were broken in succession. The task was then given up and the following day a pair was successfully mounted and has been in use since that time. The Wollaston-process gold fibers were tried but were too fine and flexible for use in the recorder.

Remarkable peaks occurred in potential-gradient at about 16^h on December 27. This large increase in the air potential corresponded to a very low value of conductivity obtained at that time when, fortunately, a diurnal-variation run was in progress.

Conductivity Apparatus.--On October 27, soon after leaving Balboa, when preparing for observations, we found that the fibers of electrometer 25 were nonconducting. New fibers were fitted but these also were found to be flaked. A third set of fibers was mounted and, after considerable adjustment for a suitable sensitivity, was found to be satisfactory. This set is still in use.

Ionic Content Apparatus.--As reported by radio, considerable trouble has been experienced with the fibers for use with this instrument. The story can best be told, perhaps, by extracts concerning this matter from the atmospheric-electric log:

Oct. 29--Adjustments to IC in p.m. Found fiber did not respond to alterations of voltage as applied by potentiometer. Cause unknown. Made exhaustive examination of instrument. Changed fiber, with no different result.
30--Spent whole morning investigating IC as above. Finally forced to conclusion that fiber was flaked. Inserted another fiber after lunch and at once got definite result.
31--Adjusting sensitivity of IC between showers. Began observations but fiber began to drift. Spent some time investigating cause and afterward made observations.
Nov. 1--Rain showers too frequent for any attempt to be made to adjust IC.
2--Adjusted IC.
5--Changed fiber in IC and adjusted. Old fiber flaked.
7--Put new fiber in IC and adjusted. Old fiber flaked.
9--Began observations but after first set IC developed large leak and fiber afterward became "dead." Spent remainder of afternoon in adjusting, but with no result.
10--Adjusted IC in a.m. Put in new fiber but that soon flaked badly, this time in view through telescope. Put in new fiber (the last good one in stock) and adjusted.
13--Began observations at noon. At 17h IC fiber flaked badly, in view through telescope. Discontinued observations.
15--Endeavored to replace IC fiber by the only other one on hand, that in the RCA but fiber broke.
Dec. 1--Successfully transferred fiber from PRA to IC and adjusted IC.

This fiber is still in use. During the shore potential-gradient work at Easter Island, the discovery was made of a single fiber in an electrometer in the instrument room, and on December 13 this fiber was inserted in the penetrating radiation apparatus where it is still in use.

We are at a loss to explain the extraordinary ease with which the gold sputtering on these fibers has flaked. There is no motion of the instrument in its gimbals when clamped, so that the defects could not be produced by continuous jarring. It would appear that those made up just prior to the departure of the Carnegie from Washington are, in some way, inferior to the older ones but the only reason for thinking this is the fact that both the single fibers now in use presumably are of an older batch. All the fibers appeared perfect when inserted in the instrument. One had suspicious dark patches on it as it lay in the carrying box and this one was not used until the last.

Attention may be called to the observations of December 21 which were made while the fiber was subject to a large drift. In view of the fact that all the insulators were subjected to a thorough cleansing more than once, it seems hard to believe that this drift resulted from insulation leak, and it is probable that the trouble was in the fiber system itself. A similar drift was noted as preceding flaking on October 31 and November 9. It was interesting to note how well the final values agreed with other data when the amount of the drift was taken care of by the "leakage" corrections.

Penetrating Radiation Apparatus 1.--Between December 1, 1928, when the fiber was transferred to the ion counter, and December 13, when a fiber from a spare electrometer was inserted, this instrument was idle. At all other times it has functioned normally. On December 28 the sodium drying tubes were changed, the same precautions as before being observed to avoid undue change of the air contained in the apparatus.

Nuclei Counter 4.--On December 18, during one of the observations of a diurnal-variation series, the receiver came apart from the pump stem. An effort was made to resolder the parts, but the heat generated to run the solder loosened the tube of stopcock A, so that this came off also. Three more attempts were made to resolder the parts and to make the receiver airtight when the cocks are closed. It appeared for a time that this had been successfully done but evidences of leak were apparent again on January 10. The values obtained since the repair are very erratic and we have no means of telling whether they are correct. It would seem advisable, therefore, for us to have a second instrument on board.

Batteries.--The silver chloride batteries have remained in good shape since the replacements were made in Balboa. Four bad cells have developed in one battery and these were cells which were in the battery when leaving Washington. It has been necessary to put only two of the Eveready batteries into service to replace two Burgess "B" batteries used for the auxiliary potential of the potential gradient recorder which had been short-circuited through a defect in the marine plug on the quarter-deck. We shall have use for more of the "B" batteries purchased in Balboa when the Kolhörster instrument is in use again.

Radioactive Content Apparatus.--Attempts have been made to maintain a high potential on the outer cylinder, but without success. With the atomizer, the potential builds up to about forty divisions and immediately falls to zero. With the old type multiple-nozzle sprayer, so far it has not been possible to obtain any deflection of the electroscope. Further efforts will be made while the vessel is at Callao.

Comments

Potential-Gradient.--Since the change in the collector on the potential-gradient recorder did not make the reduction factor much greater than unity, and since the reduction factor for different boom positions does not differ a great deal, the new arrangement no doubt will prove satisfactory. The great number of potential gradient diurnal-variation records being obtained is gratifying, especially in view of the fact that these appear to be quite reliable.

We are unable to find a satisfactory explanation for the distressing experience with the electrometer fibers unless it be that the fibers were too heavily gilded. The entire "sputtering" system was thoroughly cleaned and repaired and arranged to "sputter" platinum instead of gold. Accordingly it is hoped that the new platinized fibers will prove more durable. The item regarding the drift of fibers brings to mind similar experience at the laboratory; however, in certain of these cases the cause was not defective fibers but resulted from charges which had been developed on the insulators while these were being cleaned. A drift owing to this cause will disappear in a moment if the insulator is exposed directly to the action of the collector or of a burning match held within approximately one inch from its surface.

Batteries.--The report regarding the batteries is reassuring. From the experience reported on the earlier part of the cruise, together with recent reports from the observatories, we became convinced that the silver chloride batteries obtained in the last year or two are of inferior quality and we feared that considerable trouble with these might be encountered during the remainder of the cruise. It is also a matter of interest that the "B" batteries originally put on board have held up so long. If these had lasted only as far as Balboa, they would have been considered satisfactory.

Nuclei Counter.--The trouble with nuclei counter 4 was owing to the poor workmanship put into it by the makers. It is understood that the instrument at Huancayo was obtained to replace counter 4 and it is hoped this will prove satisfactory. As stated before, nuclei counts in recent years have become recognized of great importance in atmospheric-electric studies. Accordingly it is desirable that such counts should be made in conjunction with ion counts, conductivity, and penetrating radiation measurements whenever possible.

Radioactive Content Apparatus.--The difficulty with the radioactive content collector no doubt is owing to the insulators becoming fouled by the spray from the atomizer of the high potential generator. If this part can be enclosed in a sheet-metal shield which is so made that the spray does not readily come into contact with the high-potential insulators, then it is believed that the charging device will work satisfactorily. This shield should surround all the parts and have a tube of about one and one-half inches diameter which leads to the outside air or into the lower parts of the fan compartment. The suction of the fan with the latter arrangement may assist in giving the desired circulation inside the shield. It is hoped that it may be possible either to construct such a shield on board or have it made up at one of the ports of call. If, however, this will not be possible before reaching San Francisco and in case no other means is found which will bring about satisfactory operation of this apparatus then the office should be advised soon so that there will be time to construct something of this sort to be installed at San Francisco.

CALLAO, PERU TO PAGO PAGO, SAMOA, FEBRUARY 5 TO APRIL 1, 1929

General.--Observations of the atmospheric-electric elements have been made practically daily during the period of days at sea covered by this report. Weather conditions between February 5 and March 5 were generally favorable; after that date, frequent squalls, calms, and heavy rolling in swells have tended to produce abnormal values. Complete diurnal-variation runs, through twenty-four hours, were made on February 10 and 11, 18 and 19, and 26 and 27; incomplete runs, abandoned through squalls and generally abnormal conditions, were begun on March 10, 25, and 27. Doubtless it has been noted that the general program of observation during these diurnal-variation runs is slightly different from that of previous cruises. With the present program and the apparatus as now arranged, it is possible for the complete hourly cycle of observations to be made by one observer.

Potential-Gradient Recorder.--During the first few days after leaving Callao on February 5, parts of three days' records were lost because the loose end of the tension string (which prevents too rapid feeding of photographic paper and which had been renewed recently) became caught on the lower tension roller and stopped the supply of paper. From February 15 to March 5 inclusive, continuous record of potential-gradient was obtained. After March 5, when the ship was among the island groups, generally squally conditions prevailed; light, variable breezes and frequent calms at times necessitated the operation of the main engine. Consequently the records are intermittent; in fact, only one Greenwich mean day, March 25, is really complete between March 6 and April 2. Part of this loss, it should be noted, was caused by instrumental difficulties. The upper heating coil became open-circuited and caused loss of zero marks until it was replaced by a new one. Also, on March 26 the earthing wire became corroded and disconnected from the hull and caused erratic deflections until it was discovered and renewed on March 28.

In order to shelter the helmsman from the fierce tropical sun, frequently it has been necessary to stretch an awning over the stern. Thus, the reduction-factor observations contemplated at Apia will be extended so as to include periods with stern awning "up" and "down" to determine the effect, if any, of its presence.

Conductivity Apparatus 8A.--This apparatus has functioned normally throughout.

Ionic Content Apparatus 1.--No trouble, apart from the usual insulation difficulties, has been experienced with this apparatus. A cover for the top of the air-flow tube has been made so that the cowl can be removed when the roof opening is closed, thus minimizing the chances of jarring the tube.

Penetrating Radiation Apparatus 1.--During the early part of February there were indications that the values of R that were being obtained were not independent of fiber sensitivity. With a low sensitivity the values of R tended to be greater than those with a high sensitivity. The truth of this suspicion naturally was not very obvious in the daily observations but for the diurnal-variation run of February 10 and 11, when the scale-value curve was plotted and compared with the curve for the values of R and a remarkable similarity was disclosed, a definite relation was demonstrated.

During the diurnal-variation observations of February 18 and 19 the electrometer fiber went off scale and attached itself to one of the plates. Afterwards it was found that this action occurred because one of the cells of the plate battery had developed a high internal resistance. During efforts to release the fiber from the plate, it was broken. Later in the same day the defective cell was replaced by a new one and a new fiber was inserted in the electrometer. Tests were made to determine whether a change in scale value produced a change in R. It was found that the two values were independent of one another. With the diurnal-variation curve of February 26 and 27 also has been plotted the scale-value curve and here, again, the independence is well demonstrated.

The sodium in the drying tubes was renewed on March 27, the usual precautions being taken.

Penetrating Radiation Apparatus No. 5503.--This apparatus was received on board at Papeete, Tahiti, on March 16, 1929 after having been overhauled and reconditioned in Washington. When the apparatus was unpacked, the Zamboni pile, which presumably had been screwed on to the charging post before shipment, was hanging loose. The outer threads on the pile were stripped badly enough to prevent its being replaced on the charging post. Beyond securing the instrument in its former situation on the observing bench, between the penetrating radiation apparatus 1 and radioactive content 4 and covering the charging post with the cap provided, nothing further was done to the instrument until March 21, after leaving Papeete. On attempting to apply a charge to the fibers, it was found that the charging arm was on the wrong side of the standard pin. Efforts made to put it back on the right side by sudden movements of the magnet were unavailing and therefore it was reluctantly decided to open up the case. This was done on March 21. Other than carefully lifting the pointer past the pin, nothing inside the case was touched and the time the case was open on this occasion did not exceed 30 seconds. On resealing the case, and applying a charge to the fibers, it was apparent at once that the fibers were adhering, either to each other, or to the spines, or were crossed. The separation of the fibers at the bottom of the field of view was much greater than at the scale level, whereas at the top of the field the fibers were very close together and out of focus. In order to separate the fibers, a charge of over 460 volts (10 "B" batteries in series) was applied many times, the fibers being charged and earthed in quick succession. This charge would, of course, normally send the fibers right off scale but the total deflection of both fibers was not more than sixty divisions. An hour or more was spent in this way and further efforts in the same direction were made on March 22, but with no success. On March 23 it was decided to reopen the case and separate the fibers by passing a glass spine between them. This operation, a delicate one under the best conditions, was rendered more hazardous by the rolling of the ship in a moderate swell and also by the intense heat in the atmospheric-electric laboratory with door and all windows closed to prevent draughts. The separation was accomplished successfully at the first attempt, however, and the instrument resealed. Two trial observations made later in the day gave high values. Doubtless this can be attributed to a slight leak over the quartz rod, rendered damp by exposure; subsequent observations showed that the sodium in the drying tubes was gradually restoring the insulation.

Control observations on the quarter-deck to determine the reduction factor of penetration radiation apparatus 1 will be made as soon as possible, probably while the vessel is anchored at Apia.

Radioactive Content Apparatus 4.--Considerable time was spent between March 4 and 9 in trying to get this apparatus to function normally. On March 4 most of the parts were disassembled and cleaned. On reassembling, a potential of over 2700 volts was maintained for over thirty minutes and accordingly a fiber was inserted in the electrometer (the original fiber was broken on November 15, 1928 in an endeavor to place it in the penetrating radiation apparatus) and adjusted in readiness for a regular observation the next day. On March 5, however, when the inner cylinder with the foil was in place, no potential at all could be obtained. It was suspected that the lower end cover which, of course, is earthed, was touching the foil. With this cover removed and, indeed, without any inner cylinder, the potential on the following day could not be maintained for more than two or three minutes. Trouble was then experienced with the atomizer which became clogged; so it and also the water vessel, were thoroughly cleaned, fresh clear water was provided, and new rubber tubing fitted. On March 8 cardboard covers were made and fitted over the main insulators and some of the wiring was renewed. (It appeared to make no difference whether the hard rubber insulator on the 110-volt power line was covered or not.) With the main insulator covered, the potential obtained never exceeded 1000 volts, probably owing to the added capacity, but could be maintained, at first, for a considerable time, say fifteen to twenty minutes. Later this time became reduced to anything between one and three minutes, the same as without the cover. The most obvious explanation of the difficulty is the fouling of the insulators by the spray. But a curious fact is the ease with which the charge will rebuild just a few seconds after it has been reduced to zero. This gives one the impression of a short circuit which operates only when the vessel is highly charged, the contact being broken at zero potential. Careful search has been made to discover any lint or other material attached to any of the parts, which might act in this way, but nothing has been discovered. The use of a shield to cover the whole system appears well worth trying. It is doubtful whether such a shield could be made satisfactorily on board or at any of the ports earlier than San Francisco; therefore it would be best, perhaps, to have it made in Washington and shipped to us.

Nuclei Counter 5.--This instrument was obtained from the equipment of the Huancayo Observatory while the ship was in Callao harbor to replace no. 4, which was returned to Washington. After some slight preliminary adjustment, no difficulty was experienced in its use. During the approach to Tahiti rather large values of nuclei concentration were obtained; after leaving Tahiti there were frequent rain storms and the number of nuclear particles decreased considerably.

Comments

General.--Although a succession of squalls, calms, and periods of heavy rolling in swells interfered considerably with the atmospheric-electric observations in the latter part of this leg of cruise VII, considerable was accomplished in the earlier part. In a careful examination of the records, one is favorably impressed with the progress being made and especially with the diligence and skill of the observer and the excellent form in which the records are made up. The observations of the diurnal variation of nuclei concentration are commendable. A study of the correlation of this element with the ionic number during the day will be of great importance and will be made when the number of series is sufficient to give hopes of definite results.

Potential-Gradient.--The various instrumental difficulties with the potential-gradient recorder are all such as must be expected occasionally. No doubt the earthing connection which failed will be inspected in the future whenever the opportunity occurs so that this may be renewed in time to lessen the likelihood of failure on the high seas. The effect of the stern awning should not be very large but of course it is quite right to eliminate this possibility by ascertaining a reduction factor for use when this awning is in position. It is noted that observations on potential-gradient apparatus 1 are no longer being made. Such observations should be helpful as a test of the effectiveness of the insulation on the recorder.

Conductivity Apparatus 8A.--It is gratifying to note that the insulation-leak on this apparatus scarcely exceeds the error of an electrometer reading. This constitutes a great improvement in comparison with the apparatus of previous cruises. As far as noted, the indication of leak, when found, was always on the first reading. Can the observer suggest an explanation for this?

Ionic Content Apparatus 1.--The cover which was made for the air-flow tube of the ionic content apparatus should assist also in protecting the insulation during the period when the apparatus is not in use. Some evidence that extreme values of ion count give extreme values of mobility has been noted. Some of these cases may be owing to accidental errors of observation, but there may be other factors, for example meteorological ones, which careful scrutiny will disclose.

Penetrating Apparatus 1.--The indication that the values of R varied with the electrometer sensitivity would appear, as reported, to have been associated with the defective cell. Just how the defective cell caused this and also how it should cause the fiber to go off scale so as to adhere to the plates is not clear at present, unless the balancing condenser should be out of balance or unless the insulation at some point on the battery lines was defective. Of course if the megohm resistor should develop an open circuit either in its coils or at a binding-post connection, that of itself could cause such effects. Whatever the explanation is, it is gratifying that later comparisons gave no further evidence of a dependence of R on electrometer sensitivity. Studies of possibilities of instrumental errors such as these are very desirable even if it is necessary to omit an occasional daily program. Instruments are not infallible and it is highly desirable to ascertain for each instrument its degree of fallibility. Especially is this true of the penetrating radiation apparatuses.

Penetrating Radiation Apparatus No. 5503.--The difficulties experienced with penetrating radiation apparatus no. 5503 are to be regretted. No doubt the fiber loops would have been in good shape had the Zamboni pile not worked loose. The difficulty with the charging arm could not have been so readily avoided. If the standard pin of the electrometer element had been made long enough to prevent this sort of occurrence during shipment, that would have increased the capacitance considerably and consequently decreased the quantity sensitivity of the instrument. Under the circumstances it was quite the proper thing to open the chamber and correct the defects. Mr. Parkinson is to be congratulated on the successful outcome. It is noticed that the calibration curves do not differ much from those obtained before this instrument was shipped from the office. It is hoped that no further difficulties will be experienced with this apparatus.

An examination of the observations from March 23 to April 1, inclusive, shows that this instrument has suffered no air leak of importance. The test for this is that the pressure (p) in the chamber, divided by the absolute temperature (273 plus observed temperature, t), should be constant if the chamber is airtight. Thus

$$p/(273 + t) = K$$

The mean value found for K was 2.448 with a mean departure of ±0.005. This is only a little greater than the error of reading p or t and may be owing to the fact that doubtless the observed temperature is not always that inside the chamber.

A comparison of the values of R obtained simultaneously on the two instruments indicates more scatter due to instrumental causes than is desirable. This scatter was greater in penetrating radiation apparatus 5503 than in penetrating radiation apparatus 1, possibly because the insulation in penetrating radiation apparatus

Suggested hourly schedule for diurnal-variation atmospheric-electric observations on the Carnegie

Ship's time	Operation
h m s	
0 28 00	Charge penetrating radiation apparatus (PRA) 5503 and start ion-counter motor and conductivity motor
0 33 00	First initial reading PRA 5503
0 34 00	Second initial reading PRA 5503
0 35 00	Third initial reading PRA 5503
0 36 00	Fourth initial reading PRA 5503
0 37 00	Fifth initial reading PRA 5503
0 37 20	Begin leak-test for ion counter (IC)
0 37 30	Begin leak-test for conductivity apparatus (CA)
0 39 00	End leak-test for IC
0 39 15	Begin negative ion count
0 40 30	End leak-test for CA
0 40 45	Begin negative conductivity
0 41 00	Begin first PRA 1 run
0 45 00	(Approx.) end negative conductivity
0 45 15	(Approx.) end negative ion count
0 45 30	Begin positive ion count
0 46 00	Begin positive conductivity
0 47 00	End first PRA 1 run
0 47 15	Begin second PRA 1 run
0 50 30	(Approx.) end positive conductivity
0 51 00	Begin conductivity leak-test
0 51 30	(Approx.) end positive ion count
0 51 45	Begin leak-test IC
0 53 00	(Approx.) end PRA 1 second run
0 53 25	End leak-test IC
0 54 00	End leak-test CA
0 55 00	Begin nuclei count
1 05 00	End nuclei count
1 06 00	Begin leak-test CA
1 06 20	Begin leak-test IC
1 07 00	Begin PRA 1 run
1 08 00	End leak-test IC
1 08 30	Begin positive ion count
1 09 00	End leak-test CA
1 09 30	Begin positive conductivity run
1 12 45	(Approx.) end PRA 1 run
1 13 00	Begin PRA 1 run
1 14 00	End positive conductivity run
1 14 30	End positive ion count
1 14 45	Begin negative ion count
1 15 00	Begin negative conductivity run
1 19 00	End PRA 1 run
1 19 15	End negative conductivity run
1 19 30	Begin leak-test CA
1 20 45	End negative ion count
1 21 00	Begin leak-test IC
1 22 30	End leak-test CA
1 22 40	End leak-test IC
1 23 00	First end reading PRA 5503
1 24 00	Second end reading PRA 5503
1 25 00	Third end reading PRA 5503
1 26 00	Fourth end reading PRA 5503
1 27 00	Fifth end reading PRA 5503

5503 has not as yet become steady. There was evidence of improvement in the later readings. There is good evidence, however, of correlated variations in the two instruments which most probably are owing to actual variation in the intensity of the radiation. In order to increase the precision of measurements with penetrating radiation apparatus 5503, it is recommended that five initial and five final readings of the fibers be made as indicated in the accompanying hourly schedule.

The importance of penetrating radiation to atmospheric electricity has been increased distinctly as a result of a recent experiment by Dr. Bothe and Dr. Kolhörster of Berlin. This experiment shows rather convincingly that the penetrating radiation (except such part as is owing to the gamma rays of radioactive matter in the earth and air) is a corpuscular radiation, beta radiation of very high velocity. If this is true, the penetrating radiation should not only ionize the air but should charge the earth. Perhaps we are now on the verge of discovering how the negative charge of the earth is maintained and the Carnegie stands a good chance of aiding materially in this.[1]

Radioactive Content Apparatus 4.--A new water-spray, high-potential generator designed to obviate the fouling of insulation by the spray will be made and installed at San Francisco and our hope for its success is strengthened by this detailed report of tests and observations made on board in March.

Nuclei Counter 5.--The success of observations of nuclei is gratifying. That the values should run as high as those found on approaching Tahiti is a matter of considerable importance in attempts to account for the number of ions found at the same time.

Schedule of Atmospheric-Electric Observations.--The schedule of observations now in use has been reviewed with considerable care. It has been found difficult to offer improvements without making the program more strenuous. It is appreciated that a program which one observer may carry out is desirable, and no doubt imperative in the case of the diurnal-variation observations. Hence, in preparing the accompanying suggested schedule, this requirement has been kept in mind.

The principal objects sought in the suggested schedule are to obtain both positive and negative values of ionic numbers and of conductivity during the diurnal-variation runs, to observe the nuclei count at about the mean time of the other observations, and to increase the precision of the penetrating radiation observations made with penetrating radiation apparatus 5503. The last is to be accomplished first by charging this apparatus some five to ten minutes before the initial readings for a determination are begun. Then by taking initial readings of the position of the fibers at intervals of one minute until five minutes have elapsed (half-minute intervals could be used if preferred), and a similar set of final readings, the accidental errors in the mean fiber positions obtained from these would be reduced considerably.

It is believed that the outline of the suggested schedule will be clear as tabulated. The schedule is a somewhat more strenuous one than that which has been followed recently, and we realize the possibility that it may not be feasible, on that account, to carry it through.

This proposed schedule was designed primarily for

[1]Since this was written, investigations by many physicists show that the corpuscular components of cosmic radiation cannot contribute appreciably to the maintenance of the earth's charge. O.H.G.

the diurnal-variation observations but some of its features could be introduced into the regular daily schedule without appreciably increasing the intensity of the work.

The schedule provides for the recording conductivity apparatus when that is installed. It is hoped it will be possible to try this schedule and that the Carnegie staff and observers who have had experience in this work will study it with a view to arriving at a schedule for the rest of the cruise after San Francisco.

APIA, SAMOA TO YOKOHAMA, JAPAN, APRIL 20 TO JUNE 6, 1929

General.--Daily observations of the atmospheric-electric elements have been made as before. For the first week after leaving Apia it was necessary to use the main engine at times in order to reach the trade wind belt and conditions therefore were not favorable for a complete program. Between April 27 and May 28 good weather conditions prevailed. Diurnal-variation 24-hour runs were made on April 30 and May 1, May 9 and 10, 17 and 18, and 27 and 28.

Potential-Gradient Recorder.--Between April 28 and May 28 complete records were obtained, excluding the five days during which the vessel was moored in Guam harbor. Calibrations and leak tests have been made as before. Soon after leaving Guam it was noticed that the deflections were much smaller than those previously obtained and it was suspected that the sensitivity had changed appreciably. A calibration made on May 28 showed that this was the case. It was found that the marine plug in the auxiliary potential line (the Eveready "B" battery supplying the inner-case potential is located in the control room) had become badly corroded. The plug was thoroughly cleaned and another calibration made on May 30. It is important, of course, to be able to tell just when a change of sensitivity such as this occurs, and, to some extent, the potential applied daily for leak tests affords a rough check. In this case the change evidently occurred sometime during the period when the recorder was out of operation in Guam. In the future the recorder will be operated while in port even though the presence of surrounding objects makes the results of little value. Negative potentials have occurred on eight occasions but at no time has the potential remained negative for more than a few minutes.

Between April 10 and 13, while at Apia, the recorder was operating on the ship under varying mainsail, boom, and awning conditions and the hourly scalings from these records have been made and checked. As soon as the figures are available the scalings will be compared with the hourly values obtained from the Benndorf recorder in the reef house (designated Lagoon House) of the Apia Observatory. After an inspection of the standardizing station used by Mr. Thomson of the Apia Observatory staff, it was questioned whether the reduction factor (1.00) adopted by the Observatory for the Lagoon House was valid. To test this, eye observations were made, during the hours of low tide, on Watson's Island--an ideal location for this work, as it was about midway between the Lagoon House and the Carnegie. One disadvantage of the Observatory's standardizing site is that it is closely hemmed in by mangrove swamp and cocoanut trees; another, is that it is not possible to observe there for more than one hour at a time. The eye observations on April 11 were quite successful, five consecutive hours being obtained. The resulting ratios are:

$$\frac{\text{Island}}{\text{Lagoon}} = 0.731 \qquad \frac{\text{Island}}{\text{Land}} = 1.086 \qquad \frac{\text{Land}}{\text{Lagoon}} = 0.682$$

(Island observations were made by eye-reading apparatus and Land by the recorder at the observatory land station.) The work on the following day, April 12, was seriously interfered with by a severe thunderstorm which swept the island of Upolu from east to west and the observations may be considered worthless. It appears quite definite from the above ratios that the reduction factor for both land and lagoon stations cannot be 1.00 as hitherto assumed from Mr. Thomson's observations. Because Watson's Island has so many advantages over the old standardizing station, Mr. Sanderson was asked to obtain further observations on the reef before the Carnegie's return in November. For this purpose, Mr. Parkinson mounted a new pair of fibers in the observatory electrometer and left two more sets, with a mounting device and other equipment, the observatory having no spare fibers and no means of mounting them.

It may be mentioned that at the time of the eye observations on Watson's Island on April 11, the condition on the Carnegie was "MDBS awning up" and the mean reduction factor obtained for the Carnegie recorder for the five-hour period was 3.14. The mainsail had to be lowered during this time as there was a stiff breeze, but it is probable that the position of the boom rather than that of the sail is the controlling factor.

Conductivity Apparatus 8A.--Unusually high values of insulation-leak prevailed for a few days early in May. Thorough cleaning of all the insulators did not immediately remedy the defect, which disappeared of its own accord about May 10.

Ionic Content Apparatus 1.--During the damp night hours of the diurnal-variation runs of April 30 and May 1 and May 9 and 10, high insulation leaks developed and could not be eliminated. Apart from this the apparatus has worked perfectly well.

Penetrating Radiation Apparatuses 1 and 5503.--Special attention has been given to comparisons between these two instruments. The first attempt to obtain a comparison of values between numbers 1 and 5503 mounted in an exposed position on the quarter-deck was made on May 16. It was soon found that heating up of the chamber by the sun gave abnormally high values. During the diurnal-variation run of May 27 and 28, no. 5503 was first used inside the atmospheric-electric laboratory, then at sundown it was mounted on the quarter-deck, and it was brought inside again at sunrise on the twenty-eighth. It was found that the mean ratio of no. 5503 to no. 1 for the night observations was less than unity, a result which was probably influenced by temperature effects. A grouping was made of all comparison observations taken in the laboratory between May 2 and 30 to show how the value of this ratio is related to the temperature of 5503. Of course many more observations will be needed before any temperature correction can be deduced. Here it should be mentioned that the thermometer attached to no. 5503 is difficult to read accurately without a reading glass and it is clear that more than one reading will have to be made in the future to ensure that the value of temperature entered in the records approximates the mean value for the interval occupied by the observation. The chief source of uncertainty in comparisons of 5503 with 1 is the difficulty in obtaining with 5503 an accurate reading of fibers so widely separated, when, because of the ship's motion, both are moving irregularly. Taking this into account, and also the temperature effect already noted, the comparisons, so far, may be considered to be satisfactory. Further sets will be obtained as frequently as conditions permit.

In order to avoid the risks involved in moving the penetrating radiation apparatus 5503 during magnetic observations in the after dome, tests were made at the Apia Observatory to determine the magnetic effect of the instrument. The distance between penetrating apparatus 5503 and the marine deflector in the after dome is 3.5 meters. With magnetometer 12 mounted on the observatory pier, the deflection produced on the freely suspended magnet by the approach of 5503 was:

Distance, meters	Deflection	
	Scale divisions	Minutes
3.5	0.0	0.0
3.0	0.0	0.0
2.5	0.1	0.2
2.0	1.0	2.0

These data indicate that no important disturbance is caused by the presence of penetrating radiation apparatus 5503 even as near as 2.5 meters. It will be unnecessary, therefore, to move the instrument in the future during the magnetic program.

The sodium in the drying tubes of penetrating radiation apparatus 1 was renewed on June 2. We have only two spare glass drying tubes for this apparatus. This is just the number required to make a rapid renewal of drying material and it seems desirable that we should have a reserve stock in case of damage.

On June 3 an attempt was made to eliminate the "flicker" or sudden movement in the fiber of penetrating radiation apparatus 1 which had been evident, though not serious, for the few days preceding. It probably was caused by a defective cell or cells in one of the plate batteries, though no such defect could be located in testing the batteries with the voltmeter. The megohm resistor in the battery circuit was changed, and finally both silver chloride batteries were replaced by four Burgess "B" batteries, after which the fiber behaved quite normally. It will be interesting to see how long these batteries remain efficient for this service.

Nuclei Counter 5.--Observations have been made with this instrument at every opportunity. When near the end of the diurnal-variation run of April 30 and May 1, the observer fell, causing the instrument to fall also, breaking the pump stem at the soldered joint at the top of the pump cylinder, and shattering the mirror reflector. The stem was resoldered successfully the same day and the reflector repaired, so that observations could be made as usual the following day.

Values rather larger than ordinarily obtained thus far were encountered on May 17 and 18, just before reaching Guam and again on May 27 and 28. On the latter date the vessel was about 100 miles to leeward of the northern Marianas group, which is marked on the chart as volcanic. On May 18 an attempt was made to preserve a sample of the nuclear material by placing a microscope slide, smeared with balsam, on the wire screen of the conductivity apparatus air tube and running the fan for fifteen minutes. This sample was transmitted to Washington for examination.

Silver Chloride Batteries.--Soon after leaving Apia the whole stock of silver chloride batteries was tested and the entire supply of 280 cells received at Callao was used in making replacements. We have now, besides the batteries on service in the shelf cupboards below the instruments (five batteries in all), two complete 100-cell units and 80 cells of another which show high enough voltage to be called in good condition. The Burgess and Eveready "B" batteries used for potential gradient auxiliary potential and leak tests and those used for charging penetrating radiation apparatus 5503 appear to be holding up remarkably well.

Comments

Change of Sensitivity of Potential-Gradient Recorder.--The proposals for obtaining closer check of the sensitivity of the potential-gradient recorder should be helpful. When the change is owing to some alteration in the auxiliary potential, such as is inferred to have occurred at Guam, then a comparison of the hourly zeros should make this manifest, and an exact correction could be made if the recorder is calibrated with inner case earthed. Of course if the tension on the fibers has changed, the correction would require a knowledge of the value of the auxiliary potential. If the latter remained constant, then the change in sensitivity could be determined from a comparison of the hourly zero deflections.

Comparison of Penetrating Radiation Apparatuses.--The careful observations for comparing penetrating radiation apparatus 1 and penetrating radiation apparatus 5503 and the analyses of these observations have been studied. Apparatus 5503 is definitely subject to more variation than is no. 1, and, furthermore, those variations unmistakably are of instrumental origin. They seem to be associated with the temperature of the instrument but it is not evident how temperature should give rise to such changes. It may be necessary to replace 5503 by its companion instrument 5658 when the Carnegie arrives at San Francisco.

Nuclei Counter 5.--The accident which befell this instrument is unfortunate. This calls to attention the need of a reserve counter on the Carnegie. Accordingly it is being recommended that counter 2 be sent to the Carnegie at San Francisco.

YOKOHAMA, JAPAN TO SAN FRANCISCO, CALIFORNIA, JUNE 24 TO JULY 28, 1929

General.--Daily observations of the atmospheric-electric elements have been made, with the few exceptions noted below. The light and contrary winds which prevailed during the first week after leaving Yokohama, and the fog, mist, and rain encountered in the higher latitudes, made the period covered by this report unfavorable for atmospheric-electric work on the whole. Diurnal-variation runs were made on July 3 and 4 and 21 and 22.

Potential-Gradient Recorder.--Twenty-six complete days' traces have been secured, seventeen of which were rendered abnormal by fog and mist. On some of these abnormal days, hourly mean potentials of over 300 volts (uncorrected to volts per meter) were recorded on several occasions. Fortunately, during the stay in Yokohama, the sensitivity decreased considerably, and it is owing to this fact that complete records of the fog effects were obtained. The recorder clock, which had been showing a high and variable rate just before reaching Yokohama, was cleaned and adjusted there and has behaved remarkably well since.

On June 30 the upper heating coil burned out and a new one was fitted, the lead wires being renewed at the same time. Leak tests and calibrations have been made as before.

Conductivity Apparatus 8A.--Values of conductivity obtained near Japan, both before arrival and after departure, were abnormally low. During the periods of fog and mist already referred to, the values were extremely low. No instrumental difficulties have been encountered.

The day before reaching Yokohama, during the heavy weather of a typhoon, a block from one of the staysail sheets dropped on the cowl of the air tube, breaking two of the three horizontal supports of the cowl. Repair was made in Yokohama, but the day after leaving, June 25, a sheet of one of the staysails caught under the cowl, bending it sideways and tearing the wire screen. A temporary repair was made and it has remained effective. A more permanent repair will be made in San Francisco.

Ionic Content Apparatus 1.--On several days observation was impossible with this instrument owing to the penetrating fog fouling the upper amber ring-insulator. During the night hours of the diurnal-variation runs, the insulation broke down from this cause. It is a question whether a new design for the top of the air tube, similar to that employed on the conductivity apparatus, would not enable observations to be secured during light rains, when, with the present arrangement, observation is impossible.

Penetrating Radiation Apparatus 1.--Daily observations have been made with this instrument and no difficulties encountered. The Burgess "B" batteries used for the plate potentials have given satisfactory service. No renewal of the sodium in the drying tubes has been made.

Penetrating Radiation Apparatus No. 5503.--Comparison observations between this instrument and no. 1 have been made daily. During the diurnal-variation run of July 3 and 4, no. 5503 was mounted on the starboard side of the quarter-deck during the night hours. At 4 h on July 4 the fibers would not charge up; the instrument was opened up in the warm cabin, where the heating stove was burning, and it was found that the phosphor-bronze leading strip had parted. A new strip was fitted and the instrument has worked normally since. A summary of the comparisons between the two instruments, especially with a view to determining the temperature coefficient, has been made and the ratios for no. 5503 to no. 1 have been plotted against temperature of 5503. It appears that more observations are required at temperatures around 12° and also above 20° before an approximate temperature correction can be deduced.

Nuclei Counter 5.--Except for four days when rain prevailed, observations have been made daily. Values have been generally low, averaging around 1500 particles per cubic centimeter.

SAN FRANCISCO, CALIFORNIA TO HONOLULU, HAWAII, SEPTEMBER 3 TO 23, 1929

General.--Between September 5 and 22, daily observations of the atmospheric-electric elements have been made as previously. Some modifications of procedure have been made, but care has been taken so as to maintain a reasonable standard of accuracy and at the same time to preserve the system of simultaneity of observation. Unusually calm weather with variable winds was encountered between September 7 and 18, and very low values of conductivity and ionic content were measured. The potential-gradient was correspondingly high during this period. A diurnal-variation run was begun on September 18 but had to be abandoned after four hours, owing to instrumental troubles.

Potential-Gradient Recorder.--Altogether eleven complete days' traces have been secured during the period covered by this report. The principal cause of loss of scalable trace was the necessity for frequent operation of the main engine during the calm period referred to above. Minor losses of registration were associated with the loosening of the invar supporting rods in the electrometer, a defective plug in the hourly zero circuit, and poor illumination from the recording lamp.

Conductivity Apparatus 8A.--While the vessel was in port at San Francisco, Mr. Gish, assisted by Mr. Parkinson, installed the recording apparatus. The skillful design and beautiful mechanical workmanship of this apparatus are illustrated by the fact that only very minor difficulties were met with in its installation and records were being obtained within a few days of the unpacking of the boxes. Some adjustments were necessary when operating under sea conditions, but these involved very little loss of trace. Ten complete days' traces have been obtained, five of positive and five of negative conductivity. Owing to the possible effect of the fan motor on the magnetic apparatus in the after dome, the fan is shut off during the magnetic program. It is planned to make tests of this effect as soon as possible, so that, if it is negligible, no further interruptions of the conductivity traces will be caused.

Ionic Content Apparatus 1.--In general, this apparatus has functioned normally. On September 16, however, a large leak, or fiber drift, was observed and after exhaustive tests, it was found to be an effect of bound charges on the amber insulators. In efforts to dissipate these charges with radium, the trouble apparently was accentuated and finally the insulators were left standing for a day, after which no further trouble was encountered.

Penetrating Radiation Apparatus 1.--Except for some erratic behavior at the beginning of the diurnal-variation run on September 18, this instrument has worked normally. Comparison observations with this apparatus and the Kolhörster instruments 5503 and 5658 mentioned below have been made daily.

Kolhörster Penetrating Radiation Apparatuses 5503 and 5658.--Apparatus 5658 was received at San Francisco on the arrival of Mr. Gish. During the stay of the vessel in San Francisco, Mr. Gish, assisted by Messrs. Parkinson, Jones, and Seaton, made a series of observations with the two instruments, both in air and under water, at Crystal Lake. Both instruments appeared to be somewhat erratic in behavior and the cause for the discrepancies between them is obscure. Apparatus 5658 is being returned to Washington with Mr. Gish.

Nuclei Counters 2 and 5.--Instrument 2, received at San Francisco was tried out soon after leaving port but was found to leak badly. An examination by Mr. Gish showed some bad mechanical defects and the instrument is being returned from Honolulu. Counter 5 apparently is working normally; nevertheless, it is advisable that a second instrument be available on board for comparisons.

Radioactive Content Apparatus.--Mr. Gish has spent considerable time installing and adjusting the new potential-multiplier device received at San Francisco. He also made several alterations in the assembly and rewired the apparatus. Trouble is still experienced in maintaining a steady high potential on the central cylinder. A trial observation was made on September 22 and it is hoped that frequent determinations will be possible from now on.

Batteries.--In view of the good performance of the Burgess "B" batteries and some advantages they possess over batteries composed of silver chloride cells, the latter type has been eliminated from use with the various instruments. The present stock of Burgess batteries is ample for some considerable time, but, if further supplies have to be shipped to the *Carnegie*, it might be well to specify the "knob type" terminal rather than the "spring type" previously supplied.

HONOLULU, HAWAII TO PAGO PAGO, SAMOA, OCTOBER 2 TO NOVEMBER 18, 1929

General.--The eye observations of ionic content, penetrating radiation, and nuclei count have been made whenever possible--practically daily. Four complete diurnal-variation runs have been made. Special observations of penetrating radiation, using radium as an ionizing constant, have been made, as described below. Considerable computational work has been done on a preliminary reduction of potential-gradient values to show that diurnal variation proceeds on universal time.

Potential-Gradient Recorder.--This instrument has worked moderately well. Thirty-eight complete days' traces have been obtained. On October 3 the recording paper became loose from the lower roller and therefore did not rotate. Heavy rains on October 11 and 12 caused some loss of trace--a considerable quantity of water accumulated in the collector-insulator tube, presumably having splashed up inside from the top of the instrument box. From this time, at intervals, until the end of October, frequent periods of earthing occurred for which the reason is still uncertain. The collector system was disassembled and carefully reassembled several times but the earthing recurred after varying intervals. The indications were that there was a definite metallic connection to ground rather than poor insulation, as a spark could be obtained when the collector hood was connected to a battery. On October 23 the electromagnet, which operates the hourly zero, burned out and, presumably at the same time, the amber surface of the central insulator in the collector tube was badly scarred. It is believed that a defect in the engine room power circuit occurred during the time the hourly zero was in operation. The coil was removed and it was intended to replace it by the one on recorder 4947. The holders for these coils, however, are not interchangeable on the two instruments and, in disconnecting the good coil, the wire from the center broke off too short to be repaired without rewinding. It has been necessary, therefore, to make manual zeros, two or three each day, and, as the zeros have been very constant, it is thought that this will suffice until a new coil is received and fitted.

Conductivity Apparatus 8A.--The performance of this recorder has been most gratifying. Scalable values have been obtained for every hour, except one, of every day since leaving Honolulu. Thus forty-seven complete days' traces are available--twenty-three for positive and twenty-four for negative conductivity. Calibrations of both signs have been made frequently and the mean curves show very little variation with lapse of time. On October 29 a thermometer was fitted to the electrometer house, with bulb inside and scale outside, and, for calibrations subsequent to this date, temperature readings have been made and recorded. On October 18 one-hour runs were made, on both signs, with an ionium collector in the air-flow tube. The ratio of positive to negative conductivities derived from these tests was 1.17. From the mean values of positive and negative conductivities obtained for observations made between October 2 and 31 (using only undisturbed days, eleven of each sign) which were 1.30×10^{-4} and 1.08×10^{-4}, respectively, a ratio of 1.20 was derived. On October 24 the duration of the hourly zero was increased from four to six minutes. On October 25 one of the recording drums began to stick, in the same manner as was encountered on several days during September. The drum was taken apart and greased, but the stoppages recurred on October 29 and 31. The driving spring therefore was removed and the drum has worked quite well without it. On November 10 the same thing happened to the other drum; so the spring was removed from it also. The following interesting features of the conductivity traces might be mentioned: (a) The sudden change in type of trace at 16h 45m hours on October 7, for which no corresponding change in meteorological or other factors to which it might be related, could be found; (b) the change from land to sea conditions soon after leaving Honolulu on October 3; (c) the sudden decrease in values during rain. It was noticed that the values of ionic mobility derived from the conductivity records and from eye observations of ionic content are somewhat high and rather more variable than those previously obtained. This question invites some investigation which can no doubt be carried through more effectively at Washington than on board ship.

Ionic Content Apparatus 1.--No difficulties have occurred with this instrument. It has been possible, with a new type of hood over the apparatus, to observe during periods of light sprinkling rain without any bad effect on the insulation of the apparatus.

Penetrating Radiation Apparatus 1.--The sodium in the drying tubes was renewed on October 16. The new tubes supplied at San Francisco were found to fit; so we now have an ample supply on board. On October 17 observations with this instrument and penetrating radiation apparatus 5503 were made, using radium as an ionizing constant. The results appear quite satisfactory but it is planned to repeat them at an early date.

Penetrating Radiation Apparatus 5503.--The diurnal-variation curve of October 5 and 6 showed irregularities which obviously were instrumental and were brought about in the following way. The electrometer was charged up every two hours, and, owing to the desirability of making the mean times of observation one hour apart, the initial reading of the first, third, fifth, and subsequent odd-numbered hours was made one minute after recharging. This arrangement was adopted because the electrometer had been charged for about two hours before the beginning of the diurnal-variation run, and its performance during that period indicated that initial readings could be taken very shortly after recharging. This, however, later was found not to be justified. In order to determine the minimum time required for normal values to be obtained, a series of observations was made on October 8. The fibers were charged and readings were made after one, three, five, etc., minutes had elapsed. After twelve of these readings the instrument was left for one hour and the final reading then made. It was found that the "charging effect" persisted for about five minutes rather than only one minute, after which the values of R were consistent, within the limits of accuracy of the instrument. The hourly routine of the diurnal-variation observations therefore has been amended, as follows:

h m	Performance
00 05	First reading of 5503
00 15	First reading of penetrating radiation apparatus no. 1
	Leak test of ion counter
00 20	Begin ion count
	Nuclei count and meteorological observations
00 40	End ion count. Start leak test of ion counter
00 45	Last reading of penetrating radiation apparatus no. 1
00 55	Last reading of 5503
	Recharge 5503 immediately

Above routine repeated each hour

Two of the diurnal-variation runs (October 13 and 14 and 21 and 22) show very good agreement between instruments 1 and 5503. Both curves show a pronounced double maximum. The curves on the other two occasions during the period covered by this report are more erratic.

Radioactive Content Apparatus 4.--Difficulties with the electrometer used with this apparatus on October 3 and 4, led to exhaustive tests and finally to the exchange of this instrument for the spare, no. 15, which has flat plates instead of the knife-edge type of plates of no. 5. There was no further difficulty. Frequent attention was necessary to the collecting apparatus. The values obtained on October 8 and 10 were high; since that date low values have been recorded and a test observation made just before entering Pago Pago harbor on November 18 showed a decided increase, tending to show that the apparatus had been functioning properly. On two occasions collection had to be made without the upper earthing cap, but after tightening the friction clamp at the top, a high potential could be maintained and so the cap was used on subsequent observations.

Nuclei Counter 5.--Regular observations have been made and, in general, low values have prevailed.

Batteries.--The Burgess "B" batteries continue to give good service.

IV. ABSTRACT OF LOG

CONTENTS

IV. ABSTRACT OF LOG

Date	Noon position		Day's run	Current		Remarks
	Latitude	Longitude east		Dir.	Am't.	(Local mean time used throughout)
						Washington, D. C. to Plymouth, England
						Total distance, 3669; time of passage, 29.3 days; average day's run, 125.2 miles
1928	° ′	° ′	miles	°	miles	
May 1	Washington, D.C.		.....	....	.....	Left Colonial Beach Steamboat Co. pier under tow at 09h 00m.
2	St. Mary's River		.....	....	.....	Anchored at entrance St. Mary's River, Chesapeake Bay, at 00h 20m off Kitts Point. Swung ship for declination-observations and deviation. Clear. Light variable breeze.
3	St. Mary's River		.....	....	.....	Atmospheric-electric observations. Clear. Light NW air.
4	St. Mary's River		.....	....	.....	Atmospheric-electric observations. Clear. Calm.
5	St. Mary's River		.....	....	.....	Atmospheric-electric observations. Clear. Calm. Under way 20h 30m with pilot.
6	Newport News		.....	....	.....	Anchored at 08h 30m. Overcast. Fresh northerly breeze.
7	Newport News		.....	....	.....	In drydock of Newport News Shipbuilding and Drydock Co. at 10h 10m. Cloudy to clear. Fresh northerly breeze.
8	Newport News		.....	....	.....	In drydock. Overcast. Rain. Strong NE breeze.
9	Newport News		.....	....	.....	In drydock. Overcast. Rain. Calm.
10	Newport News		.....	....	.....	Under way at 13h 15m with pilot. Took departure from Cape Henry at 18h 20m. Gentle SE breeze. Partly cloudy.
11	37 15 N	286 09	134	244	7.5	Clear to cloudy. Smooth to moderate sea. Moderate southerly breeze.
12	38 17 N	291 56	282	61	6.4	Cloudy to overcast. Moderate to choppy sea. Moderate to fresh breeze, S in a.m., NE in p.m.
13	37 43 N	296 37	221	89	69.0	Partly cloudy. Moderate sea and northerly wind.
14	37 00 N	299 40	149	220	44.8	Overcast, rain. Gentle to fresh northerly breeze. Moderate sea.
15	37 04 N	303 24	179	295	30.0	Overcast, rain. Fresh northerly breeze. Choppy sea.
16	37 48 N	306 50	170	231	18.3	Partly cloudy. Moderate to fresh NW breeze. Moderate and broken and choppy sea.
17	38 12 N	310 21	168	225	27.6	Partly cloudy. Moderate sea. Rain squalls. Moderate breeze, NW in a.m., SW in p.m.
18	39 11 N	314 29	202	36	19.8	Cloudy, rain. Strong southerly breeze to moderate gale. Rough sea.
19	40 38 N	318 11	191	16	19.4	Partly cloudy. Fresh southerly breeze. Rough to choppy sea, squalls.
20	42 01 N	321 13	161	337	15.3	Cloudy. Fresh southerly breeze. Moderate choppy sea. Squalls.
21	44 04 N	323 54	170	19	9.2	Cloudy. Moderate southerly breeze. Moderate sea.
22	45 29 N	326 40	146	310	11.5	Cloudy. Moderate sea. Moderate to gentle SE breeze.
23	44 35 N	326 53	54	212	27.2	Overcast. Rain. Moderate to strong NE breeze. Moderate to rough sea.
24	43 51 N	328 18	75	229	10.2	Overcast. Heavy rain. Strong NE breeze to fresh gale. Rough sea.
25	43 13 N	328 30	40	260	31.5	Cloudy. Fresh NE breeze. Moderate sea, broken, and choppy.
26	44 00 N	331 35	144	153	15.4	Cloudy. Fresh northerly breeze. Moderate sea.
27	45 50 N	334 29	164	176	13.3	Cloudy. Fresh NW and SW breezes. Moderate to rough sea.
28	48 11 N	338 52	230	66	14.7	Overcast. Strong northerly breeze to moderate gale. Choppy sea.
29	48 50 N	341 10	101	197	12.4	Clear in p.m. Moderate sea. Moderate southerly breeze.
30	49 37 N	344 24	138	340	4.7	Overcast. Fog. Rain. Moderate southerly breeze and sea.
31	50 23 N	346 29	92	12	2.9	Overcast. Fog. Rain. Moderate sea. Gentle SE breeze.
June 1	50 06 N	346 54	24	42	3.9	Cloudy to overcast. Misty. Moderate sea. Moderate E to SE breeze.
2	49 32 N	347 53	51	289	10.2	Cloudy. Fresh to strong easterly breeze. Moderate to rough sea.
3	50 12 N	347 29	43	159	5.0	Cloudy to overcast. Fog. Rain. Strong to light SE breeze. Choppy sea.
4	50 16 N	347 55	17	160	16.6	Cloudy to overcast. Fog. Rain. Gentle to strong easterly breeze. Choppy sea.
5	49 55 N	348 52	42	4	3.8	Cloudy to overcast. Moderate easterly breeze. Moderate sea. Southerly swell.
6	50 10 N	349 56	44	295	3.1	Cloudy. Squalls. Light to fresh SE breeze. Moderate sea.
7	50 12 N	352 04	82	6	6.3	Cloudy to overcast. Gentle southerly breeze. Rain. Moderate sea.
8	49 59 N	354 57	112	100	1.7	Slightly cloudy in a.m., overcast in p.m. W to SW light winds in a.m. Moderate sea. Rain and strong wind in p.m.
8	Plymouth		.....	....	.....	Anchored in Plymouth harbor at 20h 30m.
						Plymouth, England to Hamburg, Germany
						Total distance, 614 miles; time of passage, 4.1 days; average day's run, 149.8 miles
1928	° ′	° ′	miles	°	miles	
June 18	Plymouth		.....	....	.....	Took departure from Plymouth Breakwater at 16h 38m. Cloudy. Moderate sea. Gentle W to SW and S breeze.
19	50 29 N	358 59	126	20	6.3	Overcast. Gentle to moderate SW to W breeze. Smooth to moderate sea.
20	51 39 N	2 24	146	120	15.8	Partly cloudy. Moderate W to NW breeze. Moderate sea.
21	53 23 N	4 24	128	40	12.6	Partly cloudy. Moderate northerly breeze in morning. Gentle southerly breeze in afternoon. Moderate sea.

Plymouth, England to Hamburg, Germany--Concluded

Date	Noon position Latitude	Longitude east	Day's run	Current Dir.	Current Am't.	Remarks (Local mean time used throughout)
1928	° ′	° ′	miles	°	miles	
June 22	Mouth of Elbe River, Germany		137	18	6.3	Arrived at Elbe lightship no. 1 at 10h 12m. Overcast. Moderate southerly breeze. Moderate sea.
22	Hamburg		77	....	.....	Picked up pilot at Elbe lightship no. 1. Picked up tug at Altenbruck. Towed 54 miles to Hamburg Harbor, Jonas Dock, Vorsetzen. Anchored at 20h 00m.

Hamburg, Germany to Reykjavik, Iceland

Total distance, 1329 miles; time of passage, 13.0 days; average day's run, 102.3 miles

Date	Latitude	Longitude east	Day's run	Current Dir.	Current Am't.	Remarks
1928	° ′	° ′	miles	°	miles	
July 7 8	Hamburg		96	....	.....	Left Hamburg Harbor at 07h 00m. Under tow from Harbor to Helgoland. Took departure from Helgoland at 08h 35m July 8. Partly cloudy. Gentle westerly breeze. Moderate sea. Tow distance 96 miles.
8	54 09 N	7 38	5	49	3.0	Partly cloudy. Gentle westerly breeze. Moderate sea.
9	55 21 N	5 13	110	42	9.6	Partly cloudy. Fresh to light WSW breeze. Moderate to smooth sea.
10	58 00 N	2 25	185	56	16.0	Cloudy in morning. Overcast and drizzling in afternoon. Fresh W to SSW breeze. Moderate to choppy sea.
11	60 29 N	0 24	162	67	20.2	Overcast and misty. Fresh W to SW breeze. Moderate to choppy sea.
12	62 16 N	354 59	169	43	14.2	Partly cloudy. Strong SW breeze. Moderate to choppy sea.
13	63 16 N	350 40	133	34	23.2	Partly cloudy. Strong SW breeze. Choppy, rough sea.
14	64 05 N	348 22	79	5	7.2	Cloudy to overcast. Squalls. Strong SW breeze in morning. Very light NE air in afternoon. Rough sea to moderate.
15	63 28 N	345 07	93	337	11.2	Partly cloudy. Light easterly air in morning. Gentle to moderate SW breeze in afternoon. Smooth to moderate sea.
16	63 20 N	342 46	64	31	13.6	Partly cloudy. Moderate westerly breeze. Moderate to choppy sea.
17	62 57 N	341 36	39	84	10.6	Overcast in morning. Rain. Cloudy in afternoon. Moderate westerly and fresh NW breeze. Moderate choppy to rough sea.
18	62 33 N	340 09	46	153	14.4	Cloudy in morning. Overcast and misty in afternoon. Moderate W to NW breeze. Moderate, choppy sea.
19	63 38 N	338 00	87	64	12.8	Overcast. Misty to drizzling. Moderate NW breeze. Moderate sea. Squally.
20	Reykjavik		61	150	16.0	Overcast and drizzling. Gentle westerly breeze. Smooth sea. At anchor in Reykjavik harbor at 08h 00m.

Reykjavik, Iceland to Barbados, B.W.I.

Total distance, 5715 miles; time of passage 51.8 days; average day's run, 110.3 miles

Date	Latitude	Longitude east	Day's run	Current Dir.	Current Am't.	Remarks
1928	° ′	° ′	miles	°	miles	
July 27	Reykjavik		.....	....	.....	Left at 12h 00m with own power. Partly cloudy. Moderate sea and moderate NE to N breeze.
28	62 31 N	333 42	156	154	7	Cloudy in early morning and evening. Clear during day. Moderate sea. Moderate northwesterly breeze.
29	60 40 N	328 45	180	144	14	Cloudy to overcast. Moderate sea. Moderate north breeze.
30	59 17 N	325 45	122	180	14	Overcast in morning. Cloudy in afternoon. Light to moderate N to W breezes. Smooth to choppy sea.
31	57 54 N	325 50	83	72	6	Cloudy to overcast. Moderate to gentle NW to SW breezes. Moderate sea.
Aug. 1	58 15 N	324 10	57	359	15	Fog, mist, and drizzling rain. Overcast. Gentle SW to NW breezes. Moderate sea.
2	58 16 N	321 18	91	153	2	Overcast and misty. Calm to fresh E and NE breezes. Moderate to choppy sea. Squalls.
3	57 52 N	314 27	219	324	4	Aurora borealis in early hours. Cloudy until evening then overcast and misty. Strong NE to E breezes. Choppy to rough sea.
4	54 30 N	310 59	233	292	15	Aurora borealis in late evening. Overcast in morning. Cloudy in afternoon. Strong E to NE breezes. Rough sea. Squalls.
5	51 38 N	310 28	174	244	14	Clouds on horizons. Moderate NE to NW breezes. Moderate sea. Iceberg abeam at 19h 35m.
6	48 26 N	311 51	199	137	12	Cloudy. Moderate WNW breeze. Moderate sea. Aurora borealis in late evening.
7	45 54 N	312 07	153	172	5	Clear during day. Few clouds on horizons in early evening. Moderate to fresh NW to W breeze. Moderate sea.
8	43 14 N	313 06	165	77	9	Cloudy, but principally on horizons. Moderate NW breeze in morning and moderate sea. Gentle NE breeze in afternoon and smooth sea.
9	42 10 N	312 39	67	139	2	Cloudy. Light NE breeze in morning and smooth sea. Moderate to fresh SE breeze and moderate sea in afternoon.
10	39 48 N	311 11	156	343	25	Cloudy to overcast. Rain and mist in middle of day. Fresh to strong SE breeze and rough sea in morning, gentle breeze in afternoon.
11	38 38 N	311 14	70	91	15	Cloudy. Calm to gentle W breeze. Moderate sea.

Reykjavik, Iceland to Barbados, B.W.I.--Concluded

Date	Noon position		Day's run	Current		Remarks
	Latitude	Longitude east		Dir.	Am't.	(Local mean time used throughout)
1928	° ′	° ′	miles	°	miles	
Aug. 12	36 58 N	311 42	103	157	17	Cloudy on horizons. Light to gentle W and SW breezes. Moderate to smooth sea.
13	36 48 N	313 34	91	85	33	Squalls in early morning. Cloudy on horizons during day. Moderate S to W breezes. Moderate sea.
14	35 14 N	315 41	139	90	16	Cloudy. Squalls in early morning. Moderate SW breeze. Moderate sea.
15	33 36 N	317 45	142	64	15	Cloudy on horizons and occasionally overhead with squalls and lightning. Moderate westerly breeze. Choppy sea.
16	31 10 N	318 56	157	117	23	Cloudy. Squalls in afternoon. Fresh to light W to NW breeze. Moderate sea.
17	29 45 N	319 24	88	160	17	Cloudy. Squalls in early morning. Clear overhead during day. Light to gentle N to E breeze. Smooth sea.
18	27 54 N	320 32	126	264	7	Cloudy on horizons with distant squalls. Gentle to fresh E breeze. Smooth to moderate sea.
19	25 39 N	321 01	137	310	6	Cloudy on horizons. Moderate to gentle SE breeze. Moderate to smooth sea.
20	23 59 N	320 23	105	65	5	Cloudy, with squall conditions. Moderate to fresh breeze in morning, gentle in afternoon. Moderate sea.
21	21 46 N	320 22	134	292	11	Cloudy on horizons. Fresh E breeze. Moderate to choppy sea.
22	19 12 N	321 31	167	255	6	Cloudy. Fresh to moderate E breeze. Moderate sea. Squalls; threatening during day.
23	16 35 N	322 10	162	215	12	Cloudy, chiefly on horizons. Moderate E breeze and moderate sea in morning. Light ENE airs and smooth sea in afternoon and evening.
24	15 48 N	322 03	47	206	20	Cloudy, chiefly on horizons. Calm to light E airs. Smooth sea.
25	14 56 N	321 50	54	218	20	Cloudy. Light ESE breeze in morning; calm thereafter. Smooth sea. Started main engine at 19h 20m.
26	13 55 N	321 58	61	161	2	Cloudy. Light E airs in morning. Light W breeze in afternoon. Smooth sea. Rain in morning and evening. Stopped engine at 08h 10m.
27	13 22 N	322 00	33	184	17	Cloudy, chiefly on horizons. Calm to light west airs. Smooth sea. Started main engine at 19h 25m.
28	11 54 N	322 08	89	184	9	Clear in early morning, cloudy thereafter. Squall in evening. Light W to SW airs and breeze. Smooth sea. Stopped main engine at 08h 00m, and started again at 20h 10m.
29	10 49 N	322 36	70	158	12	Cloudy. Light variable airs, to calm. Smooth sea. Squalls morning and evening. Stopped engine at 05h 55m and started again at 20h 15m.
30	9 28 N	322 52	83	122	10	Cloudy. Calm to light and gentle SW breezes. Smooth to moderate sea. Stopped engine at 11h 20m. Rain at midnight.
31	8 11 N	323 52	97	79	17	Squalls throughout day. Gentle to fresh westerly breeze. Moderate to choppy sea.
Sep. 1	9 26 N	323 20	81	57	25	Overcast and raining, morning and evening, otherwise cloudy. Gentle W breeze until evening, then calm. Moderate sea.
2	9 50 N	323 20	24	113	17	Cloudy, chiefly on horizons. Light to moderate westerly breeze. Smooth to moderate sea. Squall at midnight.
3	11 07 N	322 52	82	60	15	Rain morning and evening with lightning in evening. Cloudy during day. Gentle westerly breeze, to calm. Moderate to smooth sea.
4	11 23 N	321 57	57	227	18	Squall in early morning. Cloudy, chiefly on horizons. Light to moderate NE breeze. Smooth to moderate sea.
5	11 33 N	319 10	164	264	18	Cloudy, chiefly on horizons. Moderate to gentle NE breeze. Moderate sea.
6	11 40 N	317 24	105	344	1	Cloudy, chiefly on horizons. Gentle NNE to NxE breeze. Moderate sea. Heavy squall at 19h 00m.
7	11 18 N	315 42	103	202	25	Cloudy, chiefly on horizons. Light NxE breeze to light NNE airs. Moderate to smooth sea. NE swells.
8	11 36 N	314 54	51	296	33	Clear in morning, cloudy in afternoon. Light NE airs to calm. Smooth sea. NE swells.
9	11 45 N	313 53	60	214	12	Cloudy, chiefly on horizons, until evening; then rain squalls. Gentle to light northerly breeze. Moderate sea.
10	12 10 N	312 15	99	257	20	Heavy squalls during morning, cloudy thereafter. Moderate to fresh westerly breeze. Moderate to choppy sea.
11	13 13 N	310 19	130	20	22	Squalls threatening in morning, then cloudy chiefly on horizons. Moderate to light SW breeze. Choppy, moderate sea, calm in evening.
12	13 09 N	309 24	55	257	20	Cloudy, chiefly on horizons. Light ENE airs to light ENE breeze. Moderate sea.
13	13 17 N	307 39	102	305	18	Cloudy, chiefly on horizons. Gentle E breeze. Moderate sea.
14	13 02 N	305 40	117	319	3	Cloudy, chiefly on horizons. Gentle SE breeze. Moderate sea.
15	12 54 N	303 43	115	286	12	Cloudy, chiefly on horizons. Gentle ESE breeze. Moderate sea.
16	13 01 N	301 31	128	329	11	Cloudy, chiefly on horizons. Gentle ExS breeze. Moderate sea. Sighted island at 16h 30m.
17	Carlisle Bay, Barbados			....	....	Partly cloudy. Gentle ExS breeze. Moderate sea. At anchor in Carlisle Bay at 08h 35m.

Barbados, B.W.I. to Balboa, Canal Zone

Total distance, 1361 miles; time of passage, 9.7 days; average day's run, 140.3 miles

Date	Noon position		Day's run	Current		Remarks (Local mean time used throughout)
	Latitude	Longitude east		Dir.	Am't.	
	° ′	° ′	miles	°	miles	
1928						
Oct. 1	Barbados		....	....	....	Left anchorage at 11h 30m. Partly cloudy. Moderate sea and gentle NExE breeze.
2	14 41 N	298 37	141	245	17	Near the islands of St. Lucia and Martinique during morning. Cloudy, chiefly on horizons. Moderate sea and moderate to light NE breeze. Lightning in east.
3	14 46 N	296 24	129	277	22	Cloudy in morning, overcast in afternoon, with heavy shower in mid-afternoon. Lightning from NE to NW all day. Moderate to smooth sea. Gentle to moderate NNE to ExS breeze.
4	15 01 N	293 53	147	339	15	Cloudy in morning with lightning in SW in early hours. Overcast and squally during midday, clearing somewhat in afternoon. Moderate sea and moderate to light E breeze.
5	15 19 N	291 47	124	321	18	Partly cloudy. Lightning in NW and N morning and evening. Moderate sea and moderate easterly breeze.
6	15 10 N	288 45	176	303	16	Cloudy during day, clearing in evening. Lightning in NW in early morning. Moderate sea and moderate ESE breeze.
7	14 27 N	285 53	171	277	14	Cloudy, chiefly on horizons. Moderate sea and moderate E breeze.
8	13 34 N	283 31	147	306	37	Partly cloudy in morning. Overcast with rain in mid-afternoon, clearing in evening. Hazy in evening and lightning in S. Moderate sea and moderate to fresh ESE breeze.
9	11 23 N	281 29	171	317	22	Cloudy and hazy in morning. Overcast with rain, thunder and lightning in afternoon. Lightning in evening. Moderate sea and moderate to gentle easterly breeze. Hazy in evening.
10	10 15 N	280 46	81	36	18	Cloudy, with rain squalls, in morning. Cloudy in afternoon and evening. Lightning in SW in evening. Light easterly to SW breezes. Moderate to smooth sea.
11	Colon and Balboa		68	....	....	At anchor in Colon breakwater at 04h 00m. Cloudy all day. Light SxE and S breeze up to 04h 00m. Left Colon anchorage at 11h 00m with tug and docked at Balboa wharf at 19h 30m.

Balboa, Canal Zone to Easter Island

Total distance, 4788 miles; time of passage, 41.9 days; average day's run, 114.3 miles

Date	Latitude	Longitude east	Day's run	Current Dir.	Current Am't.	Remarks
1928	° ′	° ′	miles	°	miles	
Oct. 25	Balboa		....	....	....	Left dock at 10h 40m under tow. Ran 10 miles to Taboguilla Light abeam, at 12h 27m. Then took departure. Cloudy and hazy. Moderate sea and moderate NW breeze. Lightning in NW in late evening.
26	6 32 N	279 54	152	222	30	Cloudy in early morning. Overcast after 06h 00m, and all day, with rain squalls. Clear in evening. Moderate NW breeze changing to calm and, in evening to light SE and SW airs and breezes. Moderate to smooth sea.
27	5 44 N	280 06	49	115	3	Cloudy to overcast all day, with occasional short rain squalls. Clearing in evening. Lightning and thunder in east during morning. Gentle to moderate westerly breeze. Moderate sea.
28	4 15 N	280 21	90	86	13	Cloudy to overcast all day, with rain squalls and drizzling rain. Lightning and thunder in morning. Moderate to choppy sea. Variable moderate to light breezes, changing to calm in evening.
29	4 08 N	280 07	15	98	9	Cloudy, chiefly on horizons. Light to moderate southwesterly breezes. Moderate sea. Rain squalls from 16h 45m to 19h 00m.
30	2 53 N	279 52	76	94	16	Cloudy to overcast with occasional rain squalls after 04h 00m, and all day and evening. Moderate SW breeze. Moderate to choppy sea.
31	4 32 N	278 12	140	50	26	Cloudy, with frequent rain squalls throughout 24 hours. Fresh to moderate SW breeze. Choppy to moderate sea. Malpelo Island abeam at 07h 02m.
Nov. 1	6 03 N	277 01	116	76	13	Cloudy, with rain squalls all day. Clearing in evening. Gentle to moderate SW breeze. Moderate sea.
2	4 38 N	277 43	94	128	23	Overcast, with frequent rain squalls throughout 24 hours. Fresh SW breeze changing to light W and SW in evening. Choppy to moderate sea.
3	3 41 N	278 31	75	104	21	Cloudy to overcast. Squally. Rain squalls during morning. Moderate to fresh SW breeze. Moderate to choppy sea. Malpelo Island sighted at daybreak.
4	2 27 N	278 58	77	78	15	Overcast to cloudy. Moderate to gentle SSW to SWxW breezes. Moderate to choppy sea.
5	1 35 N	279 12	54	78	12	Overcast in early morning, clearing somewhat during day. Gentle to light SSW to W breeze. Moderate sea.
6	0 46 N	278 48	55	8	5	Overcast and hazy in early morning. Cloudy, chiefly on horizons, during day. Calm until 10h 00m, then gentle southwesterly breeze. Smooth to moderate sea.
7	0 27 N	277 57	89	192	9	Hazy in early morning. Cloudy until evening, then overcast and

Balboa, Canal Zone to Easter Island--Concluded

Date	Noon position		Day's run	Current		Remarks (Local mean time used throughout)
	Latitude	Longitude east		Dir.	Am't.	
1928	° ′	° ′	miles	°	miles	
Nov. 7						drizzling. Moderate southwesterly breeze. Moderate sea.
8	1 29 S	277 37	66	247	11	Overcast morning and evening; cloudy during day. Moderate SSW to light S breeze. Choppy to moderate sea.
9	1 19 S	275 05	152	262	16	Overcast in morning, otherwise cloudy chiefly on horizons. Gentle S breeze. Moderate to smooth sea.
10	1 39 S	272 55	131	253	55	Cloudy. Light to moderate S to SxE breeze. Smooth sea.
11	1 53 S	270 55	121	237	34	Cloudy, chiefly on horizons. Gentle to moderate S breeze. Moderate sea. Sighted Galapagos Islands in early p.m.
12	1 16 S	268 41	138	257	28	In vicinity of Galapagos Islands all day. Cloudy, chiefly on horizons. Light to moderate S to SE breeze. Smooth to moderate sea.
13	1 31 S	266 46	116	287	34	Overcast all day, hazy in evening. Gentle to light southeasterly breeze. Moderate to smooth sea. SE swells.
14	1 46 S	265 41	67	287	29	Overcast in early morning, clearing during day, cloudless in evening. Calm, to gentle SSE breeze. Smooth to moderate sea. SE swells.
15	2 30 S	264 15	96	269	12	Overcast in early morning, clearing overhead during the day. Gentle SSE to moderate SE breeze. Smooth to moderate sea.
16	3 04 S	261 44	154	276	10	Drizzling rain at 04h 00m. Cloudy to overcast all day and evening. Gentle to light SExS breeze. Moderate sea. SE swells.
17	3 15 S	260 07	98	280	17	Clear between 04h 00m and 08h 00m, otherwise cloudy. Light to moderate southeasterly breeze. Moderate sea. An unusual meteor appeared in ENE at 04h 45m, stopped at 35 altitude, and faded away.
18	4 01 S	257 20	173	293	22	Clear in very early morning, otherwise cloudy. Moderate to gentle SExS breeze. Moderate sea. SE swells.
19	4 35 S	254 51	152	308	30	Cloudy to overcast in very early morning; thereafter cloudy on horizons. Moderate to fresh SE to ESE breeze. Moderate sea. SE swells.
20	6 57 S	253 08	176	248	18	Clear, changing to cloudy on horizons. Moderate ESE to ExS breeze. Moderate sea.
21	9 14 S	251 34	165	250	15	Cloudy, chiefly on horizons. Moderate to fresh ExS to ESE breeze. Moderate sea.
22	11 57 S	249 45	195	261	14	Cloudy, chiefly on horizons. Fresh ESE breeze. Moderate sea.
23	14 12 S	248 04	167	256	16	Cloudy. Squally in afternoon and evening. Moderate ESE breeze. Moderate sea.
24	16 44 S	246 57	165	259	10	Cloudy and squally all day, with drizzling rain at 19h 00m. Fresh to moderate E to ESE breeze. Choppy sea.
25	19 14 S	245 52	162	252	10	Cloudy, chiefly on horizons. Fresh to moderate easterly breeze. Choppy to moderate sea. Easterly swells.
26	21 42 S	245 34	149	247	14	Cloudy, chiefly on horizons. Moderate to gentle easterly breeze. Moderate sea. Easterly swells.
27	23 20 S	245 13	100	258	10	Squally in early morning, with rain at 01h 00m. Clearing to cloudless in afternoon. Gentle easterly breeze. Moderate sea with easterly swells until noon, then SW and southerly swells.
28	24 48 S	244 35	94	282	15	Cloudy. Gentle to moderate easterly breeze. Moderate sea. Southerly swells.
29	26 36 S	244 40	108	261	16	Cloudy and squally in very early morning; rain at 02h 30m. Cloudy on horizons during day, drizzling rain in late evening. Moderate to gentle ENE breeze. Moderate sea, southerly swells.
30	28 04 S	244 51	89	247	18	Cloudy to overcast with rain squalls during morning, then cloudy to clear. Light to gentle northeasterly breeze. Moderate to smooth sea.
Dec. 1	29 12 S	245 13	70	156	6	Cloudy to clear. Light to gentle northeasterly breeze. Smooth sea.
2	30 34 S	245 44	86	162	7	Cloudy, chiefly on horizons. Light to gentle northeasterly breeze. Smooth sea. Southerly swells.
3	31 32 S	247 16	97	215	6	Overcast in mid-afternoon, otherwise cloudy. Gentle to moderate N to NW breeze. Moderate to smooth sea. Southerly swells.
4	31 23 S	249 56	137	139	16	Cloudy, chiefly on horizons. Squally in late evening. Moderate to fresh NW to WxN breeze. Moderate to choppy sea.
5	28 54 S	251 19	165	76	20	Overcast, with rain squalls in very early morning, then cloudy. Fresh to moderate W to SW breeze. Moderate sea.
6	Easter Island		117	....	....	Sighted Easter Island at 03h 40m. Cloudy. Moderate to light southwesterly breeze. Moderate sea. At anchor in Cook's Bay at 08h 55m.

Easter Island to Callao, Peru

Total distance, 3334 miles; time of passage 32.9 days; average day's run, 101.3 miles

Date	Latitude	Longitude east	Day's run	Dir.	Am't.	Remarks
1928	° ′	° ′	miles	°	miles	
Dec. 12	Easter Island		....	....	....	Ran 10 miles from anchorage in Cook's Bay, then took departure off Needle and Flat Rocks at 17h 06m. Cloudy. Gentle E to NExE breeze. Moderate sea.

Easter Island to Callao, Peru--Continued

Date	Noon position		Day's run	Current		Remarks (Local mean time used throughout)
	Latitude	Longitude east		Dir.	Am't.	
1928	° ′	° ′	miles	°	miles	
Dec. 13	28 10 S	250 49	71	....	....	Hazy morning and evening. Cloudy, chiefly on horizons. Light NE to E breezes. Smooth sea. Northeasterly swells, in morning, changing to southwesterly in afternoon and evening. Squally in evening, with rain at 20h 30m.
14	29 22 S	251 07	73	193	21	Clear overhead in early morning, thereafter cloudy to overcast, with occasional rain squalls. Light to gentle E to NE breezes until mid-afternoon, then moderate gale. Smooth to moderate to rough sea. Northeasterly swells.
15	31 08 S	250 29	112	265	17	Cloudy to overcast throughout, with frequent rain squalls. Moderate E gale to strong E breeze, changing in afternoon to fresh southeasterly breeze. Rough to choppy sea.
16	32 02 S	249 06	89	259	8	Cloudy, chiefly on horizons. Moderate to fresh to light southeasterly breezes. Choppy sea. Southeasterly swells.
17	31 45 S	250 35	78	23	12	Cloudy, chiefly on horizons, until evening; then clear. Light to moderate SE to E breezes until early evening, then calm. Moderate to smooth sea. Southeasterly swells.
18	31 53 S	251 02	25	200	10	Cloudless until noon, then cloudy on horizons. Calm to light northerly airs until mid-morning, thereafter moderate northerly breeze. Smooth to moderate sea. Easterly swells in morning.
19	32 27 S	252 37	87	154	8	Cloudy, chiefly on horizons, until evening, then overcast, with drizzling showers. Light to gentle northerly breeze until evening, then moderate northeasterly breeze. Smooth sea until evening, then moderate. Southerly swells.
20	34 03 S	253 18	102	105	13	Cloudy, chiefly on horizons. Hazy in afternoon. Moderate to gentle northeasterly breeze. Moderate sea.
21	35 17 S	254 37	98	218	11	Cloudy, chiefly on horizons, and hazy. Squally in evening. Heavy dew early morning and late evening. Moderate northeasterly breeze. Moderate sea. Southerly and westerly swells.
22	36 51 S	255 55	113	241	9	Overcast and foggy except in early morning and late evening; then cloudy and hazy. Moderate NExN and NE breeze. Moderate sea. Southerly swells.
23	38 40 S	257 06	122	204	22	Overcast to cloudy. Hazy. Moderate northeasterly breeze. Moderate sea.
24	39 54 S	258 59	114	186	17	Cloudy and hazy until noon, thereafter overcast and hazy. Moderate NNE to moderate and gentle N breeze. Moderate sea.
25	40 19 S	261 02	97	166	12	Cloudless in afternoon, otherwise cloudy on horizons. Gentle N to NNW breeze. Moderate sea. Heavy dew in late evening.
26	40 26 S	262 30	68	142	12	A few clouds on horizons, otherwise clear. Calm during morning, otherwise light N to NW airs and breezes. Smooth sea.
27	39 54 S	263 46	66	109	11	Cloudy, chiefly on horizons. Gentle to moderate northwesterly breeze. Smooth to moderate sea. Heavy dew in very early morning.
28	38 26 S	265 52	131	140	12	Cloudy and hazy in morning; overcast and hazy in afternoon and evening, with occasional showers. Moderate westerly breeze until late evening; then light SW breeze changing to calm. Smooth sea.
29	36 38 S	266 55	119	359	10	Overcast and rain in very early morning; calm. Thereafter cloudy, chiefly on horizons, with moderate SE to ESE breeze. Moderate sea.
30	34 32 S	268 10	140	283	13	Cloudy, chiefly on horizons. Moderate ESE to E breezes. Moderate sea. Rain 13h - 14h.
31	32 30 S	269 59	152	265	4	Cloudy in morning; cloudy to overcast thereafter. Moderate southeasterly breeze in morning; calm to light variable airs thereafter. Moderate to smooth sea. SE to SW swells.
1929						
Jan. 1	32 10 S	270 56	52	288	11	Cloudy, chiefly on horizons. Gentle to light SE breeze in early morning, otherwise calm. Smooth sea. Small easterly swells in morning.
2	31 54 S	271 10	21	....	....*	Cloudy, chiefly on horizons. Light southerly airs in morning, changing to northerly in afternoon. Smooth sea.
3	31 55 S	271 45	30	....	....*	Calm until midday. Light northerly airs thereafter. Cloudy, chiefly on horizons. Smooth sea.
4	31 45 S	272 45	53	....	....*	Overcast to cloudy until midday, thereafter clear or only cloudy on horizons. Light northwesterly to southwesterly airs and breezes. Smooth sea.
5	31 02 S	273 25	54	....	....*	Cloudy, chiefly on horizons, until late evening, then rain squalls. Light southwesterly airs in morning, changing to moderate southeasterly in afternoon. Smooth to moderate sea.
6	28 51 S	274 37	146	319	6	Clouds, chiefly on horizons. Moderate to fresh southeasterly breeze. Moderate sea. Overcast and rain squalls in late evening.
7	26 57 S	276 04	137	264	14	Overcast, with squall conditions. Drizzling rain and rain squalls in afternoon and evening. Fresh ESE to SE breeze. Moderate and choppy sea.
8	24 58 S	277 45	150	324	8	Overcast in morning, clear to cloudy in afternoon; overcast in evening. Moderate SE breeze. Moderate sea.

Easter Island to Callao, Peru--Concluded

Date	Noon position		Day's run	Current		Remarks (Local mean time used throughout)
	Latitude	Longitude east		Dir.	Am't.	
1929	° ′	° ′	miles	°	miles	
Jan. 9	23 06 S	278 45	125	308	12	Overcast. Moderate to gentle SE breeze. Moderate sea.
10	21 27 S	279 33	108	248	13	Overcast, with occasional small breaks in clouds. Moderate to fresh SE breeze. Moderate sea.
11	19 07 S	280 41	152	273	16	Overcast, with occasional small breaks. Moderate to fresh SE to ESE breeze. Moderate sea.
12	16 42 S	281 22	150	298	13	Overcast in morning, cloudy in afternoon. Moderate ESE to SE breeze. Moderate sea.
13	14 06 S	282 08	162	315	12	Overcast in early morning, then clearing to clouds on horizons in afternoon. Moderate southeasterly breeze and moderate sea.
14	12 16 S	282 40	114	274	12	Heavy dew in early morning. Cloudy to clear to overcast during day. Moderate to smooth sea. Gentle southeasterly breeze, changing through light E airs, to calm.
14	Callao		23	....	....	At anchor in Callao harbor at 15h 22m.

*Current data unreliable, as ship's speed insufficient to register on log.

Callao, Peru to Papeete, Tahiti

Total distance, 4470 miles; time of passage, 35.8 days; average day's run, 124.9 miles

Date	Latitude	Longitude east	Day's run	Dir.	Am't.	Remarks
1929	° ′	° ′	miles	°	miles	
Feb. 5	Callao		....	....	....	Left anchorage in Callao harbor at 15h 20m. Ran 7 miles to San Lorenzo Island abeam at 16h 32m; then took departure. Cloudiness 7 to 8. Light southwesterly breeze. Smooth sea. Hazy.
6	11 54 S	281 20	89	....	....	Cloudiness 3 to 7, and hazy. Gentle S to SE breeze. Moderate sea. Light dew in early morning and late evening.
7	10 09 S	280 02	129	329	20	Cloudiness 1 to 5, chiefly on horizons. Gentle southeasterly breeze. Moderate sea. Hazy in afternoon.
8	9 57 S	277 45	136	336	15	Cloudiness 3 to 7, chiefly on horizons. Moderate S to SSE breeze. Moderate sea. Hazy in early morning.
9	10 26 S	275 45	122	310	8	Clouds 7 in morning. Clouds 1, on horizons, in afternoon. Moderate southeasterly breeze in morning to light southerly airs in afternoon. Moderate to smooth sea.
10	10 45 S	275 02	46	257	9	Cloudiness 1 to 8, chiefly on horizons. Light southerly airs in morning and evening; calm during day. Smooth sea.
11	10 39 S	274 06	56	279	8	Nearly overcast before 08h 00m, otherwise cloudiness 1 to 2 only on horizons. Gentle to light S to SE breezes. Smooth sea. Southerly swell.
12	11 00 S	272 32	94	330	9	Cloudiness 2 to 4, chiefly on horizons. Moderate S to SE breeze. Moderate sea.
13	12 33 S	270 18	161	302	9	Cloudy to overcast after early morning hours; a few clouds on horizons before 04h 00m. Moderate to fresh SE breeze. Moderate sea.
14	14 23 S	267 45	185	255	16	Partly cloudy, amount 2 to 5, except just before noon; then nearly overcast. Fresh to moderate SE breeze. Moderate sea.
15	15 49 S	265 06	175	287	12	Cloudy to overcast, amount 9 to 10, up to noon. Squally. Drizzling rain at 07h 00m. Clearing overhead after midday, clouds 2 to 5. Hazy. Moderate SE to E breeze. Moderate sea.
16	15 16 S	262 23	161	305	5	Cloudiness 3 to 8 in morning; 8 to 10 in afternoon and evening. Moderate ESE to ExS breezes. Moderate sea. Hazy.
17	14 46 S	259 14	186	273	7	Cloudiness 6 to 9 in morning; clearing somewhat in afternoon with cloudiness 2 to 5. Moderate to fresh easterly breeze. Moderate sea. Short drizzling rain at 05h 00m.
18	14 19 S	256 41	150	273	3	Cloudiness 1 to 7; hazy. Moderate E and ExS breeze. Moderate sea.
19	13 34 S	254 07	156	291	5	Cloudiness 2 to 3, on horizons. Moderate ExS and ESE breezes. Moderate sea.
20	13 00 S	251 51	137	283	6	Cloudiness 2 to 5, on horizons, until late evening, then clouding over to amount 9. Moderate ESE to gentle ExS breeze. Moderate sea.
21	12 31 S	249 53	119	124	3	Cloudiness 2 to 7, chiefly on horizons. Gentle to moderate easterly breeze. Moderate sea.
22	12 36 S	247 40	130	196	3	Cloudiness 3 to 6, chiefly on horizons. Moderate easterly breeze. Moderate sea.
23	12 31 S	244 50	166	357	4	Cloudiness 5 to 6, chiefly on horizons. Moderate easterly breeze. Moderate sea.
24	12 41 S	242 27	140	261	6	Cloudy and partly cloudy; amounts 1 to 8. Moderate to gentle E to NE breezes. Moderate sea.
25	12 46 S	240 36	109	122	4	Cloudiness 2 to 5, chiefly on horizons, until evening, then almost overcast. Gentle to moderate ENE to E breezes. Moderate sea.
26	13 03 S	238 42	114	319	3	Cloudiness 9 to 4. Gentle to moderate easterly breeze. Moderate sea. Easterly swell.
27	13 28 S	235 50	169	236	8	Drizzling rain and a rain squall between 01h 00m and 03h 00m. Cloudiness thereafter 1 to 5, chiefly on horizons. Moderate sea. Fresh to moderate ENE to E breezes.

Callao, Peru to Papeete, Tahiti--Concluded

Date	Noon position		Day's run	Current		Remarks (Local mean time used throughout)
	Latitude	Longitude east		Dir.	Am't.	
1929	° ′	° ′	miles	°	miles	
Feb. 28	14 52 S	233 50	143	282	10	Cloudiness 3 to 9. Moderate easterly breeze. Moderate sea.
Mar. 1	16 33 S	231 56	149	303	5	Cloudiness 1 to 4, chiefly on horizons. Moderate to gentle easterly breeze. Moderate sea.
2	17 01 S	230 13	102	108	3	Clear to cloudiness 1 to 4. Gentle easterly breeze. Moderate sea.
3	17 07 S	228 18	111	141	5	Cloudiness 1 to 2, on horizons. Gentle easterly breeze. Moderate sea. Easterly swells.
4	17 12 S	226 39	94	122	8	Cloudiness 1 to 5, chiefly on horizons. Gentle E to SE breezes. Moderate sea.
5	17 05 S	224 37	117	335	4	Cloudiness 2 to 4, chiefly on horizons. Gentle ESE to ENE breezes. Moderate sea. Northeasterly swells.
6	17 13 S	223 22	72	199	2	Cloudiness 1 to 4, chiefly on horizons, except in early evening, then cloudiness 9. Light northeasterly breezes to airs in morning; calm in afternoon. Started engine at noon. Smooth sea. Rain squall at 01h 30m.
7	17 24 S	221 07	129	195	5	Sighted Tatakoto Island at 05h 30m. Cloudiness 2 to 6, chiefly on horizons. Calm until late afternoon, then light SSE airs. Smooth sea. Hazy. Engine running.
8	17 48 S	219 11	113	....	....	Sighted Amanu Island at 05h 15m. Cloudiness 1 to 6, chiefly on horizons. Light SE airs in morning. Light ESE breeze in afternoon. Smooth sea. Ship hove to from 08h 30m until 16h 00m while scientific staff ashore. Running with engine, until 17h 10m.
9	17 36 S	217 58	71	....	....	Cloudiness 2 to 5 until noon, 8 to 9 after noon. Gentle to light easterly breezes. Smooth sea. Started engine at 20h 00m. Hazy in evening.
10	18 02 S	215 55	119	167	4	Cloudiness 1 to 10; overcast and squally in afternoon. Rain from 18h 00m to 20h 00m. Variable NE to SE breezes. Smooth to moderate sea. Stopped engine at 07h 10m.
11	18 05 S	214 20	90	189	1	Cloudiness 8 to 10; squally. Rain squalls in mid-afternoon. Gentle northwesterly breezes until 20h 00m, then calm. Running engine after 15h 47m. Smooth to moderate sea.
12	17 51 S	211 59	135	270	1	Cloudiness 6 to 10; squally. Lightning in SE in early morning. Light showers before 05h 00m. Mehetia Island abeam and distant 2 miles at noon. Gentle northwesterly breezes. Smooth to moderate sea. Heavy rain squalls during evening. Engine running.
13	Papeete		95	....	....	Cloudiness 10; squally. Light NW airs to calm to light E airs. Smooth sea. At anchor in Papeete harbor at 09h 55m.

Note: cloud amounts expressed in scale from 0 for cloudless to 10 for overcast.

Papeete, Tahiti to Pago Pago, Samoa

Total distance, 1274 miles; time of passage, 12.2 days; average day's run, 104.4 miles

Date	Latitude	Longitude east	Day's run	Dir.	Am't.	Remarks
1929	° ′	° ′	miles	°	miles	
Mar. 20	Papeete		....	....	....	Left anchorage in Papeete harbor under own power at 03h 35m. Ran 3 miles, then took departure at 04h 33m. Cloudiness 8 and 9. Rain squalls in evening. Moderate to gentle easterly breeze. Moderate sea. Southeasterly swells.
21	16 46 S	209 16	78	....	....	Cloudiness 2 in very early morning; thereafter 6 to 9, with rain squalls in late afternoon. Gentle to light northerly and westerly breezes. Southeasterly swells. Started engine at 05h 55m, stopped at 08h 00m.
22	17 36 S	208 15	77	136	6	Cloudiness 7 to 9 with rain squalls during morning, otherwise cloudiness 2 to 4, chiefly on horizons. Moderate northwesterly breezes in morning; light westerly airs in afternoon. Moderate, choppy sea. Started engine at 20h 00m.
23	17 10 S	207 19	60	26	2	Cloudiness 1 to 3, on horizons. Light westerly to easterly airs, to calm. Stopped engine at 08h 00m, started at 12h 37m, stopped at 15h 45m. Smooth sea.
24	16 54 S	206 20	59	329	7	Cloudiness 2 to 5 before noon, 5 to 8 after noon. Rain squalls in late evening. Light, to gentle, to moderate easterly breeze. Smooth sea until evening, then moderate.
25	16 32 S	203 59	137	252	7	Cloudiness 7 to 10 with lightning in NE and NW in early morning and in evening. Moderate to gentle easterly breeze. Rain squalls in evening. Moderate sea.
26	16 08 S	201 38	138	157	9	Cloudiness 5 to 9, with rain squalls at intervals throughout 24 hours. Moderate E and ExN breeze. Moderate sea. Thunder in morning.
27	15 42 S	199 26	129	240	2	Cloudiness 5 to 10, with rain squalls in very early hours and threatening all day. Variable light to moderate E to N breezes. Moderate to broken sea.
28	15 32 S	198 00	84	180	7	Overcast in morning, with rain squalls very early. Cloudiness 5 to 7 in afternoon, 4 to 2 in evening. Gentle to light E breezes until evening, then calm. Moderate to smooth sea. Started engine at 21h 12m.

Papeete, Tahiti to Pago Pago, Samoa--Concluded

Date	Noon position		Day's run	Current		Remarks (Local mean time used throughout)
	Latitude	Longitude east		Dir.	Am't.	
1929	° ′	° ′	miles	°	miles	
Mar. 29	15 16 S	196 40	79	270	4	Cloudiness 2 to 4, chiefly on horizons. Calm to light variable airs. Smooth sea. Engine running.
30	14 42 S	194 20	139	341	6	Cloudiness 3 to 6, with rain squalls in afternoon. Calm, or light variable airs. Smooth sea. Engine running.
31	14 41 S	192 07	129	294	2	Cloudiness 5 to 8 until late evening, then cloudiness 2. Rain squalls in early evening. Calm in early morning, changing to light and gentle northerly breezes in forenoon and, in afternoon, to light westerly breezes. Smooth sea. Engine running.
Apr. 1	14 26 S	189 58	125	233	8	Sighted Manua Islands at 03h 00m. Cloudiness 3 to 6. Light to gentle northwesterly breezes. Smooth sea. Engine running.
1	Pago Pago		40	....	....	At anchor in Pago Pago harbor at 19h 33m.

Pago Pago, Samoa to Apia, Western Samoa

Date	Latitude	Longitude east	Day's run	Dir.	Am't.	Remarks
1929	° ′	° ′	miles	°	miles	
Apr. 5	Pago Pago		....	....	....	Left Pago Pago harbor under own power at 14h 10m. Light SW to W breezes until evening, then calm. Moderate to smooth sea. Cloudiness 3 to 4, chiefly on horizons. Engine running.
6	Apia		80	....	....	Cloudiness 3. Hazy. Light W airs, to calm. Smooth sea. Engine running. At anchor in Apia harbor at 08h 15m.

Apia, Western Samoa to Guam, Marianas Islands

Total distance, 3914 miles; time of passage, 28.8 days; average day's run, 135.9 miles

Date	Latitude	Longitude east	Day's run	Dir.	Am't.	Remarks
1929	° ′	° ′	miles	°	miles	
Apr. 20	Apia		....	....	....	Let go moorings in Apia harbor at 11h 25m. Took departure at 11h 35m. Shut down engine at 13h 13m. Cloudiness 6 to 4. Light northwesterly breeze in early afternoon, changing through calm to light northeasterly airs and breezes in late afternoon and evening. Smooth sea.
21	13 07 S	188 12	42	312	8	Cloudiness 4 to 6. Gentle easterly breeze. Smooth to moderate sea. Found two stowaways on board at 08h 00m. Returned to Apia and transferred stowaways to harbor tug at 18h 45m.
22	12 44 S	188 23	25	260	9	Cloudiness 3 in very early morning on horizons, increasing to 8 by noon. Overcast in afternoon and until late evening. Gentle to moderate easterly breeze until mid-afternoon, then varying between moderate breeze and calm. Rain squalls in afternoon and evening. Hazy in late evening.
23	11 20 S	188 24	83	254	10	Cloudiness 5 to 7 in morning, 4 in afternoon, chiefly on horizons. Moderate to fresh E to SE breezes. Moderate sea.
24	8 40 S	188 57	164	321	21	Cloudiness 4 to 7 in morning, 2 to 5 in afternoon. Easterly breeze, moderate in morning, gentle to light in afternoon. Moderate sea until late evening, then smooth with easterly swells. Rain squalls at 11h 30m and 14h 00m.
25	7 39 S	188 11	76	272	16	Cloudiness 8 to 9 in morning, with occasional rain squalls before 06h 30m. Cloudiness 6 to 4 in afternoon and 10 in late evening, with rain squall at 21h 45m. Light northerly airs to calm in morning; light NE breeze in afternoon. Smooth sea. Easterly swells. Hazy and misty during day. Engine running.
26	6 44 S	187 35	65	244	17	Cloudiness 8 and 9 in morning and evening, 4 to 6 during day. Light northerly airs to calm. Smooth sea. Easterly swells. Squally in evening. Engine running.
27	5 08 S	187 37	96	194	11	Cloudiness 3 in early morning, 5 and 6 during day, 8 in evening. Calm in morning, light NW airs and breezes in afternoon, calm in evening. Smooth sea. Squally and hazy in mid-afternoon. Engine running.
28	3 47 S	187 19	83	260	14	Cloudless and calm until 05h 00m, thereafter cloudiness 4 and 3 and northeasterly breeze, increasing through day from light, in early morning, to moderate in evening. Smooth to moderate sea. Engine running.
29	1 46 S	186 31	130	272	16	Cloudiness 3 and 4, only on horizons, until noon, increasing after noon to 9 in late evening. Gentle to moderate E to NE breezes. Moderate sea. Rain squalls at 22h 50m and 23h 40m.
30	0 22 N	185 58	135	283	12	Cloudiness 4 in early morning, decreasing to cloudless in mid-afternoon, then increasing to overcast in late evening. Fresh to moderate E to NE breezes. Moderate sea.
May 1	2 30 N	184 54	144	336	10	Cloudiness 5 to 8 in morning, 4 thereafter. Gentle to moderate to fresh northeasterly breezes. Moderate to choppy sea. Rain squalls at intervals from early morning to late evening.
2	4 22 N	183 37	136	166	6	Cloudiness 4 in early morning, thereafter 8 to 10, with rain squalls during morning and heavy showers between 16h 00m and 18h 30m. Hazy all day. Fresh to moderate northeasterly breezes. Choppy sea.

Apia, Western Samoa to Guam, Marianas Islands--Concluded

Date	Noon position		Day's run	Current		Remarks (Local mean time used throughout)
	Latitude	Longitude east		Dir.	Am't.	
1929	° ′	° ′	miles	°	miles	
May 3	6 29 N	182 16	149	231	4	Cloudiness 8 to 10 until late evening, then 6. Squally in morning. Rain squalls at 13h 30m, 15h 32m, 20h 45m. Fresh to moderate NE breeze. Moderate and choppy sea.
4	8 10 N	181 07	122	258	10	Cloudiness very variable, ranging in amount from 4 to 9. Rain squalls at 14h 15m, 15h 00m, and 18h 15m. Moderate to fresh northeasterly breeze. Moderate sea. Hazy.
5	10 47 N	179 26	185	259	20	Cloudiness 6 in early morning, thereafter 4. Squall conditions all day, with rain squall at 16h 50m. Fresh to strong northeasterly breeze. Choppy sea.
6	....	....	....	....	....	Omitted, because the 180th meridian was crossed.
7	13 31 N	177 20	205	269	26	Cloudiness 3 to 6. Light rain at 04h 00m. Strong ENE breeze in early morning, changing during day through fresh to moderate in evening. Squally in afternoon. Hazy in evening. Choppy sea.
8	15 23 N	174 43	194	253	12	Cloudiness 3 to 4, chiefly on horizons, until noon, 9 in early afternoon, and 4 to 5 thereafter. Rain squall at 22h 10m. Moderate to fresh NE to ENE breezes. Moderate sea.
9	16 28 N	171 49	179	232	10	Cloudiness 5 to 3, chiefly on horizons. Fresh NExE and ENE breezes. Choppy, moderate sea. Squally in evening, with drizzling rain at 22h 10m. Hazy. NE swells.
10	18 29 N	169 00	202	215	13	Cloudiness 10 in early morning, clearing to 3 by mid-morning, clouding over to 8 before noon and clearing to 3 in late afternoon. Squally in early morning. Fresh to moderate NExE and ENE breeze. Choppy to moderate sea. Hazy in afternoon.
11	19 19 N	166 24	156	218	7	Cloudiness 2 to 4 in morning, 7 to 2 after noon, chiefly on horizons. Moderate ENE breeze. Moderate sea. Sighted Wake Island at 08h 00m. Hazy in early morning.
12	20 17 N	163 40	165	348	3	Cloudiness 3 to 10 up to noon and 6 to 3 thereafter. Moderate to gentle ENE and NExE breezes. Moderate sea. Light rain at 03h 05m and squally during morning.
13	20 13 N	161 08	142	244	12	Cloudiness 2 to 7 in morning and 4 to 2 in afternoon, chiefly on horizons. Moderate northeasterly breeze. Moderate sea.
14	19 30 N	158 27	158	292	12	Cloudiness 3 to 5, chiefly on horizons. Gentle to fresh ExS breeze. Moderate sea.
15	18 39 N	156 02	145	313	12	Cloudiness 4 to 9 during morning, 3 to 5 after noon, chiefly on horizons. Gentle to moderate ExS and SExS breezes. Moderate sea. Horizons hazy in early morning. Lightning in S in early morning. Rain squall at 10h 30m.
16	17 28 N	153 25	165	316	20	Cloudiness 1 in early morning, thereafter 5 to 6. Moderate ExS to SExS breezes. Moderate sea. Heavy rain at 23h 20m.
17	16 08 N	150 52	166	297	14	Cloudiness 5 to 9 except for few hours in mid-afternoon, when practically cloudless. Squally in very early morning. Moderate to fresh ExS to SE breezes. Moderate sea.
18	14 54 N	148 12	171	328	23	Cloudiness 2 in early morning; increasing amount of thin clouds to 9 by noon; thereafter cloudiness 8 to 10. Moderate ExS and E breezes. Moderate sea.
19	14 02 N	145 56	142	276	8	Cloudiness, chiefly on horizons, 3 to 8 in morning, 3 to 5 after noon. Moderate to gentle E breezes. Moderate sea. Sighted Rota Island at 09h 00m and Guam at 17h 00m. Hazy in morning and evening.
20	Port Apra, Guam		89	....	....	Cloudiness 3 in early morning. Light southeasterly breeze. Smooth sea. Started engine at 05h 50m outside Port Apra. Pilot aboard at 06h 00m. Moored in Port Apra at 08h 00m.

Port Apra, Guam to Yokohama, Japan

Total distance, 1447 miles; time of passage, 13.2 days; average day's run, 109.6 miles

Date	Latitude	Longitude east	Day's run	Dir.	Am't.	Remarks
1929	° ′	° ′	miles	°	miles	
May 25	Port Apra		....	....	....	Let go moorings at 13h 45m, ran one mile under own power, and took departure at 14h 08m. Cloudiness 4 and 5, chiefly on horizons. Moderate ENE breeze. Moderate sea.
26	16 05 N	144 07	161	289	9	Cloudiness 2 to 5, chiefly on horizons, except in mid-afternoon, when cloudless. Moderate ENE to E breezes. Moderate sea. Rain at 01h 45m.
27	18 33 N	143 59	148	262	8	Cloudiness 6 to 1, chiefly on horizons. Moderate E breeze. Moderate sea. Drizzling rain at 04h 25m.
28	21 31 N	144 13	179	334	7	Cloudiness 1 to 5, chiefly on horizons. Moderate to gentle easterly breeze. Moderate to smooth sea.
29	23 26 N	144 05	115	323	10	Cloudiness 7 in very early morning, decreasing through day to 1 in late evening. Gentle to moderate E to SE breezes, until mid-afternoon, then southeasterly light breezes to light airs. Squally in early morning with rain at 00h 05m. Light dew in evening. Running with engine after 19h 23m.

Port Apra, Guam to Yokohama, Japan--Concluded

Date	Noon position		Day's run	Current		Remarks (Local mean time used throughout)
	Latitude	Longitude east		Dir.	Am't.	
1929	° ′	° ′	miles	°	miles	
May 30	25 15 N	144 09	109	228	15	Cloudiness, chiefly on horizons, 4 to 6 before noon, 3 to 4 after noon. Calm in very early morning, then light to gentle southeasterly breezes. Squally in early morning. Hazy in morning and evening. Smooth sea. Stopped engine at 07h 05m.
31	26 24 N	144 25	71	152	14	Cloudiness 4 to 8 until mid-afternoon, thereafter 2 on horizons. Gentle S breeze decreasing in force to light airs in afternoon and evening. Smooth sea. Heavy dew in morning, light in evening. Engine started 18h 00m.
June 1	28 29 N	144 00	127	298	3	Cloudiness 6 to 10. Light southerly breezes in early morning, increasing in force to strong in late evening. Smooth sea in morning, changing through day to rough in late evening. Heavy dew in morning. Rain at 23h 45m. Engine stopped 06h 00m.
2	30 10 N	143 56	101	132	14	Overcast before noon, thereafter cloudiness 7 to 9. Hazy all day. Fresh SWxW breeze until mid-morning, changing to moderate westerly breeze and decreasing in force through afternoon to calm in late evening. Choppy, moderate sea. Started engine midnight.
3	31 03 N	144 18	57	63	18	Cloudiness 8 to 10 until late evening, then 6. Very hazy all day. Light westerly airs in early morning, increasing in force to moderate in evening. Choppy, moderate sea. Northwesterly swells in early morning. Started engine at 12h 10m. Stopped engine 08h 00m.
4	32 42 N	142 13	145	307	21	Cloudiness 8 to 10 until late evening, then 5. Moderate to fresh southwesterly breezes. Choppy, moderate sea. Hazy all day. Southwesterly and westerly swells. Stopped engine at 05h 38m. Started engine at 15h 00m.
5	33 57 N	141 12	91	30	15	Cloudiness 4 in very early morning, thereafter 8 to 10. Gentle to moderate W to SW breezes. Moderate sea. Hazy all day. Westerly and northerly swells. Sighted Miyake Island at 18h 30m. Saw reflected ray from Nojima Zaki Lighthouse (SE Japan) during evening. Stopped engine at 15h 55m. Drizzling rain after 23h 06m, with rapidly falling barometer. Started engine at 17h 20m.
6	34 52 N	140 39	61	44	38	Overcast in morning, with drizzling rain in early morning; cloudiness decreasing after noon to 3 in evening. Moderate southerly breezes in early morning increasing in force to fresh gale by midday and decreasing to moderate breeze in evening. Rough sea. Stopped engine at 02h 00m, started at 04h 45m, stopped at 09h 45m and hove to on southern edge of typhoon.
7	Yokohama		82	....	....	Overcast all day, and hazy. Gentle to fresh NE breeze after 01h 30m. Moderate sea. Got under way with sails at 01h 35m. Started engine at 10h 55m and ran in to Yokohama harbor. Anchored outside breakwater at 19h 45m.

Yokohama, Japan to San Francisco, U.S.A.

Total distance, 4839 miles; time of passage, 34.9 days; average day's run, 138.7 miles

Date	Latitude	Longitude east	Day's run	Dir.	Am't.	Remarks
1929	° ′	° ′	miles	°	miles	
June 24	Yokohama		....	....	....	Took departure from Honmoku Buoy, Yokohama harbor, under own power, at noon and ran 33 miles to entrance to outer bay at 17h 50m. Overcast, hazy, rainsqualls. Gentle to moderate northeasterly breezes. Smooth to moderate sea. Easterly swells in late evening.
25	34 44 N	141 04	98	66	44	Overcast and drizzling in early hours, clearing to amount 7 by noon and to amount 4 by late evening. Hazy all day. Calm in early morning, changing to gentle easterly breezes before 06h 00m. Moderate sea.
26	36 00 N	142 05	91	47	42	Cloudiness 4 in early morning, increasing steadily to overcast by noon; thereafter overcast. Hazy throughout. Light ESE airs and breezes up to noon, thereafter light SSE breezes. Smooth sea. Heavy dew in morning, light dew in evening. Southeasterly swells.
27	36 41 N	143 38	85	33	9	Cloudiness 4 on horizons in early morning and late evening, otherwise overcast. Hazy throughout. Gentle to light SSE breezes during morning, changing through S to SSW by mid-afternoon. Light airs to calm after 15h 00m. Smooth sea. Swung ship for declination in afternoon.
28	36 46 N	145 23	85	237	4	Hazy throughout. Cloudiness 7 to 9 throughout. Heavy dew in early morning. Calm until 08h 00m, thereafter light easterly airs and breezes. Swung ship for horizontal intensity and inclination from 09h 00m to 19h 00m. Smooth sea.
29	37 45 N	145 27	59	294	18	Cloudiness 9 to 10 (overcast) throughout. Hazy after midday. Gentle easterly breezes until late afternoon; light airs to calm thereafter. Smooth sea. Started engine at 18h 57m.

Yokohama, Japan to San Francisco, U.S.A.--Continued

Date	Noon position		Day's run	Current		Remarks (Local mean time used throughout)
	Latitude	Longitude east		Dir.	Am't.	
1929	° ′	° ′	miles	°	miles	
June 30	38 06 N	147 00	76	98	9	Cloudiness 7 to 4 in morning; 7 to 10 thereafter. Hazy. Light southeasterly airs throughout, except for few hours gentle breeze in afternoon. Smooth to moderate sea. Southeasterly swells. Stopped engine at 12h 50m.
July 1	38 43 N	147 42	49	336	8	Cloudiness 2 to 6, chiefly on horizons. Slight haze in early morning. Light to gentle SE breezes. Moderate sea. Southeasterly swells in morning.
2	39 50 N	149 29	106	35	9	Cloudiness 9 in early morning, decreasing gradually to 3 in early evening, then increasing to 7 in late evening. Gentle to light southeasterly breezes. Moderate to smooth sea. Southeasterly swells in morning.
3	40 22 N	151 03	79	32	15	Cloudiness 7 to 9 during afternoon, otherwise overcast. Gentle southeasterly breezes. Smooth sea.
4	41 22 N	153 16	116	57	11	Overcast throughout. Misty and drizzling in evening. Gentle to moderate southeasterly breeze. Moderate sea.
5	42 35 N	155 33	126	309	9	Overcast throughout, with mist, fog, and drizzling rain. Moderate SExS breeze. Moderate sea.
6	43 45 N	158 12	135	355	7	Overcast throughout, with mist, fog, or drizzling rain. Gentle to moderate SSE breeze. Moderate sea.
7	45 30 N	159 40	122	14	9	Overcast throughout, with fog or drizzling rain. Gentle to moderate southerly breeze. Moderate sea.
8	46 56 N	162 58	161	35	9	Overcast throughout, with mist, fog, or drizzling rain. Moderate to gentle S and W breezes. Moderate sea.
9	47 02 N	166 34	148	153	8	Overcast throughout, with mist or fog. Moderate W breeze until evening, then light northwesterly breeze. Moderate sea.
10	46 43 N	169 27	120	185	8	Overcast throughout, with mist or haze. Moderate to gentle NNE breeze. Moderate sea. Northwesterly swells in evening.
11	46 00 N	171 41	103	235	10	Overcast throughout, with mist or fog. Moderate to gentle NNE to NE breezes. Moderate sea. Northwesterly swells in morning.
12	45 16 N	172 58	69	266	6	Overcast throughout, with thick fog. Gentle to light southeasterly breezes. Smooth sea. W and NW swells in morning, E to SE swells in afternoon.
13	46 22 N	174 08	82	5	9	Overcast throughout, with mist or thick fog. Light to gentle southeasterly breezes in morning, moderate to fresh southerly breeze after midday. Smooth to moderate and choppy sea. Rain during morning. Southeasterly swells in morning.
14	48 07 N	178 06	192	15	9	Overcast throughout, with mist, fog or rain. Fresh southerly breeze. Choppy sea.
14	49 14 N	183 20	218	18	13	Overcast throughout, with mist, thick fog, or rain. Strong to moderate SxW breezes. Choppy, rough sea.
15	50 32 N	187 18	172	63	7	Overcast throughout, with thick fog in morning; hazy thereafter. Fresh to strong SxE breeze. Moderate, choppy sea.
16	51 25 N	192 41	210	14	10	Overcast throughout; heavy mist in evening. Fresh to strong southerly breeze. Choppy sea.
17	52 22 N	198 14	214	26	8	Overcast throughout, with mist, fog, or haze. Strong SxE and S breeze. Choppy sea.
18	52 33 N	204 23	225	47	16	Overcast throughout, with thick fog or mist. Fresh S to SW breezes Choppy sea. Southwesterly swells.
19	51 57 N	209 35	195	116	7	Overcast throughout; drizzling rain in early morning, mist thereafter. Fresh SWxW breeze. Choppy sea. Southwesterly swells.
20	50 13 N	213 54	192	126	5	Overcast throughout; misty until evening, then drizzling rain. Fresh to strong SWxW and SW breeze. Choppy sea. Southwesterly swells.
21	47 59 N	217 17	189	299	13	Cloudiness 9 to 10 (overcast), misty and hazy. Strong SW to W breeze. Choppy sea. Westerly swell in afternoon.
22	45 58 N	220 15	171	311	14	Cloudiness 7 in morning, increasing to 10 (overcast) in evening. Rain in early morning and late evening. Moderate to fresh W to WSW breezes. Moderate sea.
23	44 16 N	222 25	137	295	10	Cloudiness 9 in early morning, decreasing to 4 by noon, remaining so until late evening, then increasing to 9. Drizzling rain at intervals up to 08h 00m, then hazy until noon. Clear after midday. Moderate WxS to WSW breezes. Moderate sea.
24	42 34 N	224 46	144	339	8	Overcast throughout, with rain at intervals throughout. Moderate to fresh SW to S breezes. Moderate sea.
25	40 39 N	227 39	173	283	11	Cloudiness 8 to 10 (overcast) in morning, overcast thereafter. Hazy during day. Drizzling rain and mist in evening. Fresh southerly winds to mid-day, moderate to gentle westerly thereafter. Moderate sea.
26	39 36 N	230 28	144	240	12	Cloudiness 7 just before midday, otherwise 9 to 10 (overcast). Drizzling rain and mist in early morning. Moderate to strong N breeze. Moderate to choppy sea. W swells in early morning.

Yokohama, Japan to San Francisco, U. S. A.--Concluded

Date	Noon position		Day's run	Current		Remarks (Local mean time used throughout)
	Latitude	Longitude east		Dir.	Am't.	
1929	° ′	° ′	miles	°	miles	
July 27	38 49 N	234 14	182	254	20	Cloudiness 6 to 9 until midday; overcast thereafter. Hazy in late evening. Strong NNW breeze in morning, decreasing in force through afternoon to light in evening. Choppy to moderate sea. Started engine at 21h 30m.
28	37 56 N	237 04	143	207	17	Overcast; haze and fog until noon. Light NNW airs to calm. Moderate to smooth sea. Heard Point Reyes fog signal at 08h 45m.
28	San Francisco		28	....	...	Entered San Francisco harbor at 16h 00m and dropped anchor at 16h 30m.

San Francisco, U. S. A. to Honolulu, T. H.

Total distance, 2186 miles; time of passage, 20.1 days; average day's run, 108.8 miles

Date	Latitude	Longitude east	Day's run	Dir.	Am't.	Remarks
1929	° ′	° ′	miles	°	miles	
Sep. 3	San Francisco		....	....	...	Took departure under own power from pier 16, San Francisco harbor at 10h 00m and streamed the log at 13h 45m, through the Golden Gate. Ran 12 miles to Bell No. 5 at 15h 18m, thence 64 miles to the noon position on Sep. 4. Smooth sea, easterly swells in the evening. Overcast and hazy all day. Calm to gentle breeze.
4	37 07 N	236 21	(76)	(330)	5	Smooth to moderate sea. NW swells. Light airs and light S breezes in forenoon and gentle W breezes in the afternoon and evening. Main engine stopped at 08h 00m, started at 13h 50m, and stopped again at 18h 10m.
5	35 30 N	235 02	116	294	23	Moderate sea all day with moderate NW breezes. Cloudiness 10 most of the day with a minimum of 5 at 16h 00m.
6	33 47 N	233 40	123	92	15	Moderate sea; gentle NW breezes. Light drizzle in morning and in late afternoon with the sky overcast much of the day.
7	32 25 N	232 08	112	155	12	Sea moderate in a.m. with NW swells, smooth thereafter. Light and gentle NW breezes. Sky overcast nearly all day.
8	31 36 N	231 13	68	121	8	Smooth sea; gentle NW breezes. Cloudiness 7 to 10. Started main engine at 12h 55m, stopped main engine at 20h 05m.
9	30 23 N	229 06	131	240	10	Sea smooth in morning with gentle NW breezes. Sea moderate with gentle to moderate NNE breezes in the afternoon. Sky partly cloudy.
10	29 19 N	227 27	107	70	11	Sea moderate with gentle to moderate NNE breezes. Sky partly cloudy.
11	28 12 N	225 40	114	198	1	Sea smooth with light to gentle N and NE breezes. Morning sky overcast, partly cloudy in afternoon.
12	27 44 N	224 33	66	234	4	Sea smooth. Light airs to light ExS breezes in morning; calm in afternoon. Sky overcast in morning, clear in afternoon. Main engine started at 11h 20m.
13	26 58 N	222 13	124	47	11	Sea smooth. Light SE airs. Sky clear in morning, partly clear in afternoon. Engine stopped 18h 45m.
14	26 40 N	220 52	75	280	13	Sea smooth. Light S breezes. Sky partly clear, a little rain at 06h 30m. Main engine started 00h 45m. Main engine stopped at 04h 45m, started at 19h 15m, then stopped at 23h 08m.
15	26 27 N	219 24	80	351	12	Sea smooth. Light S airs to gentle S breezes. Sky partly cloudy. Main engine started 04h 40m and stopped 10h 00m.
16	26 13 N	217 56	80	49	15	Smooth sea. Gentle SE breezes. Sky partly clear in morning, and partly overcast in the afternoon. Main engine started at 18h 50m.
17	25 07 N	216 22	108	34	10	Smooth sea in morning with light SE breeze. Moderate sea in the afternoon and evening with moderate NE breezes. Sky clear all day with horizon partly cloudy. Sky overcast in evening, rain at midnight. Stopped engine at 06h 45m.
18	24 02 N	214 26	124	24	15	Moderate sea, moderate NExN breezes. Rain at 01h 20m. Mostly clear near midday with horizon cloudy and partly clear in afternoon. Sky clear, horizon cloudy in evening.
19	23 21 N	211 18	177	76	10	Moderate sea, moderate NExE breezes in forenoon. Sky mostly overcast during afternoon, squally near midnight.
20	22 51 N	208 37	151	98	8	Moderate sea, moderate ExNE breezes in forenoon, moderate ExN breezes in afternoon. Partly cloudy with overhead clear most of the day.
21	22 16 N	206 23	129	54	15	Moderate sea, moderate ENE breezes during first part of morning with gentle breezes ExNE and NExE during the rest of the day. Horizon partly cloudy in the early morning and late evening with sky about half overcast during the day.
22	21 44 N	204 20	119	23	14	Sea moderate. Gentle ESE breezes in morning and gentle ExS breezes in the evening. Few drops of rain in early morning with squalls. Sky partly cloudy during the day.
23	Honolulu		106	....	...	Started engine at 07h 50m. In harbor at 10h 00m.

Honolulu, T. H. to Pago Pago, Samoa

Total distance, 5777 miles; time of passage, 47.2 days; average day's run, 122.2 miles

Date	Noon position		Day's run	Current		Remarks (Local mean time used throughout)
	Latitude	Longitude east		Dir.	Am't.	
1929	° ′	° ′	miles	°	miles	
Oct. 2	Honolulu harbor					Left the dock at 10h 00m assisted by tug. Left tug at 10h 25m and ran 14 miles to bearings at noon. Moderate sea with fresh ENE breeze. Cloudiness 6 to 10 with rain squalls in the evening.
2	21 16 N	201 54	(14)	....	...	
3	23 32 N	200 28	157	174	12	Moderate sea, moderate to fresh ENE breezes in morning, fresh E breezes first part of the afternoon and moderate NExE breezes in the evening. Horizons cloudy, overhead clear during the morning and rain squalls at 16h 00m.
4	26 26 N	199 28	182	198	16	Moderate sea and fresh ENE breezes. Few drops of rain at 15h 24m. Cloudiness 4 to 5, overhead clear during the morning; cloudiness diminished to 3 by evening and to 2 by 24h 00m.
5	29 08 N	198 46	165	220	12	Moderate sea. Moderate to fresh ENE breezes. Cloudiness 3 to 5 during the morning, with the sky about half overcast in the afternoon and a few drops of rain at 13h 30m and at 16h 18m. The sky was partly cloudy in the evening.
6	31 42 N	199 00	154	214	13	Moderate sea during the day; smooth sea in the evening. Moderate to gentle E breezes in a.m. and gentle to light E breezes in p.m. The sky was more than half overcast all day.
7	32 46 N	199 16	64	324	8	Smooth sea with swells. Light E breezes and light E airs in a.m. and light NExE airs and light NE breezes in the afternoon and evening. Sky clear in early morning, cloudiness 3 to 4 during the day and squally near midnight. Started the engine at 11h 18m.
8	34 16 N	200 02	98	230	10	Smooth sea during the day with moderate sea in the evening. Light NE breezes and NE airs and gentle ExS breezes in the forenoon, with light to gentle SE breezes in the afternoon and moderate to fresh SW breezes in the evening. Sky cloudy most of the day with a short drizzle at 18h 42m. Stopped engine at 11h 48m.
9	34 05 N	203 07	153	290	10	Sea moderate and choppy. Fresh to strong SW breezes during the day, with fresh to gentle NW breezes in the evening. The sky was overcast and squally all morning with a short rain squall at 06h 12m. Sky overcast during the afternoon with a little rain at about 17h 00m.
10	33 35 N	205 31	123	233	10	Sea smooth during the early morning, swells during the day, and moderate sea in the late evening. Gentle NW breezes to NW airs during the day with light S airs to gentle S breezes in the first part of the evening and gentle to moderate SxW breezes during the latter part of the evening. Engine started at 09h 00m, stopped at 20h 12m.
11	33 39 N	208 20	141	236	8	Sea moderate in a.m. and choppy in p.m. Moderate to fresh SW breezes all day. The sky was partly cloudy in the forenoon and mostly overcast in the afternoon with a little rain at about 18h 00m.
12	33 17 N	212 18	200	258	10	Sea choppy in a.m. and moderate in p.m. Strong to fresh SxW and SW breezes in a.m. with a moderate NW breeze in the first part of the afternoon; calm at 15h 00m. Gentle to moderate SW breezes during the rest of the day. The sky was overcast all day and there were occasional rains.
13	33 26 N	214 36	116	255	7	Moderate sea in a.m. and swells in p.m. Gentle to fresh NW breezes in a.m. with light NW, W, and WSW breezes in the afternoon and evening. The sky was overcast and squally in the morning, and partly cloudy for the rest of the day.
14	33 34 N	216 52	114	237	9	Moderate sea. Gentle and moderate SW breezes in a.m. with fresh SSW and SxW breezes in p.m. The sky was partly cloudy all day with a few drops of rain at 23h 30m.
15	31 48 N	219 15	161	330	18	Choppy sea. Fresh SW breezes in a.m. with breezes NW, NNW, NxE, and NExN, moderate to fresh during the rest of the day. The sky was partly cloudy in the a.m. and completely overcast in the afternoon and evening with rain from 12h 30m to 13h 00m and from 15h 30m to 16h 36m.
16	29 03 N	220 41	181	279	21	Sea moderate to choppy. Fresh NE breezes all day and light SW breezes in the evening. The sky was overcast and cloudy most of the day with a few drops of rain at 03h 30m and rain from 16h 30m to 17h 30m and a drizzle from 20h 30m to 21h 48m. Engine started at 18h 48m, stopped at 19h 42m, and started again at 20h 06m.
17	27 22 N	221 52	119	302	13	Moderate sea in the early morning and smooth sea the rest of the day. Light SSW and SxW breezes in a.m. with light S airs the first part of the afternoon and calms the rest of the day. The sky was mostly clear all day. Engine: stopped at 08h 00m and started again at 10h 42m.
18	26 01 N	222 54	98	313	7	Smooth sea all day. Calm in the early morning, variable light airs to light breezes from the SE quarter the rest of the morning and light ExS breezes in the afternoon with gentle ExS and ExN breezes in the evening. Engine stopped at 06h 36m.

Honolulu, T. H. to Pago Pago, Samoa--Continued

Date	Noon Position		Day's run	Current		Remarks (Local mean time used throughout)
	Latitude	Longitude east		Dir.	Am't.	
1929	° ′	° ′	miles	°	miles	
Oct. 19	24 57 N	222 15	373	334	16	Moderate sea. Gentle ESE breezes in a.m. and gentle to moderate ENE breezes in the afternoon. The sky was almost wholly overcast during the early morning hours, with rain squalls and rain from 02h 06m to 02h 18m, from 03h 06m to 03h 12m, and from 06 18m to 06h 42m. The sky partly cleared near midday but later became overcast. There was a drizzle from 15h 42m to 15h 48m and from 22h 42m to 22h 48m.
20	23 10 N	221 40	112	329	16	Moderate sea. Moderate ExS breezes most of the day. The sky was more than half overcast all day but the cloudiness decreased to 3 in the evening. There were frequent drizzles and rains in the early morning.
21	21 15 N	221 25	116	337	16	Moderate sea and gentle to moderate E breezes in a.m. and moderate breezes from the E, ExN, and ENE in the p.m. The cloudiness was about 8 all day.
22	18 18 N	221 59	180	306	21	Moderate sea in forenoon, choppy thereafter. Breezes: moderate to fresh from the E, ExN, ENE, and NExE. The sky was about half overcast most of the day.
23	16 11 N	222 55	138	306	29	Choppy and moderate sea. Moderate to fresh NExE breezes. The cloudiness was 10 in the early morning and the late evening with an average of 5 during the day.
24	13 34 N	223 19	159	296	24	Seas: choppy, moderate and broken. Breezes: moderate to fresh ExN, ENE, and NE until 13h 00m with light N airs in the afternoon and light SxW breezes in the evening. The sky was almost wholly overcast all day with a drizzle from 00h 12m to 01h 54m, a few drops of rain at 02h 00m and more rain from 18h 18m to 18h 30m. Engine: started at 17h 06m, stopped at 21h 48m, and started again at 23h 12m.
25	12 39 N	222 28	74	188	1	Sea smooth to moderate. In the forenoon there were light breezes variable from the SW quarter and light E airs and calms during the rest of the day. The sky was overcast nearly all day with frequent rains and squalls all day. Engine: stopped at 08h 00m and started at 13h 42m.
26	11 19 N	221 21	104	109	8	Smooth sea. Light NW airs to light NW breezes during the day and calms all evening. Engine: stopped at 08h 00m and started again at 13h 00m.
27	10 05 N	220 17	97	70	16	Smooth sea with light E airs and calms all day. The sky was mostly clear all day but there were rains between 16h 00m and 18h 00m and squalls near 24h 00m. Engine: stopped at 08h 00m and started again at 12h 00m.
28	8 36 N	219 16	107	95	34	Smooth sea. Variable light airs and light breezes from the SE quarter in the a.m. with variable light to gentle breezes from the NE quarter the rest of the day. The sky was about half overcast all day. Engine stopped at 08h 12m.
29	7 44 N	218 38	64	92	30	Smooth sea the first part of the day and moderate thereafter. Variable light to gentle E breezes all day. The sky was about 0.5 overcast all day with a little rain at 02h 42m and at 06h 54m.
30	7 03 N	217 29	80	75	32	Sea smooth to moderate. Variable light to gentle breezes from the SE quarter all morning increasing to moderate and fresh breezes from the same quarter and changeable light breezes from nearly all quarters during the evening. The sky was partly cloudy in the morning and mostly overcast in the afternoon with rains in the evening and a heavy rain from 22h 00m to 23h 00m.
31	6 43 N	216 39	54	72	19	Smooth sea with light SW and SE airs and calms during the forenoon and variable light airs to gentle breezes from the SE quarter in the afternoon. The sky was more than half overcast all day with rain from 00h 00m to 01h 12m and rain from 12h 24m to 12h 48m. Engine: started at 01h 12m, stopped at 02h 12m, and started at 03h 12m, and stopped again at 19h 30m.
Nov. 1	5 46 N	215 20	97	28	15	Sea smooth in a.m. and moderate in p.m. Breezes light to moderate from SE, SExE, and SxE in the morning and the first part of the afternoon and moderate SSE and SExE breezes all evening. The sky was mostly overcast nearly all day; there was a drizzle from 04h 48m to 04h 54m and rain from 09h 12m to 09h 30m and from 12h 48m to 14h 30m. The sky was partly clear in the evening.
2	4 52 N	213 13	137	53	12	Moderate sea with moderate SExS breezes. The sky was completly overcast most of the day.
3	4 18 N	210 44	152	16	32	Moderate sea all day and smooth sea all evening. Moderate SSE and SxE breezes all morning, calm all afternoon and most of the evening with light SExS airs near midnight. The sky was nearly all overcast all day but was partly clear in the evening. Engine started at 16h 00m.

Honolulu, T. H. to Pago Pago, Samoa--Concluded

Date	Noon position Latitude	Noon position Longitude east	Day's run	Current Dir.	Current Am't.	Remarks (Local mean time used throughout)
1929	° '	° '	miles	°	miles	
Nov. 4	3 02 N	210 12	82	13	13	Smooth sea in morning and moderate sea all evening. Light to gentle SExS breezes in a.m., and gentle to moderate SE breezes all afternoon and evening. The sky was partly overcast all day. Engine stopped at 08h 00m.
5	0 48 N	208 32	168	349	12	Moderate sea with moderate and fresh SExE and ESE breezes all day. The sky was mostly clear all day. Crossed the equator at about 18h 30m.
6	1 49 S	207 36	167	356	21	Moderate sea in early morning and choppy the rest of the day. Fresh ExS breezes in a.m. and fresh ExN and ENE breezes the rest of the day. The sky was partly overcast all day.
7	4 52 S	206 36	193	315	19	Moderate sea with moderate NE breezes. The sky was mostly clear in the morning and evening; but was partly cloudy near midday.
8	6 38 S	204 55	145	31	5	Moderate sea and moderate NE, NExE, E, and ENE breezes in the afternoon. The sky was mostly clear all day.
9	8 05 S	203 05	140	20	16	Moderate and gentle ENE, NNE, and NE breezes. The sky was partly cloudy all day.
10	9 00 S	201 56	87	116	8	Moderate sea in forenoon and smooth sea in the afternoon with gentle NE breezes most of the day. The sky was partly clear. Sighted Penrhyn Island at 05h 12m. At Penrhyn Island from 09h 48m to 18h 00m. Engine for short intervals 07h 30m to 18h 00m. Engine: started at 18h 12m and stopped at 19h 54m.
11	9 24 S	200 58	62	58	15	Smooth sea with gentle NE, N, ENE, and ExN breezes. The sky was partly clear most of the day.
12	10 24 S	198 56	135	22	15	Moderate sea in the morning and in the evening with smooth sea near midday, with moderate to gentle ExN, NE, and NNE breezes. The sky was mostly clear all day. Arrived at Tauhunu village Manahiki Island at 12h 24m and left the island at 17h 42m. Engine at intervals 12h 00m to 18h 00m.
13	10 58 S	198 02	63	126	13	Moderate sea almost all day with smooth sea in early morning and late evening. Light to gentle NExE breezes in the forenoon and moderate to light NNE breezes in the afternoon. The sky was about 0.5 overcast except near 08h 00m when it was completely overcast, with rain from 06h 12m to 07h 42m and from 09h 00m to 09h 12m.
14	11 35 S	196 36	92	95	13	Smooth sea with light NNE airs in the forenoon and calms in the afternoon. The sky was mostly clear. Started the engine at 08h 42m.
15	12 03 S	195 03	95	65	17	Smooth sea. Light S airs and light E breezes in the forenoon and light NE, SE, and S airs in the afternoon. The sky was mostly clear all day. Engine: stopped at 08h 00m and started again at 13h 48m.
16	12 50 S	193 01	128	30	10	Smooth sea with light SSE breezes and light S airs in the forenoon and calms most of the afternoon. The sky was almost wholly clear all day.
17	13 37 S	191 37	95	109	14	Smooth sea with calms and light SW, W, and WxN airs. The sky was mostly clear all day. Engine: stopped at 08h 00m and started again at 11h 48m.
18	14 13 S	189 34	124 (17)	56	13	Smooth sea with calms and light WNW airs to gentle WNW and NW breezes. The sky was mostly clear. Ran 17 miles from noon position to moorings in Pago Pago harbor at 15h 00m.

Note: Left Pago Pago for Apia about 15h 00m, Nov. 27, arriving at Apia about 08h 00m, Nov. 28. Under engine power all the way with head winds on first leaving Pago Pago, 80 miles.

V. DAILY ATMOSPHERIC-ELECTRIC RESULTS

EXPLANATORY NOTES AND COMMENTS

In accordance with procedures and instructions outlined in section II of this volume, observations were made each day, if weather permitted, of several atmospheric-electric elements. Generally, the observations were made between ten hours and fifteen hours local mean time and they required between one and two hours for completion. During the observing period note was made of the prevailing meteorological conditions. The elements observed were: Potential-gradient, positive and negative conductivity, small-ion concentration, nuclei concentration, and rate of ion production by penetrating radiations.

Potential-Gradient.--Only eye-reading measurements of potential-gradient were available for use in the present table up to July 10, 1928; thereafter, until August 14, 1928, recorder values were used for some days and eye-reading values for others. From August 14, 1928, for the balance of the table, recorder values have been given exclusively. Recorder values have the advantage of being obtainable from the photographic record for the exact period of time occupied in making the three sets (occasionally two) of measurements of conductivity and small-ion concentration which were obtained each day, and each recorder value of potential-gradient given in this table is a mean value for that period.

On some days the values of potential-gradient are omitted and the letter e inserted instead; this notation indicates that the ship's main engine was operating during the observing period, and that exhaust gases coming from the exhaust pipe near the water line under the stern rail had affected the potential-gradient and given a spurious value that could not be used. Inspection of the photographic records indicated when this effect was present; on many occasions no effect from the exhaust gases could be noted. Apparently the wind, on these latter occasions, would blow sufficiently strongly across the stern of the ship to carry the exhaust gases away so rapidly that no effect would be produced.

Conductivity and Small-Ion Concentration.--The daily observations of conductivity consisted generally of two measurements of conductivity of one sign separated by one measurement of the conductivity of opposite sign. On occasions when diurnal-variation observations were made over a twenty-four-hour period, however, the program consisted of one measurement of a given sign of conductivity, followed by twenty-four measurements of opposite sign, and one final measurement of the original sign. On these occasions therefore, there were two instead of three measurements available for inclusion in the present table, the beginning and ending pairs of measurements being used to represent two successive days. Observations of small-ion concentration were made simultaneously with the conductivity measurements on all possible occasions, but rain, mist, and spray interrupted the small-ion measurements much more frequently than they did the conductivity measurements and the small-ion data are less complete. Care was taken to insure that the concentration of ions measured was of the same sign as the conductivity being measured at any given time. From these simultaneous measurements the ionic mobility was computed.

Computed Small-Ion Mobility.--The computed mobility values in this table are found to be reasonably consistent up to October 16, 1929. From this date until November 6, 1929, numerous high values are encountered. Careful examination of the observational data has failed to disclose a reason for the high values of this period. High values of mobility similarly are found in the last two sets of diurnal-variation data in the table in section VI. These two sets were obtained October 21-22, 1929, and November 4-5, 1929, both of which occasions are within the period just mentioned.

Computed Air-Earth Current Density.--From the conductivity measurements and simultaneous values of potential gradient, values of air-earth current density have been computed and included in this table. The values range, in general, between 5.0 and 15.0×10^{-7} esu but there is a considerable group of very low values for the period August 11 to August 24, 1928. After September 3, 1929, when only one sign of conductivity was measured each day, the other sign was computed from the relation $\lambda_+/\lambda_- = 1.10$, and this computed value used in the computation of air-earth current density.

Penetrating Radiation Data.--Values of ion-pairs produced per cubic centimeter per second in penetrating radiation apparatus 1 during each daily observing period of approximately one hour, are tabulated as measured, no correction being made for residual ionization. Inspection of the tabulated values indicates that the residual ionization probably is nearer one ion-pair per cubic centimeter per second than two.

Meteorological Data.--For brevity, various conventional symbols are used in presenting the meteorological data, as follows.

Cloud Types	
cirrus	ci
cirrocumulus	cicu
cirrostratus	cist
altocumulus	acu
altostratus	ast
cumulus	cu
fractocumulus	frcu
stratocumulus	stcu
stratus	st
cumulonimbus	cunb
nimbus	nb
nimbostratus	nbst

Wind Force (Beaufort)	
0	calm
1	light air
2	light breeze
3	gentle breeze
4	moderate breeze
5	fresh breeze
6	strong breeze
7	moderate gale
8	fresh gale
9	strong gale
10	whole gale
11	storm
12	hurricane

Weather Notes

d	drizzling	q	squalls or squally
f	fog	r	rain
h	hail	s	spray
l	lightning	t	thunder
m	mist	z	haze
p	passing showers		

Cloud amount on scale of 0 for cloudless to 10 for overcast.

Visibility on scale of 1 for poor visibility, with noticeably hazy or smoky air, to 3 for good visibility with air very clear. Visibility 2 represents conditions not poor enough for the former nor good enough for the latter.

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient Volts	Potential-gradient Sail position	Potential-gradient V/m	Conductivity λ_+ (in 10^{-4} esu)	Conductivity λ_- (in 10^{-4} esu)	Small ions n_+ (per cc)	Small ions n_- (per cc)	Mobility k_+ (cm/s/v/cm)	Mobility k_- (cm/s/v/cm)
1928		Atlantic Ocean											
May 11	18.7	13.8	37.3 N	286.4	50	MUBP	165	.....	.....	....	....	.....	.....
12	22.2	17.6	38.1 N	292.6	...	....	....	0.44	.....	....	....	.....	.....
13	14.3	10.0	37.7 N	296.5	...	....	....	.....	.....	....	324	.....	.....
14	13.2	9.1	37.1 N	299.4	...	....	....	.....	0.73	....	....	.....	.....
14	14.0	9.9	37.1 N	299.4	...	....	....	0.51	.....	....	....	.....	.....
14	14.7	10.7	37.1 N	299.4	...	....	....	.....	0.85	....	....	.....	.....
14	16.0	12.0	37.0 N	299.7	...	....	....	.....	.....	....	....	.....	.....
15	13.3	9.5	36.9 N	303.0	...	....	....	.....	.....	....	....	.....	.....
15	14.2	10.4	37.0 N	303.3	...	....	....	.....	0.92	....	....	.....	.....
15	14.7	11.0	37.0 N	303.3	...	....	....	1.39	.....	....	....	.....	.....
15	15.3	11.5	37.0 N	303.3	...	....	....	.....	0.97	....	....	.....	.....
16	18.4	14.9	37.9 N	307.2	...	....	....	1.35	.....	608	....	1.52	.....
16	18.6	15.1	37.9 N	307.2	40	MUBS	132	.....	1.27	....	681	.....	1.30
16	20.5	17.0	37.9 N	307.7	46	MUBS	152	.....	.....	....	....	.....	.....
17	10.0	6.6	38.1 N	309.7	30	MUBS	99	.....	.....	....	....	.....	.....
17	13.4	10.1	38.2 N	310.2	...	....	....	.....	0.98	....	464	.....	1.47
17	13.8	10.5	38.2 N	310.2	...	....	....	.....	.....	607	....	.....	.....
17	14.1	10.8	38.2 N	310.2	...	....	....	1.34	.....	589	....	1.57	.....
18	12.5	9.5	39.1 N	314.3	...	....	....	.....	1.01	....	437	.....	1.60
18	12.8	9.8	39.1 N	314.3	...	....	....	1.05	.....	611	....	1.19	.....
18	13.2	10.1	39.1 N	314.3	...	....	....	.....	0.97	....	438	.....	1.54
19	12.2	9.4	40.4 N	317.8	...	....	....	.....	.....	....	....	.....	.....
19	16.6	13.8	40.8 N	318.5	...	....	....	0.59	.....	270	....	1.51	.....
19	17.2	14.4	40.8 N	318.5	...	....	....	.....	0.46	....	186	.....	1.72
19	17.8	15.1	40.8 N	318.5	...	....	....	0.62	.....	309	....	1.39	.....
20	11.3	8.7	41.9 N	321.1	42	MUBP	139	.....	.....	....	....	.....	.....
20	12.6	10.0	41.9 N	321.1	...	....	....	.....	0.49	....	249	.....	1.36
20	13.0	10.4	41.9 N	321.1	...	....	....	0.65	.....	275	....	1.64	.....
20	13.5	10.9	41.9 N	321.1	...	....	....	.....	0.50	....	265	.....	1.31
20	14.4	11.8	41.9 N	321.1	...	....	....	.....	.....	....	....	.....	.....
21	16.8	14.4	44.1 N	324.0	34	MUBP	112	.....	.....	....	....	.....	.....
21	17.8	15.5	44.1 N	324.2	...	....	....	.....	.....	....	....	.....	.....
21	18.5	16.1	44.1 N	324.3	...	....	....	1.36	.....	613	....	1.54	.....
21	18.8	16.4	44.1 N	324.3	...	....	....	.....	0.92	....	376	.....	1.70
21	19.1	16.7	44.1 N	324.3	...	....	....	1.23	.....	546	....	1.56	.....
21	19.7	17.3	44.2 N	324.4	...	....	....	.....	.....	....	....	.....	.....
22	11.6	9.3	45.5 N	326.7	...	....	....	.....	.....	....	....	.....	.....
22	11.7	9.4	45.5 N	326.7	...	....	....	.....	.....	....	....	.....	.....
22	11.8	9.5	45.5 N	326.7	...	....	....	.....	.....	....	....	.....	.....
22	12.7	10.4	45.4 N	326.5	41	MUBP	135	.....	.....	....	....	.....	.....
22	13.2	11.0	45.4 N	326.5	...	....	....	.....	0.80	....	392	.....	1.42
22	13.6	11.4	45.4 N	326.5	...	....	....	0.93	.....	562	....	1.15	.....
22	14.0	11.8	45.4 N	326.5	...	....	....	.....	0.74	....	372	.....	1.38
22	14.3	12.1	45.5 N	326.7	55	MUBP	182	.....	.....	....	....	.....	.....
22	15.6	13.4	45.6 N	327.0	...	....	....	.....	.....	....	....	.....	.....
22	16.3	14.1	45.6 N	327.0	...	....	....	.....	.....	....	....	.....	.....
22	18.8	16.6	45.8 N	327.2	...	....	....	.....	.....	....	....	.....	.....
22	20.3	18.1	45.8 N	327.2	...	....	....	.....	.....	....	....	.....	.....
23	10.3	8.2	44.8 N	326.9	...	....	....	.....	.....	....	....	.....	.....
25	10.2	8.2	43.3 N	328.4	...	....	....	.....	.....	....	....	.....	.....
25	12.2	10.2	43.2 N	328.5	...	....	....	.....	.....	....	....	.....	.....
25	16.6	14.6	43.4 N	329.9	...	....	....	.....	.....	....	....	.....	.....
25	17.5	15.5	43.4 N	329.9	...	....	....	.....	.....	....	....	.....	.....
25	18.5	16.5	43.4 N	329.9	...	....	....	.....	.....	....	....	.....	.....
25	21.7	19.7	43.4 N	329.9	...	....	....	.....	.....	483	....	.....	.....
25	22.3	20.3	43.4 N	329.9	...	....	....	.....	.....	496	....	.....	.....
25	22.8	20.8	43.4 N	329.9	...	....	....	.....	.....	506	....	.....	.....
25	23.6	21.6	43.4 N	329.9	...	....	....	0.48	.....	....	....	.....	.....
25	0.4	22.4	43.4 N	329.9	...	....	....	0.47	.....	....	....	.....	.....
25	1.0	23.0	43.4 N	329.9	...	....	....	0.47	.....	....	....	.....	.....
26	10.3	8.4	44.0 N	331.6	...	....	....	.....	.....	....	....	.....	.....
26	10.9	9.0	43.9 N	331.3	32	MUBS	106	.....	.....	....	....	.....	.....
26	16.9	15.0	44.1 N	332.0	...	....	....	.....	.....	....	....	.....	.....
26	18.6	16.8	44.2 N	332.2	46	MUBS	152	.....	.....	....	....	.....	.....
27	10.2	8.5	45.5 N	334.1	...	....	....	.....	.....	....	....	.....	.....
27	10.5	8.8	45.6 N	334.2	32	MUBS	106	.....	.....	....	....	.....	.....
27	11.0	9.3	45.7 N	334.3	...	....	....	.....	0.72	....	....	.....	.....
27	11.5	9.8	45.7 N	334.3	...	....	....	0.75	.....	....	....	.....	.....
27	12.1	10.3	45.7 N	334.3	...	....	....	.....	0.65	....	....	.....	.....
27	12.5	10.8	45.7 N	334.3	36	MUBS	119	.....	.....	....	....	.....	.....

observations on the Carnegie, cruise VII, 1928-1929

Air-earth current density i, in 10^{-7} esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	r
.....	......	.....	.....	...	....	...	..	....	..	r
.....	......	.....	.....	...	....	...	..	....	..	r
.....	......	3.62[a]	.....	...	....	...	..	....	..	.....
.....	......	4.63	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	s
.....	......	.....	.....	...	....	...	..	....	..	s
.....	......	.....	.....	...	....	...	..	....	..	s
.....	......	.....	.....	...	....	...	..	....	..	.....
11.5	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	3.07	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	3.27	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	2.96	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	1560	.....	16.4	82	SE	2	2	ci-acu	2	.....
.....	1700	.....	15.5	91	ESE	2	5	cist-acu	2	.....
.....	780	.....	15.5	91	ESE	2	5	cist-acu	2	.....
.....	1630	.....	15.5	91	ESE	2	5	cist-acu	2	z
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
9.0	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	630	.....	17.5	80	ESE	3	5	cist	2	.....
.....	......	2.60	.....	...	....	...	..	....	..	.....
.....	630	.....	17.0	81	ESE	1	8	stcu	3	.....
.....	420	.....	14.9	94	S	2	9	stcu	3	.....
.....	940	.....	15.0	91	SE	3	10	nb	3	.....
.....	970	.....	13.9	67	E×S	3	9	cu-stcu	3	.....
.....	890	.....	14.3	66	NE	2	7	cu-cunb	3	.....
.....	......	3.42	.....	...	....	...	..	....	..	.....
.....	......	3.61	.....	...	....	...	..	....	..	.....
.....	......	3.68	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	1130	.....	13.6	68	NNW	1	7	frcu	3	p
.....	......	.....	.....	...	....	...	..	....	..	p
.....	1010	.....	16.0	65	NW	1	7	cist-stcu	3	p
.....	......	.....	.....	...	....	...	..	....	..	p
.....	740	.....	13.5	81	W	3	6	ci-cist	2	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
5.3	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient			Conductivity in 10^{-4} esu		Small ions per cc		Mobility cm/s/v/cm	
					Volts	Sail position	V/m	λ_+	λ_-	n_+	n_-	k_+	k_-
1928													
May 27	13.4	11.7	45.7 N	334.3	...	....	....	.....	.....	....	....	.....	.....
28	11.6	10.2	48.1 N	338.6	...	....	....	0.96	.....	398	....	1.67	.....
28	12.0	10.6	48.1 N	338.6	...	....	....	.....	0.85	....	453	.....	1.30
28	12.4	11.0	48.1 N	338.6	...	....	....	0.90	.....	429	....	1.46	.....
28	13.2	11.8	48.1 N	338.6	...	....	....	.....	.....	....	....	.....	.....
29	10.7	9.5	48.8 N	340.7	...	....	....	.....	.....	....	....	.....	.....
29	16.0	14.8	48.9 N	341.5	...	....	....	.....	.....	....	....	.....	.....
29	17.8	16.6	48.9 N	342.0	...	....	....	.....	0.77	....	394	.....	1.36
29	18.2	17.0	48.9 N	342.0	...	....	....	1.04	.....	539	....	1.34	.....
29	18.6	17.5	48.9 N	342.0	...	....	....	.....	0.50	....	252	.....	1.38
30	6.7	5.6	49.3 N	343.5	...	....	....	.....	.....	....	....	.....	.....
30	15.7	14.7	49.8 N	344.9	...	....	....	0.52	.....	....	....	.....	.....
30	16.3	15.3	49.8 N	344.9	...	....	....	.....	0.37	....	....	.....	.....
30	17.0	16.0	49.8 N	344.9	...	....	....	0.36	.....	....	....	.....	.....
31	10.5	9.6	50.4 N	346.5	...	....	....	.....	.....	....	....	.....	.....
June 1	8.7	7.8	50.1 N	346.8	...	....	....	.....	.....	....	....	.....	.....
2	9.0	8.2	49.4 N	347.8	...	....	....	.....	.....	....	....	.....	.....
2	10.6	9.8	49.5 N	347.9	...	....	....	.....	0.19	....	82	.....	1.61
2	11.3	10.5	49.5 N	347.9	...	....	....	0.21	.....	93	....	1.57	.....
2	12.1	11.3	49.5 N	347.9	...	....	....	.....	0.14	....	110	.....	0.88
2	12.8	11.9	49.5 N	347.9	...	....	....	.....	.....	....	....	.....	.....
4	9.1	8.2	50.4 N	347.5	...	....	....	.....	.....	....	....	.....	.....
4	11.7	10.9	50.3 N	347.9	...	....	....	0.27	.....	....	....	.....	.....
4	12.3	11.5	50.3 N	347.9	...	....	....	.....	0.22	....	....	.....	.....
4	12.9	12.1	50.3 N	347.9	...	....	....	0.24	.....	....	....	.....	.....
4	16.7	16.0	50.0 N	348.4	...	....	....	.....	.....	....	....	.....	.....
5	9.1	8.2	50.1 N	348.7	...	....	....	.....	.....	....	....	.....	.....
5	11.5	10.7	49.9 N	348.8	...	....	....	.....	0.64	....	337	.....	1.32
5	12.0	11.3	49.9 N	348.8	...	....	....	0.74	.....	313	....	1.64	.....
5	12.5	11.8	49.9 N	348.8	...	....	....	.....	0.59	....	291	.....	1.41
5	12.9	12.2	49.9 N	348.8	50	MUBS	132	.....	.....	....	....	.....	.....
6	10.9	10.2	50.2 N	349.9	...	....	....	0.80	.....	388	....	1.43	.....
6	11.5	10.8	50.2 N	349.9	...	....	....	.....	0.67	....	311	.....	1.50
6	11.9	11.2	50.2 N	349.9	...	....	....	0.82	.....	349	....	1.63	.....
6	12.6	11.9	50.2 N	349.9	35	MUBS	116	.....	.....	....	....	.....	.....
6	17.1	16.5	50.4 N	350.7	...	....	....	.....	.....	....	....	.....	.....
6	17.5	16.9	50.4 N	350.7	...	....	....	.....	.....	....	....	.....	.....
7	9.5	8.9	50.3 N	351.9	...	....	....	.....	.....	....	....	.....	.....
7	11.8	11.2	50.2 N	352.0	...	....	....	.....	0.48	....	383	.....	0.87
7	12.2	11.6	50.2 N	352.0	...	....	....	0.61	.....	423	....	1.00	.....
7	12.6	12.1	50.2 N	352.0	...	....	....	.....	0.45	....	328	.....	0.95
7	15.5	15.0	50.1 N	352.5	...	....	....	.....	.....	....	....	.....	.....
7	16.3	15.8	50.1 N	352.6	20	MUBP	66	.....	.....	....	....	.....	.....
7	16.8	16.3	50.1 N	352.6	...	....	....	.....	.....	....	....	.....	.....
8	8.8	8.4	49.9 N	354.5	...	....	....	.....	.....	....	....	.....	.....
July 8	10.4	10.9	54.1 N	7.7	...	....	....	.....	.....	....	....	.....	.....
8	13.7	14.2	54.2 N	7.5	...	....	....	.....	.....	....	....	.....	.....
8	19.3	19.8	54.5 N	7.0	...	....	....	.....	.....	....	....	.....	.....
9	9.4	9.7	55.3 N	5.3	...	....	....	.....	.....	....	....	.....	.....
9	13.0	13.3	55.4 N	5.1	...	....	....	.....	.....	....	....	.....	.....
9	17.2	17.5	55.8 N	4.6	...	....	....	.....	.....	....	....	.....	.....
9	18.7	19.0	55.9 N	4.5	...	....	....	.....	.....	....	....	.....	.....
10	8.1	8.3	57.6 N	2.9	...	....	....	.....	.....	....	....	.....	.....
10	10.2	10.4	57.8 N	2.6	...	....	....	.....	0.42	....	168	.....	1.74
10	10.7	10.9	57.8 N	2.6	107	MUBS	353	0.54	.....	236	....	1.59	.....
10	11.2	11.4	57.8 N	2.6	97	MUBS	320	.....	0.41	....	185	.....	1.54
10	11.9	12.1	57.8 N	2.6	107	MUBS	353	.....	.....	....	....	.....	.....
11	8.2	8.2	60.1 N	0.9	...	....	....	.....	.....	....	....	.....	.....
11	10.8	10.8	60.4 N	0.6	...	....	....	.....	.....	....	....	.....	.....
11	13.6	13.6	60.6 N	0.1	...	....	....	.....	.....	....	....	.....	.....
11	14.4	14.4	60.8 N	359.8	...	....	....	0.36	.....	168	....	1.49	.....
11	15.0	15.0	60.8 N	359.8	...	....	....	.....	0.53	....	214	.....	1.72
11	15.4	15.4	60.8 N	359.8	...	....	....	0.92	.....	391	....	1.64	.....
11	15.8	15.8	60,8 N	359.8	...	....	....	.....	0.64	....	348	.....	1.28
11	16.2	16.2	60.8 N	359.8	...	....	....	1.00	.....	486	....	1.43	.....
11	16.8	16.8	60.9 N	359.5	...	....	....	.....	.....	....	....	.....	.....
12	8.8	8.5	62.0 N	356.0	...	....	....	.....	.....	....	....	.....	.....
12	9.8	9.5	62.1 N	355.7	...	....	....	.....	.....	....	....	.....	.....

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10-7esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
.....	......	3.60	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	3.40	.....	...	....	...	..	....	..	.....
.....	1050	.....	14.2	89	SSE	3	2	ci	3	.....
.....	1470	.....	14.7	88	ESE	2	0	....	3	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	2.67	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	r
.....	......	.....	.....	...	....	...	..	....	..	r
.....	......	.....	.....	...	....	...	..	....	..	r
.....	900	.....	13.0	95	NE	1	10	st	1	p
.....	1140	.....	13.2	95	E	1	8	acu-st	2	m
.....	1850	.....	14.4	88	E	3	6	frcu	1	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	2.74	.....	...	....	...	..	....	..	.....
.....	5890	.....	12.6	98	ENE	3	10	st	1	m
.....	......	.....	.....	...	....	...	..	....	..	r
.....	......	.....	.....	...	....	...	..	....	..	r
.....	......	.....	.....	...	....	...	..	....	..	r
.....	......	2.39	.....	...	....	...	..	....	..	.....
.....	3120	.....	13.4	94	ESE	3	10	st	2	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	1420	.....	13.7	93	E	3	10	st	2	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	2.85	.....	...	....	...	..	....	..	.....
.....	1350	.....	14.0	90	S	2	8	frcu	2	.....
.....	1990	.....	14.4	89	E	1	7	frcu	2	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	1850	.....	14.2	92	SW×S	2	6	ci-cu	3	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	2.80	.....	...	....	...	..	....	..	.....
.....	1350	.....	13.3	86	WSW	4	4	ast	2	.....
.....	7540	.....	14.1	79	W×N	3	9	cu	2	.....
.....	9750	.....	14.8	83	W×S	2	0	....	2	.....
.....	3620	.....	15.0	90	W×S	3	0	....	2	.....
.....	......	2.91	.....	...	....	...	..	....	..	.....
.....	5400	.....	14.5	90	W	2	0	....	2	.....
.....	12480	.....	14.0	90	W	3	2	cu	2	.....
.....	14690	.....	13.6	89	W	4	8	cu-acu	2	.....
.....	2560	.....	12.0	91	W×S	4	7	cist	2	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
10.8	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	1350	.....	12.0	98	W×S	4	10	st	1	.....
.....	......	2.71	.....	...	....	...	..	....	..	.....
.....	8380	.....	11.6	94	W×S	4	9	st	1	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	1490	.....	13.0	90	W	3	9	stcu	2	.....
.....	1060	.....	10.1	98	WSW	5	8	ci-acu	2	.....
.....	......	2.97	.....	...	....	...	..	....	..	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Lati-tude °	Longi-tude east °	Potential-gradient Volts	Sail position	V/m	Conductivity λ+ (in 10^{-4} esu)	λ-	Small ions n+ (per cc)	n-	Mobility k+ (cm/s/v/cm)	k-
1928													
July 13	9.7	9.1	63.2 N	351.3	...	....	....	.....	.....	....	....	.....	.....
13	10.7	10.1	63.2 N	351.0	...	....	....	.....	0.99	....	440	.....	1.56
13	11.1	10.5	63.2 N	351.0	96[b]	MUBS	67	1.24	.....	609	....	1.41	.....
13	11.5	10.9	63.2 N	351.0	...	....	....	.....	1.01	....	517	.....	1.36
13	17.2	16.5	63.5 N	350.3	...	....	....	.....	.....	....	....	.....	.....
13	20.9	20.2	63.6 N	349.8	...	....	....	.....	.....	....	....	.....	.....
14	9.3	8.5	64.1 N	348.4	...	....	....	1.15	.....	574	....	1.39	.....
14	9.7	9.0	64.1 N	348.4	...	....	....	1.08	.....	....	....	.....	.....
14	10.2	9.4	64.1 N	348.4	...	....	....	1.07	.....	865	....	0.86	.....
14	10.6	9.9	64.1 N	348.4	...	....	....	.....	0.95	....	566	.....	1.16
14	11.1	10.3	64.1 N	348.4	...	....	....	1.03	.....	702	....	1.02	.....
14	12.2	11.4	64.1 N	348.4	...	....	....	.....	.....	....	....	.....	.....
14	18.2	17.3	63.9 N	347.2	...	....	....	.....	.....	....	....	.....	.....
14	9.3	8.3	63.5 N	345.3	...	....	....	.....	.....	....	....	.....	.....
15	9.8	8.8	63.5 N	345.3	...	....	....	.....	0.89	....	480	.....	1.29
15	10.3	9.3	63.5 N	345.3	...	....	....	0.94	.....	642	....	1.02	.....
15	10.7	9.7	63.5 N	345.3	...	....	....	.....	0.95	....	484	.....	1.36
15	16.7	15.7	63.4 N	344.8	...	....	....	.....	.....	....	....	.....	.....
15	17.6	16.6	63.4 N	344.6	...	....	....	.....	.....	....	....	.....	.....
15	22.2	21.1	63.3 N	344.1	...	....	....	.....	.....	....	....	.....	.....
15	22.5	21.4	63.3 N	344.1	...	....	....	.....	.....	....	....	.....	.....
16	10.7	9.6	63.4 N	342.8	...	....	....	.....	.....	....	....	.....	.....
17	10.1	8.9	62.9 N	342.1	...	....	....	.....	.....	....	....	.....	.....
17	17.7	16.5	62.7 N	341.1	...	....	....	0.71	.....	455	....	1.08	.....
17	18.4	17.1	62.7 N	341.1	...	....	....	.....	0.49	....	271	.....	1.25
17	19.1	17.8	62.7 N	341.1	...	....	....	0.84	.....	532	....	1.10	.....
17	19.3	18.0	62.7 N	341.1	...	....	....	.....	.....	....	....	.....	.....
18	9.9	8.6	62.8 N	340.2	...	....	....	.....	.....	....	....	.....	.....
18	10.7	9.4	62.6 N	340.1	...	....	....	.....	1.05	....	520	.....	1.40
18	11.1	9.8	62.6 N	340.1	25	MUBP	82	1.22	.....	611	....	1.39	.....
18	11.6	10.2	62.6 N	340.1	...	....	....	.....	1.15	....	547	.....	1.46
18	12.8	11.5	62.6 N	340.1	...	....	....	.....	.....	....	....	.....	.....
19	9.8	8.4	63.4 N	338.3	...	....	....	.....	.....	....	....	.....	.....
19	10.2	8.8	63.4 N	338.2	...	....	....	1.69	.....	820	....	1.43	.....
19	10.6	9.1	63.4 N	338.2	...	....	....	.....	1.51	....	704	.....	1.49
19	10.9	9.5	63.4 N	338.2	...	....	....	1.66	.....	854	....	1.35	.....
19	11.7	10.3	63.4 N	338.2	...	....	....	.....	.....	....	....	.....	.....
19	14.0	12.6	63.7 N	338.0	...	....	....	.....	.....	....	....	.....	.....
19	16.2	14.8	63.8 N	337.7	...	....	....	.....	.....	....	....	.....	.....
28	13.8	12.0	62.5 N	333.7	...	....	....	.....	.....	....	....	.....	.....
28	18.5	16.7	62.2 N	332.7	...	....	....	.....	0.67	....	285	.....	1.63
28	19.2	17.4	62.2 N	332.7	211[b]	MUBP	148	0.79	.....	432	....	1.27	.....
28	19.8	18.0	62.2 N	332.7	...	....	....	.....	0.58	....	276	.....	1.46
28	20.7	18.9	62.0 N	332.3	...	....	....	.....	.....	....	....	.....	.....
28	21.7	19.8	61.9 N	332.1	...	....	....	.....	.....	....	....	.....	.....
29	11.7	9.7	60.9 N	329.3	...	....	....	.....	.....	....	....	.....	.....
29	14.0	11.9	60.7 N	328.8	...	....	....	.....	.....	....	....	.....	.....
29	19.0	16.8	60.2 N	327.6	...	....	....	0.92	.....	472	....	1.36	.....
29	19.3	17.2	60.2 N	327.6	61	MUBP	201	.....	0.69	....	398	.....	1.20
29	19.6	17.5	60.2 N	327.6	...	....	....	0.94	.....	456	....	1.43	.....
29	22.7	20.5	60.0 N	326.9	...	....	....	.....	.....	....	....	.....	.....
30	12.9	10.6	59.3 N	325.8	...	....	....	.....	.....	....	....	.....	.....
30	16.2	13.9	58.8 N	326.0	29	MUBP	96	.....	.....	....	....	.....	.....
30	16.5	14.2	58.8 N	326.0	...	....	....	1.04	.....	600	....	1.20	.....
30	17.5	15.2	58.8 N	326.0	31	MUBP	102	1.10	.....	609	....	1.25	.....
30	18.5	16.2	58.8 N	326.0	27	MUBS	89	0.94	.....	405	....	1.61	.....
31	14.5	12.3	57.8 N	326.1	33	MUBP	109	1.09	.....	554	....	1.36	.....
31	15.6	13.3	57.8 N	326.1	32	MUBP	106	0.98	.....	517	....	1.31	.....
31	16.2	14.9	57.8 N	326.1	42	MUBP	139	.....	.....	....	....	.....	.....
31	18.9	16.6	57.8 N	326.1	...	....	....	.....	.....	....	....	.....	.....
Aug 1	16.3	13.9	58.4 N	324.0	...	....	....	.....	0.80	....	325	.....	1.71
1	16.7	14.3	58.4 N	324.0	53	MUBS	175	0.77	.....	322	....	1.66	.....
1	17.1	14.7	58.4 N	324.0	...	....	....	.....	0.57	....	224	.....	1.77
1	17.9	15.5	58.4 N	324.0	...	....	....	.....	.....	....	....	.....	.....
2	16.1	13.5	58.3 N	321.0	...	....	....	.....	.....	....	....	.....	.....
2	18.4	15.7	58.2 N	320.6	...	....	....	.....	.....	....	....	.....	.....
2	20.3	17.6	58.2 N	320.2	...	....	....	1.19	.....	663	....	1.25	.....
2	20.6	17.9	58.2 N	320.2	158[b]	MUBP	111	.....	0.85	....	500	.....	1.18

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10^{-7} esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
.....	2410	2.94	10.0	89	SW	5	3	ci-acu	2	s
.....	......	.....	.....	...	....	...	..	....	..	.....
5.0	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	1560	.....	10.8	91	W	6	7	frcu	2	s
.....	1210	.....	10.0	92	W×S	5	1	ci	2	s
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	r
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	2.41	.....	...	....	...	..	....	..	.....
.....	4830	.....	8.4	91	NE	1	10	st	2	.....
.....	6600	.....	11.3	84	CALM	0	1	ast	3	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	2410	.....	12.1	88	WSW	3	3	ci-acu	3	.....
.....	1060	3.30	11.0	91	WSW	3	9	stcu	3	.....
.....	2130	.....	10.9	91	WSW	3	8	stcu	3	.....
.....	1060	.....	10.9	91	WSW	3	9	stcu	2	.....
.....	2060	3.14	11.2	87	WSW	2	3	cu	2	.....
.....	......	3.30	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	3410	.....	12.0	87	NW	5	2	acu	2	.....
.....	1420	.....	10.8	94	NW×W	4	7	ci-cu	2	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
6.3	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	3.06	.....	...	....	...	..	....	..	.....
.....	200	.....	10.9	92	NW×N	4	8	ci-cu	2	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	3.24	.....	...	....	...	..	....	..	.....
.....	370	.....	11.0	96	NW×N	4	10	cu-nb	1	.....
.....	370	.....	11.2	90	NW×W	3	10	stcu	1	.....
.....	1920	.....	11.0	90	N	3	0	....	2	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
7.0	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	1560	.....	13.0	88	NNE	3	0	....	2	.....
.....	......	2.72	.....	...	....	...	..	....	..	.....
.....	990	.....	10.1	92	N	3	10	stcu	2	.....
.....	710	.....	10.5	92	N	3	9	stcu	2	.....
.....	......	.....	11.2	90	....	...	..	....	..	.....
10.9	......	.....	11.2	89	....	...	..	....	..	.....
.....	......	.....	11.1	88	....	...	..	....	..	.....
.....	840	2.73	10.3	95	N	3	9	stcu	2	.....
.....	1700	.....	10.2	93	N	2	8	stcu	2	.....
.....	......	.....	10.4	80	....	...	..	....	..	.....
.....	......	.....	10.4	80	....	...	..	....	..	.....
.....	......	3.25	10.6	81	....	...	..	....	..	.....
.....	......	.....	10.5	83	....	...	..	....	..	.....
.....	......	.....	12.0	81	....	...	..	....	..	.....
.....	......	3.22	12.4	80	....	...	..	....	..	.....
.....	......	.....	12.6	83	....	...	..	....	..	.....
.....	390	.....	11.2	88	WSW	3	10	st	1	.....
.....	......	.....	10.0	94	....	...	..	....	..	.....
8.5	......	.....	9.9	93	....	...	..	....	..	.....
.....	......	.....	9.8	91	....	...	..	....	..	.....
.....	......	3.06	9.2	92	....	...	..	....	..	.....
.....	4470	.....	11.1	72	SE×E	2	10	st	2	d
.....	......	2.64	11.2	84	....	...	..	....	..	.....
.....	......	.....	11.6	84	....	...	..	....	..	.....
7.1	......	.....	10.9	86	....	...	..	....	..	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient Volts	Sail position	V/m	Conductivity λ_+ (in 10^{-4} esu)	λ_-	Small ions n_+ (per cc)	n_-	Mobility k_+ (cm/s/v/cm)	k_-
1928													
Aug 2	20.9	18.2	58.2 N	320.2	....	....	....	0.96	.....	592	....	1.13	.....
3	17.4	14.3	57.5 N	313.8	....	....	....	.....	0.94	....	498	.....	1.31
3	17.7	14.6	57.5 N	313.8	187[b]	MDBP	131	1.00	.....	627	....	1.11	.....
3	17.9	14.8	57.5 N	313.8	....	....	....	.....	0.99	....	559	.....	1.23
3	18.9	15.9	57.7 N	313.8	....	....	....	.....	.....	....	....	.....	.....
3	20.7	17.6	57.2 N	313.4	....	....	....	.....	.....	....	....	.....	.....
4	15.5	12.2	54.5 N	311.0	....	....	....	.....	.....	....	....	.....	.....
4	17.1	13.8	54.2 N	310.8	....	....	....	1.01	.....	633	....	1.11	.....
4	17.4	14.1	54.2 N	310.8	154[b]	MDBS	108	.....	0.97	....	490	.....	1.37
4	17.6	14.4	54.2 N	310.8	....	....	....	1.07	.....	693	....	1.07	.....
4	20.4	17.1	53.7 N	310.7	....	....	....	.....	.....	....	....	.....	.....
5	16.9	13.6	51.3 N	310.6	....	....	....	.....	1.00	....	685	.....	1.01
5	17.2	13.9	51.3 N	310.6	39	MUBP	129	1.00	.....	816	....	0.85	.....
5	17.5	14.2	51.3 N	310.6	....	....	....	.....	0.95	....	639	.....	1.03
5	18.3	15.0	51.3 N	310.6	....	....	....	.....	.....	....	....	.....	.....
6	17.6	14.4	48.0 N	312.0	....	....	....	0.83	.....	631	....	0.91	.....
6	17.9	14.7	48.0 N	312.0	194[b]	MUBP	136	.....	0.68	....	424	.....	1.11
6	18.3	15.0	48.0 N	312.0	....	....	....	0.81	.....	566	....	0.99	.....
6	19.0	15.8	48.0 N	312.0	....	....	....	.....	.....	....	....	.....	.....
6	20.0	16.8	47.8 N	312.0	....	....	....	.....	.....	....	....	.....	.....
7	13.9	10.7	45.9 N	312.1	....	....	....	.....	0.69	....	422	.....	1.14
7	14.4	11.2	45.9 N	312.1	200[b]	MUBP	140	0.86	.....	524	....	1.14	.....
7	14.9	11.8	45.9 N	312.1	....	....	....	.....	0.60	....	417	.....	1.00
7	17.5	14.3	45.9 N	312.1	....	....	....	.....	.....	....	....	.....	.....
8	14.5	11.4	43.2 N	313.1	....	....	....	.....	0.98	....	420	.....	1.62
8	15.1	11.9	43.2 N	313.1	42	MUBP	139	0.95	.....	567	....	1.16	.....
8	15.6	12.4	43.2 N	313.1	....	....	....	.....	0.92	....	466	.....	1.37
9	18.2	15.1	41.9 N	312.4	....	....	....	1.04	.....	578	....	1.25	.....
9	18.6	15.4	41.9 N	312.4	42	MUBS	139	.....	1.00	....	491	.....	1.41
9	19.1	15.9	41.9 N	312.4	....	....	....	1.07	.....	548	....	1.36	.....
9	20.3	17.1	41.9 N	312.4	....	....	....	.....	.....	....	....	.....	.....
10	18.2	15.0	39.5 N	311.2	....	....	....	.....	0.68	....	459	.....	1.03
10	18.7	15.5	39.5 N	311.2	140[b]	MUBS	98	0.88	.....	613	....	1.00	.....
10	19.2	15.9	39.5 N	311.2	....	....	....	.....	0.68	....	486	.....	0.97
10	20.6	17.4	39.5 N	311.2	....	....	....	.....	.....	....	....	.....	.....
11	17.8	14.5	38.4 N	311.3	....	....	....	0.45	.....	407	....	0.77	.....
11	18.4	15.2	38.4 N	311.3	175[b]	MUBP	122	.....	0.41	....	336	.....	0.85
11	18.9	15.7	38.4 N	311.3	....	....	....	0.56	.....	455	....	0.85	.....
11	20.6	17.4	38.2 N	311.3	....	....	....	.....	.....	....	....	.....	.....
12	12.5	9.3	37.1 N	311.6	....	....	....	.....	0.25	....	223	.....	0.78
12	13.1	9.9	37.1 N	311.6	216[b]	MUBP	151	0.30	.....	239	....	0.87	.....
12	13.7	10.5	37.1 N	311.6	....	....	....	.....	0.21	....	179	.....	0.82
12	14.7	11.4	37.1 N	311.6	....	....	....	.....	.....	....	....	.....	.....
13	18.1	15.0	36.6 N	313.9	....	....	....	0.45	.....	510	....	0.61	.....
13	18.7	15.6	36.6 N	313.9	61	MUBP	201	.....	0.33	....	309	.....	0.74
13	19.2	16.1	36.6 N	313.9	....	....	....	0.47	.....	448	....	0.73	.....
13	20.4	17.4	36.4 N	314.0	....	....	....	.....	.....	....	....	.....	.....
14	13.6	10.6	35.3 N	315.5	....	....	....	.....	.....	....	....	.....	.....
14	18.3	15.4	35.0 N	316.0	....	....	....	.....	0.50	....	432	.....	0.80
14	18.6	15.7	35.0 N	316.0	172[c]	MUBP	120	0.68	.....	517	....	0.91	.....
14	19.0	16.1	35.0 N	316.0	....	....	....	.....	.....	....	....	.....	.....
16	18.0	15.2	30.7 N	318.9	....	....	....	0.62	.....	589	....	0.73	.....
16	18.5	15.7	30.7 N	318.9	173	MUBP	121	.....	0.46	....	463	.....	0.69
16	18.9	16.1	30.7 N	318.9	....	....	....	0.66	.....	575	....	0.80	.....
16	20.4	17.7	30.5 N	319.0	....	....	....	.....	.....	....	....	.....	.....
17	15.2	12.6	29.8 N	319.4	....	....	....	.....	0.66	....	362	.....	1.27
17	15.6	12.9	29.8 N	319.4	138	MUBS	97	0.83	.....	535	....	1.08	.....
17	18.2	15.5	29.6 N	319.5	....	....	....	.....	.....	....	....	.....	.....
18	14.7	12.1	27.9 N	320.5	108	MUBP	76	0.81	.....	438	....	1.28	.....
18	15.2	12.5	27.9 N	320.5	....	....	....	.....	0.70	....	331	.....	1.47
18	15.5	12.8	27.9 N	320.5	....	....	....	.....	.....	....	....	.....	.....
19	14.1	11.5	25.7 N	321.0	....	....	....	.....	.....	....	....	.....	.....
19	19.3	16.7	25.3 N	320.8	....	....	....	.....	0.66	....	351	.....	1.31
19	19.7	17.1	25.3 N	320.8	138	MUBS	97	0.75	.....	505	....	1.03	.....
19	20.1	17.4	25.3 N	320.8	....	....	....	.....	0.63	....	381	.....	1.15
21	18.9	16.3	21.3 N	320.5	....	....	....	.....	.....	....	....	.....	.....
21	19.5	16.9	21.3 N	320.5	....	....	....	.....	.....	....	....	.....	.....
21	21.8	19.2	20.8 N	320.8	....	....	....	0.66	.....	337	....	1.36	.....
21	22.2	19.6	20.8 N	320.8	....	....	....	.....	0.63	....	310	.....	1.41

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10^{-7} esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
.....	......	.....	10.9	86	....	...	..	....	..	.....
.....	......	.....	9.6	87	....	...	..	....	..	.....
8.6	......	.....	9.6	87	....	...	..	....	..	.....
.....	......	.....	9.6	87	....	...	..	....	..	.....
.....	......	2.50	9.6	87	....	...	..	....	..	.....
.....	3410	.....	9.2	73	ESE	6	8	ci-frcu	2	.....
.....	2130	.....	10.0	78	NE×E	5	8	cu	2	.....
.....	......	.....	10.4	81	....	...	..	....	..	.....
7.2	......	.....	10.4	81	....	...	..	....	..	.....
.....	......	.....	10.5	80	....	...	..	....	..	.....
.....	......	2.77	10.6	80	....	...	..	....	..	.....
.....	......	.....	10.2	80	....	...	..	....	..	.....
8.5	......	.....	10.0	82	....	...	..	....	..	.....
.....	......	.....	10.1	81	....	...	..	....	..	......
.....	6960	2.41	10.0	78	NW	3	1	acu	2	.....
.....	......	.....	11.5	84	....	...	..	....	..	.....
6.8	......	.....	11.4	84	....	...	..	....	..	.....
.....	......	.....	11.4	84	....	...	..	....	..	.....
.....	......	2.89	11.6	85	....	...	..	....	..	.....
.....	1850	.....	11.1	86	NW×W	3	1	acu	3	.....
.....	......	.....	12.7	86	....	...	..	....	..	.....
7.0	......	.....	12.8	85	....	...	..	....	..	.....
.....	......	.....	13.3	81	....	...	..	....	..	.....
.....	......	2.42	14.5	80	....	...	..	....	..	.....
.....	......	.....	15.6	84	....	...	..	....	..	.....
8.8	......	2.44	15.8	83	....	...	..	....	..	.....
.....	......	.....	16.1	81	....	...	..	....	..	.....
.....	......	.....	18.3	77	....	...	..	....	..	.....
9.5	......	.....	18.3	77	....	...	..	....	..	.....
.....	......	.....	18.4	77	....	...	..	....	..	.....
.....	750	2.52	18.7	76	SSE	2	1	ci	2	.....
.....	......	.....	24.4	82	....	...	..	....	..	.....
5.1	......	.....	24.4	83	....	...	..	....	..	.....
.....	......	.....	24.4	83	....	...	..	....	..	.....
.....	......	2.40	24.5	84	....	...	..	....	..	.....
.....	......	.....	26.3	82	....	...	..	....	..	.....
3.7	......	.....	26.5	81	....	...	..	....	..	.....
.....	480	.....	26.7	81	SW×W	3	1	acu	2	.....
.....	......	2.70	26.2	83	....	...	..	....	..	.....
.....	......	.....	26.2	82	....	...	..	....	..	.....
2.7	......	.....	26.5	80	....	...	..	....	..	d
.....	......	.....	26.6	80	....	...	..	....	..	.....
.....	640	2.43	27.1	83	SW	2	2	frcu	2	.....
.....	......	.....	27.0	84	....	...	..	....	..	.....
5.3	......	.....	27.0	84	....	...	..	....	..	.....
.....	......	.....	27.0	84	....	...	..	....	..	.....
.....	690	1.99	27.0	89	W×S	4	2	cist-cu	3	.....
.....	300	.....	26.9	86	SW	6	4	cu-cunb	3	.....
.....	......	.....	27.5	85	....	...	..	....	..	.....
4.7	......	.....	27.5	85	....	...	..	....	..	.....
.....	......	2.74	27.5	85	....	...	..	....	..	.....
.....	......	.....	28.2	83	....	...	..	....	..	.....
4.4	......	.....	28.2	83	....	...	..	....	..	.....
.....	......	.....	28.1	83	....	...	..	....	..	.....
.....	320	.....	27.6	88	NW	2	3	cu-cunb	2	.....
.....	......	.....	27.6	82	....	...	..	....	..	.....
4.8	......	.....	27.6	83	....	...	..	....	..	.....
.....	......	2.14	27.2	80	....	...	..	....	..	.....
3.8	......	.....	27.4	77	....	...	..	....	..	.....
.....	......	.....	27.2	77	....	...	..	....	..	.....
.....	......	2.03	27.1	77	....	...	..	....	..	.....
.....	1350	.....	27.1	76	S×E	2	2	cu-ast	3	.....
.....	......	.....	26.8	76	....	...	..	....	..	.....
4.5	......	.....	26.9	76	....	...	..	....	..	.....
.....	......	.....	26.9	76	....	...	..	....	..	.....
.....	......	2.78	26.7	75	....	...	..	....	..	.....
.....	800	.....	26.0	80	E×N	5	3	cu-cunb	3	.....
.....	......	.....	26.2	78	....	...	..	....	..	.....
.....	......	.....	26.2	77	....	...	..	....	..	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient Volts	Sail position	V/m	Conductivity λ_+ in 10^{-4} esu	λ_-	Small ions n_+ per cc	n_-	Mobility k_+ cm/s/v/cm	k_-
Aug 21	22.5	19.8	20.8 N	320.8	....	....	....	0.75	.....	330	....	1.58	.....
22	17.2	14.6	18.8 N	321.7	....	....	....	.....	0.76	....	507	.....	1.04
22	17.5	14.9	18.8 N	321.7	117	MUBS	82	0.97	.....	633	....	1.06	.....
22	17.8	15.2	18.8 N	321.7	....	....	....	.....	0.81	....	527	.....	1.07
22	18.9	16.3	18.8 N	321.7	....	....	....	.....	.....	....	....	.....	.....
22	19.3	16.7	18.8 N	321.7	....	....	....	.....	.....	....	....	.....	.....
23	16.9	14.4	16.3 N	322.1	....	....	....	0.56	.....	472	....	0.82	.....
23	17.9	15.4	16.3 N	322.1	128	MUBS	90	.....	0.60	....	358	.....	1.16
23	18.2	15.7	16.3 N	322.1	....	....	....	0.69	.....	483	....	0.99	.....
23	19.5	17.0	16.3 N	322.1	....	....	....	.....	.....	....	....	.....	.....
23	20.0	17.5	16.2 N	322.1	....	....	....	.....	.....	....	....	.....	.....
24	15.0	12.5	15.5 N	321.9	....	....	....	0.91	.....	587	....	1.08	.....
24	15.3	12.8	15.5 N	321.9	78	MUBP	55	.....	0.91	....	499	.....	1.27
24	15.7	13.2	15.5 N	321.9	....	....	....	.....	.....	....	....	.....	.....
24	17.3	14.8	15.5 N	321.9	....	....	....	.....	.....	....	....	.....	.....
25	13.4	10.9	15.0 N	321.8	....	....	....	.....	.....	....	....	.....	.....
25	14.0	11.5	14.9 N	321.8	....	....	....	.....	0.85	....	425	.....	1.39
25	14.3	11.8	14.9 N	321.8	121	MUBP	85	0.96	.....	534	....	1.25	.....
25	14.7	12.1	14.9 N	321.8	....	....	....	.....	.....	....	....	.....	.....
26	17.1	14.6	13.9 N	322.0	....	....	....	.....	.....	737	....	.....	.....
26	17.4	14.9	13.9 N	322.0	84	MUBP	59	.....	.....	....	597	.....	.....
26	17.7	15.2	13.9 N	322.0	....	....	....	.....	.....	746	....	.....	.....
26	18.7	16.2	13.9 N	322.0	....	....	....	.....	.....	....	....	.....	.....
27	17.1	14.6	13.4 N	322.0	....	....	....	.....	1.37	....	544	.....	1.75
27	17.6	15.0	13.4 N	322.0	178	MUBP	125	1.31	.....	634	....	1.43	.....
27	18.0	15.5	13.4 N	322.0	....	....	....	.....	1.24	....	468	.....	1.84
27	19.2	16.6	13.4 N	322.0	....	....	....	.....	.....	....	....	.....	.....
27	19.8	17.3	13.4 N	322.0	....	....	....	.....	.....	....	....	.....	.....
27	20.0	17.4	13.4 N	322.0	....	....	....	.....	.....	....	....	.....	.....
28	14.4	11.9	11.9 N	322.1	....	....	....	.....	.....	....	....	.....	.....
28	15.9	13.4	11.8 N	322.1	....	....	....	.....	.....	....	....	.....	.....
28	17.9	15.3	11.7 N	322.2	....	....	....	1.49	.....	716	....	1.44	.....
28	18.3	15.8	11.7 N	322.2	208	MUBP	146	.....	1.24	....	633	.....	1.36
28	18.7	16.2	11.7 N	322.2	....	....	....	1.55	.....	744	....	1.45	.....
28	20.1	17.6	11.7 N	322.2	....	....	....	.....	.....	....	....	.....	.....
29	17.1	14.6	10.8 N	322.7	....	....	....	.....	1.27	....	553	.....	1.59
29	17.5	15.0	10.8 N	322.7	229	MUBP	160	1.31	.....	635	....	1.43	.....
29	18.0	15.5	10.8 N	322.7	....	....	....	.....	1.07	....	452	.....	1.64
29	19.5	17.0	10.8 N	322.7	....	....	....	.....	.....	....	....	.....	.....
30	17.1	14.6	9.3 N	323.2	....	....	....	1.57	.....	768	....	1.42	.....
30	17.5	15.0	9.3 N	323.2	120	MUBP	84	.....	1.45	....	699	.....	1.44
30	17.8	15.4	9.3 N	323.2	....	....	....	1.59	.....	827	....	1.33	.....
30	19.6	17.2	9.3 N	323.2	....	....	....	.....	.....	....	....	.....	.....
30	19.9	17.4	9.3 N	323.2	....	....	....	.....	.....	....	....	.....	.....
31	14.4	12.0	8.2 N	323.9	....	....	....	.....	1.29	....	614	.....	1.46
31	14.7	12.3	8.2 N	323.9	151	MUBP	106	1.56	.....	635	....	1.71	.....
31	15.1	12.7	8.2 N	323.9	....	....	....	.....	.....	....	....	.....	.....
Sep 1	16.8	14.3	9.6 N	323.4	....	....	....	1.66	.....	693	....	1.66	.....
1	17.2	14.7	9.6 N	323.4	236	MUBS	165	.....	1.36	....	647	.....	1.46
1	17.6	15.1	9.6 N	323.4	....	....	....	1.63	.....	860	....	1.31	.....
1	19.9	17.4	9.6 N	323.4	....	....	....	.....	.....	....	....	.....	.....
2	12.5	10.0	9.7 N	323.4	....	....	....	.....	.....	....	....	.....	.....
2	17.6	15.1	10.0 N	323.3	....	....	....	.....	.....	....	....	.....	.....
2	21.4	18.9	10.3 N	323.1	....	....	....	.....	1.24	....	492	.....	1.75
2	21.7	19.3	10.3 N	323.1	159	MUBS	111	1.52	.....	691	....	1.53	.....
2	22.1	19.7	10.3 N	323.1	....	....	....	.....	1.30	....	504	.....	1.79
3	14.8	12.3	11.2 N	322.8	....	....	....	.....	1.35	....	594	.....	1.58
3	15.1	12.7	11.2 N	322.8	....	....	....	1.53	.....	643	....	1.65	.....
3	16.1	13.7	11.2 N	322.8	....	....	....	1.51	.....	655	....	1.60	.....
3	17.2	14.7	11.2 N	322.8	....	....	....	1.45	.....	....	....	.....	.....
3	18.0	15.5	11.2 N	322.8	....	....	....	1.45	.....	617	....	1.63	.....
3	19.1	16.6	11.2 N	322.8	....	....	....	1.37	.....	....	....	.....	.....
4	12.0	9.5	11.4 N	322.2	....	....	....	.....	.....	....	....	.....	.....
4	17.4	14.8	11.4 N	321.4	....	....	....	1.24	.....	626	....	1.38	.....
4	17.9	15.3	11.4 N	321.4	....	....	....	.....	0.99	....	510	.....	1.35
4	18.3	15.8	11.4 N	321.4	....	....	....	1.17	.....	645	....	1.26	.....
4	19.5	17.0	11.4 N	321.4	....	....	....	.....	.....	....	....	.....	.....
5	15.1	12.4	11.6 N	319.2	....	....	....	.....	1.12	....	597	.....	1.30

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10-7 esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Tem-pera-ture °C	Rel. hum. per cent	Wind		Clouds		Visi-bility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
.....	......	.....	26.2	77	....	...	..	....	..	.....
.....	......	.....	27.1	78	....	...	..	....	..	.....
4.8	......	.....	27.1	79	....	...	..	....	..	.....
.....	......	.....	27.0	79	....	...	..	....	..	.....
.....	......	2.50	26.6	81	....	...	..	....	..	.....
.....	340	.....	26.0	84	ENE	4	8	stcu-frcu	2	.....
.....	......	.....	27.2	79	....	...	..	....	..	.....
3.7	......	.....	27.1	79	....	...	..	....	..	.....
.....	......	.....	27.1	79	....	...	..	....	..	.....
.....	......	2.46	27.1	79	....	...	..	....	..	.....
.....	890	.....	26.9	79	ENE	2	5	cu-stcu	3	.....
.....	500	.....	29.2	72	ENE	1	2	cu-frcu	3	.....
3.3	......	.....	29.3	71	....	...	..	....	..	.....
.....	......	2.53	29.3	71	....	...	..	....	..	.....
.....	730	.....	28.9	73	CALM	0	6	cu-cunb	3	.....
.....	530	.....	28.9	74	ESE	1	8	ci-cu	3	.....
.....	......	.....	28.2	80	....	...	..	....	..	.....
5.1	......	.....	28.4	79	....	...	..	....	..	.....
.....	......	2.82	28.6	78	....	...	..	....	..	.....
.....	......	.....	29.8	72	....	...	..	....	..	.....
.....	......	.....	29.9	72	....	...	..	....	..	.....
.....	......	.....	29.8	72	....	...	..	....	..	.....
.....	......	2.14	28.9	75	....	...	..	....	..	.....
.....	......	.....	30.4	70	....	...	..	....	..	.....
10.9	......	.....	30.6	69	....	...	..	....	..	.....
.....	......	.....	29.7	72	....	...	..	....	..	.....
.....	......	2.60	28.8	74	....	...	..	....	..	.....
.....	440	.....	28.8	73	CALM	0	2	ci-cu	3	.....
.....	......	2.77	28.8	74	....	...	..	....	..	.....
.....	370	.....	29.3	74	W	2	9	cu-nb	3	.....
.....	300	.....	26.9	84	W	2	9	cist-cu	3	.....
.....	......	.....	27.8	81	....	...	..	....	..	.....
13.4	......	.....	27.7	80	....	...	..	....	..	.....
.....	......	.....	27.8	80	....	...	..	....	..	.....
.....	......	2.26	27.8	79	....	...	..	....	..	.....
.....	......	.....	28.2	78	....	...	..	....	..	.....
13.2	......	.....	28.6	75	....	...	..	....	..	.....
.....	......	.....	28.4	76	....	...	..	....	..	.....
.....	......	2.85	25.8	88	....	...	..	....	..	r
.....	......	.....	27.6	80	....	...	..	....	..	.....
8.5	......	.....	27.6	80	....	...	..	....	..	.....
.....	......	.....	27.5	80	....	...	..	....	..	.....
.....	......	2.25	27.2	78	....	...	..	....	..	.....
.....	500	.....	26.9	80	SW	4	5	acu-cu	3	.....
.....	......	.....	27.5	80	....	...	..	....	..	.....
10.1	......	.....	27.4	80	....	...	..	....	..	.....
.....	......	2.06	27.4	80	....	...	..	....	..	.....
.....	......	.....	26.6	82	....	...	..	....	..	.....
16.5	......	.....	26.7	81	....	...	..	....	..	r
.....	......	.....	26.6	82	....	...	..	....	..	.....
.....	......	2.61	24.4	90	....	...	..	....	..	.....
.....	200	.....	27.9	80	W×N	3	4	acu-stcu	3	.....
.....	......	2.60	26.8	82	....	...	..	....	..	.....
.....	......	.....	26.4	83	....	...	..	....	..	.....
10.3	......	.....	26.3	83	....	...	..	....	..	.....
.....	......	.....	26.3	83	....	...	..	....	..	.....
.....	......	.....	27.9	79	....	...	..	....	..	.....
.....	......	2.53	28.0	79	....	...	..	....	..	.....
.....	......	2.41	27.9	80	....	...	..	....	..	.....
.....	......	2.50	27.4	82	....	...	..	....	..	r
.....	......	2.66	27.2	82	....	...	..	....	..	.....
.....	......	.....	26.9	83	....	...	..	....	..	q
.....	270	.....	28.2	77	NE	5	3	cu-frcu	2	.....
.....	......	.....	28.4	78	....	...	..	....	..	.....
.....	410	.....	28.2	76	NE	4	4	cu-frcu	2	.....
.....	......	.....	28.1	79	....	...	..	....	..	.....
.....	......	2.55	27.9	80	....	...	..	....	..	.....
.....	......	.....	28.4	74	....	...	..	....	..	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient			Conductivity		Small ions		Mobility	
					Volts	Sail position	V/m	λ_+	λ_-	n_+	n_-	k_+	k_-
								in 10^{-4} esu		per cc		cm/s/v/cm	
1928													
Sep 5	15.6	12.8	11.6 N	319.2	157	MUBP	110	1.11	.....	658	....	1.17	.....
5	16.1	13.3	11.6 N	319.2	....	....	....	.....	.....	....	....	.....	.....
5	17.9	15.2	11.6 N	318.9	....	....	....	.....	.....	....	....	.....	.....
5	21.1	18.3	11.6 N	318.7	....	....	....	.....	.....	....	....	.....	.....
6	13.6	10.8	11.7 N	317.5	....	....	....	.....	.....	....	....	.....	.....
6	14.1	11.3	11.7 N	317.4	....	....	....	1.16	.....	614	....	1.31	.....
6	14.6	11.8	11.7 N	317.4	148	MUBP	104	.....	1.06	....	504	.....	1.46
6	14.8	12.0	11.7 N	317.4	....	....	....	.....	.....	....	....	.....	.....
7	17.5	14.6	11.3 N	315.5	....	....	....	1.18	.....	659	....	1.24	.....
7	18.0	15.0	11.3 N	315.5	190	MUBP	133	.....	1.06	....	521	.....	1.41
7	18.4	15.5	11.3 N	315.5	....	....	....	1.24	.....	771	....	1.12	.....
7	19.5	16.5	11.3 N	315.5	....	....	....	.....	.....	....	....	.....	.....
7	20.0	17.1	11.3 N	315.5	....	....	....	.....	.....	....	....	.....	.....
8	17.1	14.1	11.6 N	314.8	....	....	....	.....	1.19	....	517	.....	1.60
8	17.5	14.5	11.6 N	314.8	146	MUBP	102	1.16	.....	670	....	1.20	.....
8	17.9	14.9	11.6 N	314.8	....	....	....	.....	1.15	....	544	.....	1.47
8	20.0	17.0	11.6 N	314.8	....	....	....	.....	.....	....	....	.....	.....
8	20.7	17.7	11.6 N	314.8	....	....	....	.....	.....	....	....	.....	.....
8	20.8	17.8	11.6 N	314.8	....	....	....	.....	.....	....	....	.....	.....
8	20.9	17.9	11.6 N	314.8	....	....	....	.....	.....	....	....	.....	.....
9	18.0	14.9	11.8 N	313.7	....	....	....	1.24	.....	558	....	1.54	.....
9	18.5	15.4	11.8 N	313.7	160	MUBP	112	.....	1.07	....	531	.....	1.40
9	18.9	15.8	11.8 N	313.7	....	....	....	1.21	.....	624	....	1.35	.....
9	20.0	16.9	11.7 N	313.7	....	....	....	.....	.....	....	....	.....	.....
9	20.2	17.1	11.7 N	313.7	....	....	....	.....	.....	....	....	.....	.....
10	18.7	15.5	12.5 N	311.7	....	....	....	.....	.....	....	....	.....	.....
10	19.9	16.7	12.5 N	311.7	....	....	....	.....	1.18	....	....	.....	.....
10	20.4	17.2	12.5 N	311.7	153	MUBS	107	1.33	.....	....	....	.....	.....
10	20.8	17.6	12.5 N	311.7	....	....	....	.....	1.14	....	....	.....	.....
11	17.9	14.6	13.2 N	310.2	....	....	....	1.19	.....	584	....	1.41	.....
11	18.3	15.0	13.2 N	310.2	137	MUBS	96	.....	1.00	....	393	.....	1.77
11	18.8	15.5	13.2 N	310.2	....	....	....	1.24	.....	596	....	1.44	.....
11	20.1	16.8	13.2 N	310.2	....	....	....	.....	.....	....	....	.....	.....
11	20.7	17.4	13.2 N	310.2	....	....	....	.....	.....	....	....	.....	.....
12	17.6	14.3	13.2 N	309.2	....	....	....	.....	1.12	....	564	.....	1.38
12	18.1	14.7	13.2 N	309.2	127	MUBP	89	1.14	.....	670	....	1.18	.....
12	18.6	15.2	13.2 N	309.2	....	....	....	.....	1.07	....	579	.....	1.28
12	20.2	16.9	13.2 N	309.2	....	....	....	.....	.....	....	....	.....	.....
13	15.0	11.5	13.3 N	307.6	....	....	....	1.05	.....	568	....	1.28	.....
13	15.5	11.9	13.3 N	307.6	162	MUBP	113	.....	0.99	....	476	.....	1.44
13	15.9	12.4	13.3 N	307.6	....	....	....	.....	.....	....	....	.....	.....
14	14.0	10.4	13.1 N	305.8	....	....	....	.....	.....	....	....	.....	.....
14	14.4	10.9	13.0 N	305.7	....	....	....	.....	0.99	....	535	.....	1.28
14	14.9	11.3	13.0 N	305.7	169	MUBS	118	1.16	.....	656	....	1.23	.....
14	15.2	11.6	13.0 N	305.7	....	....	....	.....	.....	....	....	.....	.....
15	17.8	14.0	12.9 N	303.3	....	....	....	1.16	.....	553	....	1.46	.....
15	18.4	14.6	12.9 N	303.3	196	MUBS	137	.....	0.98	....	476	.....	1.43
15	18.8	15.1	12.9 N	303.3	....	....	....	1.14	.....	546	....	1.45	.....
15	20.4	16.7	12.9 N	303.3	....	....	....	.....	.....	....	....	.....	.....
15	20.7	16.9	12.9 N	303.3	....	....	....	.....	.....	....	....	.....	.....
16	13.4	9.5	13.0 N	301.8	....	....	....	.....	.....	....	....	.....	.....
16	17.1	13.2	13.0 N	301.4	....	....	....	.....	.....	....	....	.....	.....
16	17.7	13.8	13.0 N	301.3	....	....	....	.....	0.97	....	531	.....	1.27
16	18.1	14.2	13.0 N	301.3	157	MUBS	110	1.18	.....	635	....	1.29	.....
16	18.6	14.7	13.0 N	301.3	....	....	....	.....	1.01	....	505	.....	1.39
16	19.3	15.4	13.0 N	301.3	....	....	....	.....	.....	....	....	.....	.....
16	20.7	16.8	13.0 N	301.3	....	....	....	.....	.....	....	....	.....	.....
Oct 2	15.3	11.2	14.7 N	298.8	....	....	....	.....	.....	....	....	.....	.....
2	21.7	17.5	14.7 N	297.9	....	....	....	.....	.....	....	....	.....	.....
3	18.7	14.4	14.8 N	296.1	....	....	....	1.70	.....	935	....	1.26	.....
3	19.1	14.8	14.8 N	296.1	196	MUBP	137	.....	1.64	....	889	.....	1.28
3	19.5	15.3	14.8 N	296.1	....	....	....	1.44	.....	944	....	1.06	.....
3	19.9	15.7	14.8 N	296.1	....	....	....	.....	.....	....	....	.....	.....
3	21.7	17.4	14.8 N	295.8	....	....	....	.....	.....	....	....	.....	.....
4	18.0	13.6	15.0 N	293.6	....	....	....	.....	0.85	....	....	.....	.....
4	18.6	14.2	15.0 N	293.6	163	MUBP	114	0.90	.....	....	....	.....	.....
4	19.1	14.7	15.0 N	293.6	....	....	....	.....	0.71	....	....	.....	.....
5	18.0	13.4	15.3 N	291.6	....	....	....	0.73	.....	583	....	0.87	.....

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10-7 esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
8.2	......	.....	28.4	75	....	...	..	....	..	.....
.....	......	2.54	28.4	75	....	...	..	....	..	.....
.....	2060	.....	27.9	74	NE	3	2	cu-acu	2	.....
.....	990	.....	28.5	71	NE	3	9	cu-cunb	2	.....
.....	1350	.....	29.0	74	NNE	3	7	cu-nb	3	.....
.....	......	.....	29.1	68	....	...	..	....	..	.....
7.7	......	.....	29.0	71	....	...	..	....	..	.....
.....	......	2.68	29.0	72	....	...	..	....	..	.....
.....	......	.....	28.4	76	....	...	..	....	..	.....
10.1	......	.....	28.3	77	....	...	..	....	..	.....
.....	......	.....	28.3	77	....	...	..	....	..	.....
.....	1140	.....	27.7	77	NNE	2	7	cu-cunb	3	.....
.....	......	2.46	27.9	74	....	...	..	....	..	.....
.....	......	.....	29.4	69	....	...	..	....	..	.....
7.9	......	.....	29.2	70	....	...	..	....	..	.....
.....	......	.....	29.0	70	....	...	..	....	..	.....
.....	......	2.51	28.4	71	....	...	..	....	..	.....
.....	5610	.....	28.1	72	NE	1	2	ci-cu	3	.....
.....	8160	.....	28.1	72	NE	1	2	ci-cu	3	.....
.....	9300	.....	28.1	72	NE	1	2	ci-cu	3	.....
.....	......	.....	29.2	73	....	...	..	....	..	.....
8.6	......	.....	29.3	73	....	...	..	....	..	.....
.....	......	.....	29.4	72	....	...	..	....	..	.....
.....	500	.....	28.5	75	N×E	3	7	ast-cu	2	.....
.....	......	2.94	28.9	73	....	...	..	....	..	.....
.....	......	2.46	27.4	82	....	...	..	....	..	.....
.....	......	.....	27.3	82	....	...	..	....	..	s
8.9	......	.....	27.3	82	....	...	..	....	..	s
.....	......	.....	27.2	83	....	...	..	....	..	s
.....	......	.....	29.1	75	....	...	..	....	..	.....
7.1	......	.....	28.9	75	....	...	..	....	..	.....
.....	......	.....	28.6	76	....	...	..	....	..	.....
.....	......	2.70	28.3	78	....	...	..	....	..	.....
.....	570	.....	28.7	66	SW	2	8	cist-frcu	2	.....
.....	......	.....	29.2	72	....	...	..	....	..	.....
6.6	......	.....	29.0	73	....	...	..	....	..	.....
.....	......	.....	28.7	74	....	...	..	....	..	.....
.....	......	2.62	28.2	75	....	...	..	....	..	.....
.....	......	.....	28.4	72	....	...	..	....	..	.....
7.7	......	.....	28.4	71	....	...	..	....	..	.....
.....	......	2.63	28.5	71	....	...	..	....	..	.....
.....	500	.....	28.7	63	SE	2	1	ci-cist	2	.....
.....	......	.....	29.1	65	....	...	..	....	..	.....
8.4	......	.....	29.1	65	....	...	..	....	..	.....
.....	......	2.69	29.2	65	....	...	..	....	..	.....
.....	......	.....	28.8	74	....	...	..	....	..	.....
9.7	......	.....	28.6	75	....	...	..	....	..	.....
.....	......	.....	28.5	75	....	...	..	....	..	.....
.....	......	2.47	28.3	77	....	...	..	....	..	.....
.....	640	.....	28.1	76	ESE	3	4	cu-frcu	3	.....
.....	1490	.....	29.5	74	E×S	2	8	cist-cu	2	.....
.....	710	.....	30.3	71	E×S	2	7	cist-cu	2	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
8.0	......	.....	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	......	2.41	.....	...	....	...	..	....	..	.....
.....	920	.....	29.4	74	E	2	8	acu-cu	3	.....
.....	1630	.....	30.5	64	NW	2	3	ci-cu	2	.....
.....	1210	2.91	28.1	78	NE	3	1	ci-cu	2	.....
.....	......	.....	30.0	73	....	...	..	....	..	.....
14.7	......	.....	29.7	72	....	...	..	....	..	.....
.....	......	.....	29.3	72	E	2	..	....	..	.....
.....	......	2.44	29.3	75	....	...	..	....	..	q
.....	......	3.06	25.3	83	....	...	..	....	..	.....
.....	......	.....	27.1	79	....	...	..	....	..	r
6.4	......	.....	27.1	78	E	...	..	....	..	r
.....	......	.....	27.8	80	....	...	..	....	..	r
.....	......	.....	28.8	75	....	...	..	....	..	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient			Conductivity		Small ions		Mobility	
					Volts	Sail position	V/m	λ_+	λ_-	n_+	n_-	k_+	k_-
								in 10^{-4} esu		per cc		cm/s/v/cm	
1928													
Oct 5	18.5	13.9	15.3 N	291.6	224	MUBP	157	.....	0.56	....	395	.....	0.98
5	19.0	14.5	15.3 N	291.6	....	....	....	0.76	.....	663	....	0.79	.....
6	18.4	13.6	15.1 N	288.5	....	....	....	.....	0.84	....	567	.....	1.03
6	18.8	14.0	15.1 N	288.5	166	MUBS	116	0.94	.....	....	....	.....	.....
6	19.1	14.3	15.1 N	288.5	....	....	....	.....	0.80	....	....	.....	.....
7	19.0	14.0	14.3 N	285.6	....	....	....	0.97	.....	775	....	0.87	.....
7	19.4	14.5	14.3 N	285.6	146	MUBS	102	.....	0.82	....	575	.....	0.99
7	19.8	14.9	14.3 N	285.6	....	....	....	1.01	.....	838	....	0.84	.....
8	16.7	11.6	13.3 N	283.3	....	....	....	0.78	.....	....	....	.....	.....
8	17.1	12.0	13.3 N	283.3	....	....	....	.....	.....	....	....	.....	.....
8	17.5	12.3	13.3 N	283.3	....	....	....	0.78	.....	610	....	0.89	.....
8	17.8	12.6	13.3 N	283.3	....	....	....	.....	.....	....	....	.....	.....
8	18.2	13.1	13.3 N	283.3	....	....	....	0.72	.....	570	....	0.88	.....
8	18.6	13.5	13.3 N	283.3	....	....	....	.....	.....	....	....	.....	.....
8	19.2	14.1	13.3 N	283.3	....	....	....	0.74	.....	635	....	0.81	.....
8	19.6	14.5	13.3 N	283.3	....	....	....	.....	.....	....	....	.....	.....
8	20.3	15.2	13.3 N	283.3	....	....	....	0.61	.....	....	....	.....	.....
8	20.7	15.6	13.3 N	283.3	....	....	....	.....	.....	....	....	.....	.....
8	21.6	16.5	13.3 N	283.3	....	....	....	1.09	.....	....	....	.....	.....
8	22.2	17.1	13.3 N	283.3	....	....	....	1.02	.....	....	....	.....	.....
8	23.0	17.9	13.3 N	283.3	....	....	....	.....	.....	....	....	.....	.....
9	14.8	9.6	11.5 N	281.5	....	....	....	1.10	.....	545	....	1.40	.....
9	16.1	10.8	11.5 N	281.5	....	....	....	.....	1.03	....	520	.....	1.37
9	16.4	11.2	11.5 N	281.5	179	MUBS	125	1.09	.....	587	....	1.29	.....
9	16.8	11.6	11.5 N	281.5	....	....	....	.....	0.98	....	519	.....	1.31
9	17.1	11.8	11.5 N	281.5	....	....	....	.....	.....	....	....	.....	.....
10	17.0	11.8	10.3 N	280.8	....	....	....	.....	.....	....	....	.....	.....
10	18.3	13.0	10.2 N	280.7	....	....	....	.....	.....	....	....	.....	.....
10	19.8	14.6	10.1 N	280.6	....	....	....	.....	.....	....	....	.....	.....
10	20.7	15.4	10.0 N	280.6	....	....	....	.....	.....	....	....	.....	.....
10	23.0	17.7	9.8 N	280.5	....	....	....	.....	.....	....	....	.....	.....
10	0.7	19.4	9.8 N	280.4	....	....	....	.....	.....	....	....	.....	.....
10	2.0	20.7	9.7 N	280.4	....	....	....	.....	.....	....	....	.....	.....
10	3.0	21.7	9.7 N	280.3	....	....	....	.....	.....	....	....	.....	.....
		Pacific Ocean											
Oct 25	18.2	12.9	8.7 N	280.5	....	....	....	.....	.....	....	....	.....	.....
26	19.9	14.5	6.3 N	279.8	....	....	....	0.89	.....	....	....	.....	.....
26	20.5	15.1	6.3 N	279.8	....	....	....	.....	0.60	....	....	.....	.....
26	21.1	15.8	6.3 N	279.8	....	....	....	0.77	.....	....	....	.....	.....
28	20.2	14.9	4.2 N	280.2	....	....	....	.....	1.06	....	....	.....	.....
28	20.7	15.4	4.2 N	280.2	....	....	....	1.47	.....	....	....	.....	.....
28	21.1	15.8	4.2 N	280.2	....	....	....	.....	1.69	....	....	.....	.....
28	22.2	16.9	4.2 N	280.2	....	....	....	.....	.....	....	....	.....	.....
29	17.0	11.7	4.1 N	280.1	....	....	....	.....	.....	....	....	.....	.....
29	0.7	19.4	3.7 N	280.0	....	....	....	1.35	.....	....	....	.....	.....
29	1.1	19.8	3.7 N	280.0	....	....	....	.....	1.23	....	....	.....	.....
29	1.6	20.2	3.7 N	280.0	....	....	....	1.41	.....	....	....	.....	.....
30	20.4	15.0	2.9 N	279.6	....	....	....	.....	1.12	....	....	.....	.....
30	20.8	15.5	2.9 N	279.6	....	....	....	1.30	.....	....	....	.....	.....
30	21.2	15.9	2.9 N	279.6	....	....	....	.....	1.19	....	....	.....	.....
31	18.9	13.4	5.0 N	277.8	...	....	....	1.57	.....	....	....	.....	.....
31	21.6	16.1	5.0 N	277.8	....	....	....	1.54	.....	....	....	.....	.....
31	22.0	16.5	5.0 N	277.8	....	....	....	.....	1.41	....	....	.....	.....
31	22.4	16.9	5.0 N	277.8	....	....	....	1.54	.....	....	....	.....	.....
Nov 1	19.1	13.6	6.2 N	276.8	....	....	....	.....	1.34	....	....	.....	.....
1	19.5	14.0	6.2 N	276.8	....	....	....	1.50	.....	....	....	.....	.....
1	19.9	14.4	6.2 N	276.8	....	....	....	.....	1.22	....	....	.....	.....
1	22.1	16.5	6.1 N	276.8	....	....	....	.....	.....	....	....	.....	.....
2	19.4	13.9	4.6 N	277.8	....	....	....	1.24	.....	418	....	2.06	.....
2	19.8	14.4	4.6 N	277.8	....	....	..	.....	1.12	....	323	.....	2.41
2	20.2	14.8	4.6 N	277.8	....	....	....	1.22	.....	355	....	2.39	.....
2	20.6	15.1	4.6 N	277.8	....	....	....	.....	.....	....	....	.....	.....
3	20.2	14.8	3.4 N	278.7	....	....	....	.....	1.11	....	....	.....	.....
3	20.7	15.3	3.4 N	278.7	....	....	....	1.25	.....	....	....	.....	.....
3	21.1	15.7	3.4 N	278.7	....	....	....	.....	1.12	....	....	.....	.....
3	21.8	16.4	3.4 N	278.7	....	....	....	.....	.....	....	....	.....	.....
4	19.0	13.6	2.5 N	278.8	....	....	....	1.06	.....	....	....	.....	.....

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10-7 esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
6.8	......	2.42	29.1	73	....	...	..	....	..	.....
.....	990	.....	29.0	73	E×N	3	7	cu	3	.....
.....	......	.....	29.9	74	....	...	..	....	..	.....
6.8	......	2.44	30.0	74	....	...	..	....	..	.....
.....	640	.....	29.8	73	SE	3	8	cu	3	.....
.....	......	.....	29.5	77	....	...	..	....	..	.....
6.2	......	2.90	29.2	77	....	...	..	....	..	.....
.....	500	.....	28.5	77	SE	4	2	frcu-cu	3	.....
.....	......	2.82	28.8	81	....	...	..	....	..	.....
.....	280	.....	28.9	79	SE×E	4	8	cu-cunb	2	.....
.....	......	2.72	29.0	80	....	...	..	....	..	.....
.....	390	.....	29.0	79	SE×E	4	7	cist-cu	2	.....
.....	......	2.88	29.2	79	....	...	..	....	..	.....
.....	550	.....	29.0	78	SE×E	4	7	ci-cu	2	.....
.....	......	2.86	28.8	81	....	...	..	....	..	.....
.....	430	.....	28.4	81	SE×E	4	8	ast-cu	2	.....
.....	......	2.91	28.5	82	....	...	..	....	..	r
.....	360	.....	27.7	82	ESE	4	10	ast-nb	2	.....
.....	......	2.99	28.2	80	....	...	..	....	..	.....
.....	390	2.90	28.0	80	ESE	5	10	st-nb	2	.....
.....	370	.....	28.0	81	ESE	5	10	ast-cunb	2	.....
.....	......	3.08	28.7	81	....	...	..	....	..	r
.....	......	.....	28.4	83	....	...	..	....	..	.....
8.8	......	2.78	28.5	82	....	...	..	....	..	.....
.....	......	.....	28.8	81	....	...	..	....	..	.....
.....	410	.....	29.0	79	E×S	4	8	cu-cunb	2	.....
.....	1920	.....	28.1	78	WSW	2	10	st	2	.....
.....	1060	.....	28.9	77	WSW	2	10	st-cu	2	.....
.....	1280	.....	28.3	77	WSW	2	10	st-nb	2	.....
.....	2980	.....	28.1	79	WSW	2	10	st-nb	2	.....
.....	2770	.....	28.0	78	W×S	1	10	st-nb	2	.....
.....	2560	.....	27.7	80	W×S	1	..	....	..	.....
.....	2340	.....	27.0	83	W×S	1	..	....	..	.....
.....	1780	.....	26.6	86	W×S	1	..	....	..	.....
.....	680	.....	29.1	79	W×N	4	7	ci-nb	2	.....
.....	......	.....	27.0	89	....	...	..	....	..	r
.....	......	2.30	27.2	88	....	...	..	....	..	r
.....	......	.....	27.4	87	....	...	..	....	..	r
.....	......	.....	24.4	92	....	...	..	....	..	r
.....	......	.....	24.3	92	....	...	..	....	..	r
.....	......	.....	24.2	93	....	...	..	....	..	r
.....	......	3.63	24.3	93	....	...	..	....	..	r
.....	680	.....	27.9	74	SW	2	3	frcu-ci	3	.....
.....	......	.....	25.5	90	W×S	3	..	....	..	.....
.....	......	3.22	25.6	89	....	...	..	....	..	.....
.....	......	.....	25.6	90	....	...	..	....	..	.....
.....	......	.....	25.2	87	....	...	..	....	..	r
.....	......	3.29	25.2	86	....	...	..	....	..	r
.....	......	.....	25.3	86	....	...	..	....	..	r
.....	......	2.98	26.3	85	....	...	..	....	..	.....
.....	......	.....	26.4	84	....	...	..	....	..	.....
.....	......	3.35	26.4	84	....	...	..	....	..	.....
.....	320	.....	26.1	83	SW	4	2	cu	2	.....
.....	......	.....	26.2	87	....	...	..	....	..	r
.....	......	3.52	26.2	87	....	...	..	....	..	r
.....	......	.....	26.0	88	....	...	..	....	..	r
.....	390	.....	25.9	84	SW×S	5	9	cu-nb	2	.....
.....	......	.....	26.4	83	....	...	..	....	..	.....
.....	......	3.04	26.3	83	....	...	..	....	..	p
.....	......	.....	26.3	83	....	...	..	....	..	.....
.....	530	.....	26.1	81	SW×S	5	10	nb	2	.....
.....	......	.....	26.2	82	....	...	..	....	..	r
.....	......	3.10	26.3	81	....	...	..	....	..	r
.....	......	.....	26.4	80	....	...	..	....	..	r
.....	340	.....	26.1	79	WSW	4	7	cu-frcu	2	.....
.....	......	.....	24.4	83	....	...	..	....	..	r

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient			Conductivity in 10^{-4} esu		Small ions per cc		Mobility cm/s/v/cm	
					Volts	Sail position	V/m	λ_+	λ_-	n_+	n_-	k_+	k_-
1928													
Nov 4	19.5	14.1	2.5 N	278.8	....	....	....	....	1.00	....	....	....	....
4	20.0	14.5	2.5 N	278.8	....	....	....	1.15	....	....	....	....	....
4	20.3	14.8	2.5 N	278.8	....	....	....	....	....	....	....	....	....
5	19.0	13.6	1.4 N	279.3	....	....	....	....	0.73	....	318	....	1.59
5	19.6	14.2	1.4 N	279.3	81	MUBP	235	0.85	....	384	....	1.54	....
5	20.2	14.9	1.4 N	279.3	....	....	....	....	0.71	....	330	....	1.49
5	20.8	15.4	1.4 N	279.3	....	....	....	....	....	....	....	....	....
6	21.6	16.2	0.4 N	278.8	....	....	....	0.95	....	....	....	....	....
6	22.0	16.6	0.4 N	278.8	73	MUBP	212	....	0.88	....	....	....	....
6	22.4	17.0	0.4 N	278.8	....	....	....	0.95	....	....	....	....	....
7	20.5	15.0	0.7 S	278.0	....	....	....	....	0.61	....	318	....	1.33
7	21.0	15.5	0.7 S	278.0	84	MUBP	244	0.79	....	384	....	1.43	....
7	21.5	16.0	0.7 S	278.0	....	....	....	....	0.71	....	377	....	1.31
7	21.9	16.4	0.7 S	278.0	....	....	....	....	....	....	....	....	....
8	19.0	13.5	1.4 S	277.4	....	....	....	0.65	....	462	....	0.98	....
8	19.5	14.0	1.4 S	277.4	....	....	....	....	0.54	....	401	....	0.94
8	20.0	14.5	1.4 S	277.4	....	....	....	0.65	....	426	....	1.06	....
8	20.3	14.8	1.4 S	277.4	....	....	....	....	....	....	....	....	....
9	19.8	14.2	1.4 S	274.8	....	....	....	....	0.56	....	....	....	....
10	21.8	16.0	1.7 S	272.6	....	....	....	....	0.87	....	351	....	1.72
10	22.3	16.5	1.7 S	272.6	51	MUBS	163	1.06	....	535	....	1.37	....
10	22.8	16.9	1.7 S	272.6	....	....	....	....	0.87	....	381	....	1.59
10	23.1	17.2	1.7 S	272.6	....	....	....	....	....	....	....	....	....
11	20.0	14.1	1.8 S	270.7	....	....	....	1.14	....	360	....	2.20	....
11	20.5	14.6	1.8 S	270.7	58	MUBS	186	....	0.90	....	242	....	2.58
11	21.0	15.1	1.8 S	270.7	....	....	....	1.19	....	437	....	1.89	....
11	21.2	15.2	1.8 S	270.7	....	....	....	....	....	....	....	....	....
12	20.0	13.9	1.2 S	268.5	....	....	....	....	1.08	....	474	....	1.58
12	20.5	14.4	1.2 S	268.5	40	MUBS	128	1.16	....	570	....	1.41	....
12	21.0	14.9	1.2 S	268.5	....	....	....	....	1.05	....	452	....	1.61
12	22.2	16.1	1.2 S	268.4	....	....	....	....	....	....	....	....	....
13	17.9	11.6	1.5 S	266.8	....	....	....	....	0.89	....	339	....	1.83
13	18.4	12.1	1.5 S	266.8	47	MUBS	150	1.11	....	564	....	1.36	....
13	18.6	12.4	1.5 S	266.8	....	....	....	....	....	....	....	....	....
14	17.1	10.9	1.8 S	265.7	....	....	....	1.26	....	....	....	....	....
14	17.7	11.5	1.8 S	265.7	56	MUBS	179	....	0.98	....	....	....	....
14	18.2	12.0	1.8 S	265.7	....	....	....	....	....	....	....	....	....
15	20.8	14.4	2.6 S	264.0	....	....	....	1.16	....	....	....	....	....
15	21.3	14.9	2.6 S	264.0	50	MUBS	160	....	0.95	....	....	....	....
15	21.8	15.4	2.6 S	264.0	....	....	....	1.11	....	....	....	....	....
15	22.0	15.6	2.6 S	264.0	....	....	....	....	....	....	....	....	....
16	20.0	13.5	3.1 S	261.6	....	....	....	....	1.03	....	....	....	....
16	20.5	13.9	3.1 S	261.6	47	MUBS	150	1.23	....	....	....	....	....
16	21.0	14.4	3.1 S	261.6	....	....	....	....	0.98	....	....	....	....
16	21.3	14.7	3.1 S	261.6	....	....	....	....	....	....	....	....	....
17	20.3	13.6	3.3 S	259.8	....	....	....	1.25	....	....	....	....	....
17	20.8	14.1	3.3 S	259.8	31	MUBS	99	....	1.10	....	....	....	....
17	21.3	14.6	3.3 S	259.8	....	....	....	1.22	....	....	....	....	....
17	21.5	14.8	3.3 S	259.8	....	....	....	....	....	....	....	....	....
18	20.3	13.5	4.1 S	257.0	....	....	....	....	1.06	....	....	....	....
18	20.8	13.9	4.1 S	257.0	38	MUBS	122	1.18	....	....	....	....	....
18	21.3	14.4	4.1 S	257.0	....	....	....	....	1.07	....	....	....	....
18	21.5	14.6	4.1 S	257.0	....	....	....	....	....	....	....	....	....
19	20.4	13.4	4.8 S	254.7	....	....	....	1.08	....	....	....	....	....
19	21.0	14.0	4.8 S	254.7	40	MUBS	128	....	0.97	....	....	....	....
19	21.5	14.5	4.8 S	254.7	....	....	....	1.08	....	....	....	....	....
19	21.8	14.7	4.8 S	254.7	....	....	....	....	....	....	....	....	....
20	20.6	13.5	7.2 S	253.0	....	....	....	....	0.90	....	....	....	....
20	21.1	14.0	7.2 S	253.0	35	MUBS	112	1.04	....	....	....	....	....
20	21.7	14.5	7.2 S	253.0	....	....	....	....	0.97	....	....	....	....
20	22.0	14.9	7.2 S	253.0	....	....	....	....	....	....	....	....	....
21	18.3	11.0	9.2 S	251.6	....	....	....	1.05	....	....	....	....	....
21	18.8	11.5	9.2 S	251.6	33	MUBS	106	....	1.01	....	....	....	....
21	19.1	11.8	9.2 S	251.6	....	....	....	....	....	....	....	....	....
22	18.1	10.8	11.9 S	249.8	....	....	....	....	0.97	....	....	....	....
22	18.6	11.3	11.9 S	249.8	37	MUBS	118	1.05	....	....	....	....	....
22	18.9	11.6	11.9 S	249.8	....	....	....	....	....	....	....	....	....
23	20.9	13.4	14.4 S	248.0	....	....	....	....	1.12	....	....	....	....
23	21.4	13.9	14.4 S	248.0	36	MUBS	115	1.25	....	....	....	....	....

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10-7 esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
.....	......	2.93	24.3	83	SSW	5	..	....	..	r
.....	......	.....	24.3	84	....	...	..	....	..	r
.....	320	.....	24.1	82	SSW	5	10	nb	2	.....
.....	......	.....	25.0	77	....	...	..	....	..	.....
12.3	......	3.97	24.9	76	....	...	..	....	..	.....
.....	......	.....	24.9	76	....	...	..	....	..	.....
.....	300	.....	24.7	75	SW	4	3	acu-frcu	2	.....
.....	......	.....	24.2	80	....	...	..	....	..	.....
12.9	......	.....	23.9	81	....	...	..	....	..	.....
.....	620	.....	23.8	78	SW	3	9	stcu	2	.....
.....	......	.....	22.7	81	....	...	..	....	..	.....
11.8	......	3.65	22.8	82	....	...	..	....	..	.....
.....	......	.....	22.8	82	....	...	..	....	..	.....
.....	850	.....	22.0	82	SW×S	3	10	stcu	2	.....
.....	......	.....	19.7	87	....	...	..	....	..	.....
.....	......	2.55	19.5	88	....	...	..	....	..	.....
.....	......	.....	19.4	87	....	...	..	....	..	.....
.....	320	.....	19.2	83	SSW	3	10	stcu	2	.....
.....	......	2.73	20.3	82	....	...	..	....	..	.....
.....	......	.....	20.7	75	....	...	..	....	..	.....
10.5	......	2.99	20.8	76	....	...	..	....	..	.....
.....	......	.....	20.9	78	....	...	..	....	..	.....
.....	170	.....	20.5	76	S×E	2	3	frcu	3	.....
.....	......	.....	21.1	71	....	...	..	....	..	.....
12.8	......	2.65	21.0	72	....	...	..	....	..	.....
.....	......	.....	20.9	72	....	...	..	....	..	.....
.....	210	.....	20.8	69	S	2	1	ci	3	.....
.....	......	.....	21.1	71	....	...	..	....	..	.....
9.5	......	2.62	20.9	75	....	...	..	....	..	.....
.....	......	.....	20.6	80	....	...	..	....	..	.....
.....	250	.....	19.6	75	SE×S	3	4	stcu	3	.....
.....	......	2.63	20.7	75	....	...	..	....	..	.....
10.0	......	2.73	20.9	74	....	...	..	....	..	.....
.....	280	.....	20.9	72	....	0	10	ast	3	.....
.....	......	2.96	20.1	79	....	...	..	....	..	.....
13.3	......	.....	20.2	79	....	...	..	....	..	.....
.....	590	.....	20.1	76	SE×S	3	1	frcu-stcu	3	.....
.....	......	.....	21.0	80	....	...	..	....	..	.....
11.1	......	2.71	20.8	81	....	...	..	....	..	.....
.....	......	.....	20.4	83	....	...	..	....	..	.....
.....	500	.....	20.1	81	SE	4	1	frcu	3	.....
.....	......	.....	21.7	82	....	...	..	....	..	.....
11.2	......	2.87	21.7	82	....	...	..	....	..	.....
.....	......	.....	21.6	83	....	...	..	....	..	.....
.....	250	.....	21.3	81	SE×S	1	10	ast	3	.....
.....	......	.....	22.0	77	....	...	..	....	..	.....
7.7	......	2.52	22.0	78	....	...	..	....	..	.....
.....	......	.....	21.8	79	....	...	..	....	..	.....
.....	480	.....	21.7	68	SSE	4	2	cu-frcu	3	.....
.....	......	.....	22.6	77	....	...	..	....	..	.....
9.1	......	2.79	22.8	78	....	...	..	....	..	.....
.....	......	.....	22.7	77	....	...	..	....	..	.....
.....	500	.....	22.5	75	SE×S	4	6	ast-cu	3	.....
.....	......	.....	23.3	71	....	...	..	....	..	.....
8.7	......	2.66	23.1	72	....	...	..	....	..	.....
.....	......	.....	23.0	74	....	...	..	....	..	.....
.....	250	.....	22.8	71	ESE	4	1	frcu	3	.....
.....	......	.....	23.6	76	....	...	..	....	..	.....
7.4	......	2.61	23.2	78	....	...	..	....	..	.....
.....	......	.....	23.0	80	....	...	..	....	..	.....
.....	570	.....	22.7	77	ESE	4	3	frcu	3	.....
.....	......	2.91	24.1	72	....	...	..	....	..	.....
7.3	......	2.73	24.1	72	....	...	..	....	..	.....
.....	550	.....	24.0	68	ESE	4	3	acu-cu	3	.....
.....	......	2.51	24.1	73	....	...	..	....	..	.....
7.9	......	2.83	24.1	73	....	...	..	....	..	.....
.....	570	.....	23.9	71	ESE	5	8	acu-cu	3	.....
.....	......	.....	23.8	76	....	...	..	....	..	.....
9.2	......	2.65	23.4	78	....	...	..	....	..	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient			Conductivity		Small ions		Mobility	
					Volts	Sail position	V/m	λ_+	λ_-	n_+	n_-	k_+	k_-
								in 10^{-4} esu		per cc		cm/s/v/cm	
1928													
Nov 23	21.8	14.4	14.4 S	248.0	....	....	....	.....	1.18	....	....	.....	.....
23	22.2	14.7	14.4 S	248.0	....	....	....	.....	.....	....	....	.....	.....
24	21.7	14.2	17.0 S	246.9	....	....	....	1.24	.....	....	....	.....	.....
24	22.2	14.6	17.0 S	246.9	36	MUBS	115	.....	1.20	....	....	.....	.....
24	22.6	15.1	17.0 S	246.9	....	....	....	1.21	.....	....	....	.....	.....
24	22.9	15.4	17.0 S	246.9	....	....	....	.....	.....	....	....	.....	.....
25	21.2	13.6	19.5 S	245.9	....	....	....	.....	1.17	....	....	.....	.....
25	21.6	14.0	19.5 S	245.9	35	MUBS	112	1.32	.....	....	....	.....	.....
25	22.1	14.5	19.5 S	245.9	....	....	....	.....	1.19	....	....	.....	.....
25	22.4	14.8	19.5 S	245.9	....	....	....	.....	.....	....	....	.....	.....
26	21.6	13.9	22.0 S	245.6	....	....	....	1.46	.....	....	....	.....	.....
26	22.1	14.4	22.0 S	245.6	32	MUBS	102	.....	1.30	....	....	.....	.....
26	22.6	14.9	22.0 S	245.6	....	....	....	1.47	.....	....	....	.....	.....
26	22.9	15.3	22.0 S	245.6	....	....	....	.....	.....	....	....	.....	.....
27	18.0	10.3	23.3 S	245.2	....	....	....	.....	.....	....	....	.....	.....
27	18.4	10.8	23.3 S	245.2	....	....	....	.....	1.19	....	....	.....	.....
27	18.9	11.3	23.3 S	245.2	48	MUBS	154	1.34	.....	....	....	.....	.....
27	19.2	11.6	23.3 S	245.2	....	....	....	.....	.....	....	....	.....	.....
28	18.0	10.4	24.8 S	244.6	....	....	....	1.34	.....	....	....	.....	.....
28	18.5	10.8	24.8 S	244.6	48	MUBS	154	.....	1.10	....	....	.....	.....
28	18.8	11.1	24.8 S	244.6	....	....	....	.....	.....	....	....	.....	.....
29	20.9	13.2	26.7 S	244.7	....	....	....	1.23	.....	....	....	.....	.....
29	21.4	13.7	26.7 S	244.7	43	MUBS	138	.....	1.10	....	....	.....	.....
29	21.9	14.2	26.7 S	244.7	....	....	....	1.31	.....	....	....	.....	.....
30	21.1	13.4	28.2 S	244.9	....	....	....	.....	1.00	....	....	.....	.....
30	21.6	13.9	28.2 S	244.9	45	MUBS	144	1.13	.....	....	....	.....	.....
30	22.0	14.4	28.2 S	244.9	....	....	....	.....	1.01	....	....	.....	.....
30	22.2	14.6	28.2 S	244.9	....	....	....	.....	.....	....	....	.....	.....
Dec 1	20.9	13.2	29.3 S	245.3	....	....	....	1.28	.....	....	....	.....	.....
1	21.4	13.7	29.3 S	245.3	61	MUBS	195	.....	1.04	....	....	.....	.....
1	21.9	14.2	29.3 S	245.3	....	....	....	1.31	.....	....	....	.....	.....
2	21.0	13.4	30.7 S	245.8	....	....	....	.....	1.14	....	480	.....	1.65
2	21.4	13.8	30.7 S	245.8	43	MUBS	138	1.27	.....	585	....	1.51	.....
2	21.9	14.3	30.7 S	245.8	....	....	....	.....	1.16	....	444	.....	1.82
2	22.2	14.6	30.7 S	245.8	....	....	....	.....	.....	....	....	.....	.....
3	18.2	10.7	31.5 S	247.3	....	....	....	.....	.....	....	....	.....	.....
3	18.3	10.9	31.5 S	247.3	....	....	....	1.24	.....	626	....	1.38	.....
3	18.7	11.3	31.5 S	247.3	39	MUBS	125	.....	1.05	....	471	.....	1.55
3	19.1	11.6	31.5 S	247.3	....	....	....	.....	.....	....	....	.....	.....
4	18.1	10.6	31.4 S	249.9	....	....	....	.....	0.98	....	357	.....	1.90
4	18.5	11.1	31.4 S	249.9	48	MUBS	154	1.27	.....	500	....	1.76	.....
4	18.8	11.4	31.4 S	249.9	....	....	....	.....	.....	....	....	.....	.....
5	20.8	13.5	28.6 S	251.3	....	....	....	.....	1.00	....	364	.....	1.91
5	21.3	14.0	28.6 S	251.3	53	MUBS	170	1.22	.....	519	....	1.63	.....
5	21.7	14.5	28.6 S	251.3	....	....	....	.....	1.02	....	387	.....	1.83
5	22.0	14.8	28.6 S	251.3	....	....	....	.....	.....	....	....	.....	.....
13	20.7	13.4	28.3 S	250.8	....	....	....	.....	1.23	....	440	.....	1.94
13	21.2	13.9	28.3 S	250.8	42	MUBS	134	1.42	.....	565	....	1.74	.....
13	21.7	14.4	28.3 S	250.8	....	....	....	.....	1.24	....	439	.....	1.96
13	22.1	14.8	28.3 S	250.8	....	....	....	.....	.....	....	....	.....	.....
14	20.7	13.5	29.5 S	251.2	....	....	....	1.40	.....	525	....	1.85	.....
14	21.2	14.0	29.5 S	251.2	50	MUBS	160	.....	1.16	....	438	.....	1.84
14	21.8	14.5	29.5 S	251.2	....	....	....	1.41	.....	587	....	1.67	.....
14	22.1	14.8	29.5 S	251.2	....	....	....	.....	.....	....	....	.....	.....
15	20.8	13.5	31.3 S	250.5	....	....	....	.....	1.09	....	....	.....	.....
15	21.2	14.0	31.3 S	250.5	....	....	....	1.25	.....	....	....	.....	.....
15	21.8	14.5	31.3 S	250.5	....	....	....	.....	1.10	....	....	.....	.....
16	21.2	13.8	32.0 S	249.4	....	....	....	0.99	.....	532	....	1.29	.....
16	21.9	14.5	32.0 S	249.4	....	....	....	.....	0.91	....	455	.....	1.39
16	22.4	15.1	32.0 S	249.4	....	....	....	0.93	.....	529	....	1.22	.....
16	22.8	15.4	32.0 S	249.4	....	....	....	.....	.....	....	....	.....	.....
17	20.9	13.6	31.7 S	250.7	....	....	....	.....	0.84	....	334	.....	1.75
17	21.5	14.2	31.7 S	250.7	70	MUBP	203	0.99	.....	480	....	1.43	.....
17	22.0	14.7	31.7 S	250.7	....	....	....	.....	0.85	....	385	.....	1.53
17	22.3	15.0	31.7 S	250.7	....	....	....	.....	.....	....	....	.....	.....
18	18.1	11.0	31.9 S	251.0	....	....	....	.....	0.87	....	315	.....	1.92
18	18.5	11.4	31.9 S	251.0	62	MUBS	198	1.15	.....	349	....	2.29	.....
18	18.8	11.6	31.9 S	251.0	....	....	....	.....	.....	....	....	.....	.....

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10^{-7} esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
.....	......	.....	23.3	79	....	...	..	....	..	.....
.....	410	.....	23.0	76	E×S	4	5	cu-cunb	3	.....
.....	......	.....	23.5	72	....	...	..	....	..	.....
9.3	......	2.63	23.3	73	....	...	..	....	..	.....
.....	......	.....	23.3	74	....	...	..	....	..	.....
.....	800	.....	23.0	74	E	4	7	acu-cunb	3	.....
.....	......	.....	23.2	76	....	...	..	....	..	.....
9.3	......	2.69	23.2	78	....	...	..	....	..	.....
.....	......	.....	23.1	77	....	...	..	....	..	.....
.....	300	.....	22.9	74	E	4	2	cu	3	.....
.....	......	.....	22.9	74	....	...	..	....	..	.....
9.4	......	2.54	22.9	75	....	...	..	....	..	.....
.....	......	.....	22.8	76	....	...	..	....	..	.....
.....	300	.....	22.7	72	E×N	3	3	ast	3	.....
.....	140	.....	22.9	77	E×S	3	8	cist-stcu	3	.....
.....	......	2.70	23.1	78	....	...	..	....	..	.....
13.0	......	2.64	23.2	78	....	...	..	....	..	.....
.....	120	.....	23.1	79	E×S	3	7	frcu	3	.....
.....	......	2.60	23.2	77	....	...	..	....	..	.....
12.5	......	2.70	23.3	77	....	...	..	....	..	.....
.....	520	.....	23.1	78	E×S	4	2	frcu	3	.....
.....	......	.....	23.0	79	....	...	..	....	..	.....
10.9	......	2.81	23.1	78	....	...	..	....	..	.....
.....	270	.....	22.9	79	E×N	3	7	cu-frcu	3	.....
.....	......	.....	22.9	75	....	...	..	....	..	.....
10.3	......	3.10	22.7	78	....	...	..	....	..	.....
.....	......	.....	22.6	78	....	...	..	....	..	.....
.....	270	.....	22.2	77	ENE	3	1	frcu	3	.....
.....	......	.....	23.7	69	....	...	..	....	..	.....
15.2	......	2.85	23.7	69	....	...	..	....	..	.....
.....	200	.....	23.7	67	NE×E	3	1	ast	3	.....
.....	......	.....	23.3	71	....	...	..	....	..	.....
11.1	......	.....	23.2	72	....	...	..	....	..	.....
.....	......	.....	23.2	72	....	...	..	....	..	.....
.....	110	.....	23.0	73	NE	3	7	cist-frcu	3	.....
.....	160	.....	22.7	74	N×W	4	7	cist-frcu	3	.....
.....	......	.....	22.8	75	....	...	..	....	..	.....
9.5	......	.....	23.0	74	....	...	..	....	..	.....
.....	120	.....	22.9	73	N×W	4	7	cist-frcu	3	.....
.....	......	.....	22.4	84	....	...	..	....	..	.....
11.5	......	.....	22.4	84	....	...	..	....	..	.....
.....	180	.....	22.2	83	NW×W	4	10	cist-frcu	3	.....
.....	......	.....	23.1	84	....	...	..	....	..	.....
12.6	......	.....	23.1	84	....	...	..	....	..	.....
.....	......	.....	23.2	84	....	...	..	....	..	.....
.....	160	.....	22.9	84	W×S	4	7	ci-cu	3	.....
.....	......	.....	23.9	73	....	...	..	....	..	.....
11.9	......	2.38	24.0	73	....	...	..	....	..	.....
.....	......	.....	23.8	74	....	...	..	....	..	.....
.....	120	.....	23.1	78	E×N	2	7	cu-frcu	3	.....
.....	......	.....	23.6	74	....	...	..	....	..	.....
13.7	......	3.14	23.7	74	....	...	..	....	..	.....
.....	......	.....	23.7	75	....	...	..	....	..	.....
.....	140	.....	23.2	77	NE×N	3	8	cu-cunb	3	.....
.....	......	.....	19.2	83	....	...	..	....	..	r-s
.....	......	.....	19.1	84	....	...	..	....	..	r-s
.....	......	.....	17.7	88	E	6	..	....	..	r-s
.....	......	.....	20.3	67	....	...	..	....	..	.....
.....	......	2.53	20.3	67	....	...	..	....	..	.....
.....	......	.....	20.3	67	....	...	..	....	..	.....
.....	550	.....	20.0	68	SE×S	5	6	frcu	3	.....
.....	......	.....	20.8	67	....	...	..	....	..	.....
12.5	......	2.69	20.9	67	....	...	..	....	..	.....
.....	......	.....	20.9	66	....	...	..	....	..	.....
.....	280	.....	20.6	67	SE×S	3	3	frcu	3	.....
.....	......	2.74	21.0	67	....	...	..	....	..	.....
13.3	......	2.72	20.9	67	....	...	..	....	..	.....
.....	270	.....	20.4	68	N×E	3	2	ci	3	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient			Conductivity		Small ions		Mobility	
					Volts	Sail position	V/m	λ_+	λ_-	n_+	n_-	k_+	k_-
								in 10^{-4} esu		per cc		cm/s/v/cm	
1928													
Dec 18	19.7	12.5	31.9 S	251.0	....	....	....	.....	.....	....	....	.....	.....
18	20.8	13.6	31.9 S	251.1	....	....	....	.....	.....	....	....	.....	.....
18	21.7	14.5	32.0 S	251.1	....	....	....	.....	.....	....	....	.....	.....
18	22.7	15.5	32.0 S	251.2	....	....	....	.....	.....	....	....	.....	.....
18	23.8	16.6	32.0 S	251.3	....	....	....	.....	.....	....	....	.....	.....
19	17.4	10.3	32.5 S	252.6	....	....	....	1.01	.....	427	....	1.64	.....
19	17.9	10.7	32.5 S	252.6	64	MUBS	205	.....	0.83	....	322	.....	1.79
20	20.9	13.8	34.2 S	253.4	....	....	....	1.10	.....	415	....	1.84	.....
20	21.5	14.4	34.2 S	253.4	58	MUBS	186	.....	0.81	....	298	.....	1.89
20	22.1	15.0	34.2 S	253.4	....	....	....	1.10	.....	420	....	1.82	.....
21	23.4	16.4	35.5 S	255.1	....	....	....	.....	1.02	....	394	.....	1.80
21	23.7	16.7	35.5 S	255.1	40	MUBS	128	1.18	.....	535	....	1.53	.....
21	0.2	17.1	35.5 S	255.1	....	....	....	.....	1.04	....	432	.....	1.67
22	20.5	13.5	36.9 S	255.9	....	....	....	0.39	.....	173	....	1.57	.....
22	21.2	14.2	36.9 S	255.9	....	....	....	.....	0.17	....	87	.....	1.36
22	21.8	14.9	36.9 S	255.9	....	....	....	0.65	.....	252	....	1.79	.....
23	20.5	13.7	38.8 S	257.2	....	....	....	.....	0.48	....	165	.....	2.02
23	21.0	14.2	38.8 S	257.2	80	MUBS	256	0.81	.....	333	....	1.69	.....
23	21.5	14.7	38.8 S	257.2	....	....	....	.....	0.51	....	206	.....	1.72
24	20.3	13.6	40.0 S	259.2	....	....	....	1.25	.....	521	....	1.67	.....
24	20.8	14.1	40.0 S	259.2	54	MUBS	173	.....	0.95	....	371	.....	1.78
24	21.5	14.8	40.0 S	259.2	....	....	....	1.21	.....	536	....	1.57	.....
25	15.2	8.5	40.3 S	260.7	....	....	....	.....	0.82	....	392	.....	1.45
25	15.5	8.9	40.3 S	260.7	63	MUBS	202	1.10	.....	599	....	1.27	.....
25	15.9	9.3	40.3 S	260.7	....	....	....	.....	0.75	....	377	.....	1.38
26	18.2	11.7	40.4 S	262.5	....	....	....	.....	0.40	....	174	.....	1.60
26	18.8	12.3	40.4 S	262.5	110	MUBS	352	0.72	.....	371	....	1.35	.....
27	16.4	10.0	40.2 S	263.3	....	....	....	.....	.....	....	....	.....	.....
27	17.7	11.3	39.9 S	263.8	....	....	....	0.92	.....	591	....	1.08	.....
27	18.2	11.7	39.9 S	263.8	68	MUBS	218	.....	0.76	....	393	.....	1.34
28	19.7	13.5	38.2 S	266.0	....	....	....	1.05	.....	481	....	1.52	.....
28	20.4	14.1	38.2 S	266.0	51	MUBS	163	.....	0.90	....	353	.....	1.77
28	20.9	14.7	38.2 S	266.0	....	....	....	1.12	.....	505	....	1.54	.....
29	19.8	13.6	36.5 S	267.0	....	....	....	.....	1.01	....	627	.....	1.12
29	20.3	14.1	36.5 S	267.0	66	MUBP	191	1.14	.....	804	....	0.98	.....
29	20.9	14.7	36.5 S	267.0	....	....	....	.....	0.98	....	543	.....	1.25
29	21.2	15.0	36.5 S	267.0	....	....	....	.....	.....	....	....	.....	.....
30	20.2	14.1	34.3 S	268.3	....	....	....	1.27	.....	675	....	1.31	.....
30	20.7	14.6	34.3 S	268.3	58	MUBP	168	.....	1.12	....	578	.....	1.35
30	21.3	15.2	34.3 S	268.3	....	....	....	1.23	.....	677	....	1.26	.....
30	21.8	15.6	34.3 S	268.3	....	....	....	.....	.....	....	....	.....	.....
31	20.3	14.3	32.5 S	270.0	....	....	....	.....	1.30	....	499	.....	1.81
31	20.9	14.9	32.5 S	270.0	50	MUBS	160	1.23	.....	530	....	1.61	.....
31	21.5	15.5	32.5 S	270.0	....	....	....	.....	1.12	....	429	.....	1.81
31	21.9	15.9	32.5 S	270.0	....	....	....	.....	.....	....	....	.....	.....
1929													
Jan 1	16.9	11.0	32.2 S	270.9	....	....	....	.....	0.98	....	402	.....	1.69
1	17.4	11.5	32.2 S	270.9	58	MUBP	168	0.99	.....	606	....	1.13	.....
2	16.2	10.3	31.9 S	271.2	....	....	....	1.03	.....	534	....	1.34	.....
2	16.6	10.7	31.9 S	271.2	58	MUBP	168	.....	0.90	....	451	.....	1.39
3	19.2	13.3	31.9 S	271.8	....	....	....	.....	.....	....	....	.....	.....
3	20.1	14.2	31.9 S	271.8	....	....	....	1.14	.....	406	....	1.95	.....
3	20.6	14.7	31.9 S	271.8	38	MUBS	122	.....	1.10	....	349	.....	2.21
3	21.1	15.2	31.9 S	271.8	....	....	....	1.13	.....	424	....	1.85	.....
3	21.3	15.5	31.9 S	271.8	....	....	....	.....	.....	....	....	.....	.....
4	19.1	13.2	31.7 S	272.8	....	....	....	.....	1.21	.....	369	.....	2.28
4	19.6	13.8	31.7 S	272.8	32	MUBS	102	1.28	.....	651	....	1.36	.....
4	20.1	14.3	31.7 S	272.8	....	....	....	.....	1.25	....	595	.....	1.46
4	20.4	14.6	31.7 S	272.8	....	....	....	.....	.....	....	....	.....	.....
5	19.2	13.5	30.9 S	273.5	....	....	....	1.26	.....	728	....	1.20	.....
5	19.7	14.0	30.9 S	273.5	38	MUBS	122	.....	1.25	....	575	.....	1.51
5	20.3	14.5	30.9 S	273.5	....	....	....	1.29	.....	675	....	1.33	.....
5	20.5	14.7	30.9 S	273.5	....	....	....	.....	.....	....	....	.....	.....
6	19.3	13.6	28.7 S	274.7	....	....	....	.....	0.99	....	527	.....	1.30
6	19.9	14.2	28.7 S	274.7	70	MUBP	203	1.10	.....	585	....	1.31	.....
6	20.4	14.7	28.7 S	274.7	....	....	....	.....	0.87	....	398	.....	1.52
6	20.8	15.2	28.6 S	274.7	....	....	....	.....	.....	....	....	.....	.....
7	19.2	13.6	26.8 S	276.3	....	....	....	1.18	.....	655	....	1.25	.....

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10-7 esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Tem-pera-ture °C	Rel. hum. per cent	Wind		Clouds		Visi-bility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
.....	300	.....	20.6	66	N×E	4	2	ci	3	.....
.....	200	.....	20.7	66	NNE	4	2	ci	3	.....
.....	180	.....	20.6	67	N×E	4	3	ci	3	.....
.....	370	.....	20.8	68	N	3	4	ci-frcu	3	.....
.....	410	.....	20.4	70	N	4	10	ci-cu	3	.....
.....	......	2.58	22.6	71	....	...	..	....	..	.....
12.8	......	2.46	22.1	71	NE×N	1	8	cist-stcu	...	.....
.....	......	.....	20.4	91	....	...	..	....	..	.....
11.8	......	1.85	20.4	91	....	...	..	....	..	.....
.....	......	.....	20.0	91	NE	...	..	....	..	.....
.....	......	.....	20.1	91	....	...	..	....	..	.....
9.4	......	2.65	19.9	92	....	...	..	....	..	.....
.....	......	.....	19.2	95	NE	4	..	....	..	.....
.....	......	.....	17.4	95	....	...	..	....	..	.....
.....	......	2.59	17.4	95	....	...	..	....	..	.....
.....	......	.....	16.2	96	NE	4	..	....	..	f
.....	......	.....	16.6	92	....	...	..	....	..	.....
11.1	......	2.53	16.6	92	....	...	..	....	..	.....
.....	......	.....	16.2	95	NNE	...	..	....	..	.....
.....	......	.....	16.4	86	....	...	..	....	..	.....
12.6	......	2.76	16.4	86	....	...	..	....	..	.....
.....	......	.....	15.9	80	N	...	..	....	..	.....
.....	......	.....	15.6	81	....	...	..	....	..	.....
12.7	......	2.97	15.8	81	....	...	..	....	..	.....
.....	......	.....	15.5	85	N×W	...	..	....	..	.....
.....	......	2.82	17.3	90	....	...	..	....	..	.....
13.1	......	2.68	17.3	84	....	...	..	....	..	.....
.....	390	.....	16.0	94	NW×W	3	1	stcu	3	.....
.....	......	2.65	17.3	85	....	...	..	....	..	.....
12.2	......	2.79	17.3	84	....	...	..	....	..	.....
.....	......	.....	18.6	84	....	...	..	....	..	.....
11.3	......	2.71	18.7	84	....	...	..	....	..	.....
.....	200	.....	18.1	89	W	3	10	cunb-nb	2	.....
.....	......	.....	19.2	77	....	...	..	....	..	.....
13.6	......	2.88	19.1	77	....	...	..	....	..	.....
.....	......	.....	18.8	80	....	...	..	....	..	.....
.....	180	.....	18.2	86	ESE	4	7	cu-cunb	3	.....
.....	......	.....	18.5	77	....	...	..	....	..	.....
13.3	......	2.81	18.6	78	....	...	..	....	..	.....
.....	......	.....	18.7	80	....	...	..	....	..	.....
.....	120	.....	18.6	79	ESE	4	5	frcu	3	.....
.....	......	.....	19.4	76	....	...	..	....	..	.....
13.0	......	2.77	19.3	75	....	...	..	....	..	.....
.....	......	.....	19.8	72	....	...	..	....	..	.....
.....	120	.....	19.8	74	CALM	0	8	stcu-nb	3	.....
.....	......	2.60	23.2	64	....	...	..	....	..	.....
11.0	......	2.73	23.1	67	CALM	0	6	cu	..	.....
.....	......	2.49	22.5	70	....	...	..	....	..	.....
10.8	......	2.66	22.1	68	NNE	1	7	cist-frcu	..	.....
.....	270	.....	21.1	65	NNE	1	6	cu-stcu	3	.....
.....	......	.....	21.8	63	....	...	..	....	..	.....
9.1	......	2.64	21.9	63	....	...	..	....	..	.....
.....	......	.....	21.8	64	....	...	..	....	..	.....
.....	220	.....	22.0	66	NNE	1	7	cu-stcu	3	.....
.....	......	.....	21.3	62	....	...	..	....	..	.....
8.5	......	2.68	21.7	61	....	...	..	....	..	.....
.....	......	.....	21.9	60	....	...	..	....	..	.....
.....	160	.....	21.9	59	NW×W	1	1	frcu	3	.....
.....	......	.....	22.1	72	....	...	..	....	..	.....
10.3	......	2.60	22.0	71	....	...	..	....	..	.....
.....	......	.....	22.0	72	....	...	..	....	..	.....
.....	110	.....	22.1	69	SW×W	3	2	ast-frcu	3	.....
.....	......	.....	22.0	75	....	...	..	....	..	.....
13.7	......	2.57	21.9	76	....	...	..	....	..	.....
.....	......	.....	21.8	75	....	...	..	....	..	.....
.....	120	.....	21.8	72	SE×E	4	4	cu	3	.....
.....	......	.....	19.9	73	....	...	..	....	..	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient Volts	Potential-gradient Sail position	Potential-gradient V/m	Conductivity λ_+ in 10^{-4} esu	Conductivity λ_- in 10^{-4} esu	Small ions n_+ per cc	Small ions n_- per cc	Mobility k_+ cm/s/v/cm	Mobility k_- cm/s/v/cm
1929													
Jan 7	19.8	14.2	26.8 S	276.3	64	MUBP	186	.....	1.00	....	488	.....	1.42
7	20.3	14.7	26.8 S	276.3	....	....	....	1.19	.....	662	....	1.25	.....
7	20.5	14.9	26.8 S	276.3	....	....	....	.....	.....	....	....	.....	.....
8	20.4	14.9	24.9 S	277.8	....	....	....	.....	0.93	....	454	.....	1.42
8	20.9	15.4	24.9 S	277.8	57	MUBP	165	1.07	.....	567	....	1.31	.....
8	21.4	15.9	24.9 S	277.8	....	....	....	.....	0.96	....	496	.....	1.34
8	21.8	16.3	24.9 S	277.8	....	....	....	.....	.....	....	....	.....	.....
9	14.5	9.1	23.3 S	278.7	....	....	....	.....	.....	....	....	.....	.....
9	19.3	13.9	22.9 S	278.8	....	....	....	1.03	.....	611	....	1.17	.....
9	19.8	14.4	22.9 S	278.8	56	MUBP	162	.....	1.00	....	494	.....	1.41
9	20.4	15.0	22.9 S	278.8	....	....	....	1.11	.....	643	....	1.20	.....
9	20.8	15.3	22.9 S	278.8	....	....	....	.....	.....	....	....	.....	.....
10	16.5	11.2	21.4 S	279.6	....	....	....	.....	0.57	....	277	.....	1.43
10	17.1	11.8	21.4 S	279.6	68	MUBP	197	0.65	.....	341	....	1.32	.....
11	16.2	10.9	19.1 S	280.7	....	....	....	0.75	.....	397	....	1.31	.....
11	16.7	11.4	19.1 S	280.7	70	MUBP	203	.....	0.64	....	355	.....	1.25
12	19.3	14.1	16.4 S	281.4	....	....	....	.....	0.67	....	375	.....	1.24
12	20.0	14.7	16.4 S	281.4	74	MUBP	215	0.81	.....	509	....	1.10	.....
12	20.6	15.4	16.4 S	281.4	....	....	....	.....	0.69	....	386	.....	1.24
13	18.1	12.9	14.0 S	282.1	....	....	....	0.74	.....	420	....	1.22	.....
13	18.6	13.4	14.0 S	282.1	84	MUBP	244	.....	0.60	....	334	.....	1.25
13	19.1	13.9	14.0 S	282.1	....	....	....	0.77	.....	455	....	1.17	.....
Feb 6	19.2	13.9	11.7 S	281.2	....	....	....	0.98	.....	553	....	1.23	.....
6	19.8	14.6	11.7 S	281.2	....	....	....	.....	0.98	....	488	.....	1.39
6	20.4	15.1	11.7 S	281.2	....	....	....	1.00	.....	559	....	1.24	.....
6	20.8	15.6	11.7 S	281.2	....	....	....	.....	.....	....	....	.....	.....
7	19.8	14.4	10.1 S	279.8	....	....	....	.....	0.75	....	314	.....	1.66
7	20.4	15.0	10.1 S	279.8	51	MUBS	163	0.90	.....	458	....	1.36	.....
7	20.9	15.6	10.1 S	279.8	....	....	....	.....	0.75	....	267	.....	1.95
7	21.2	15.9	10.1 S	279.8	....	....	....	.....	.....	....	....	.....	.....
8	15.8	10.4	10.0 S	277.8	....	....	....	.....	.....	....	....	.....	.....
8	19.6	14.2	10.0 S	277.6	....	....	....	1.00	.....	387	....	1.79	.....
8	20.2	14.7	10.0 S	277.6	47	MUBS	150	.....	0.84	....	309	.....	1.89
8	20.8	15.3	10.0 S	277.6	....	....	....	1.01	.....	482	....	1.45	.....
8	21.1	15.6	10.0 S	277.6	....	....	....	.....	.....	....	....	.....	.....
9	16.4	10.8	10.4 S	275.8	....	....	....	.....	.....	....	....	.....	.....
9	19.8	14.2	10.5 S	275.7	....	....	....	.....	0.91	....	408	.....	1.55
9	20.3	14.7	10.5 S	275.7	....	....	....	1.00	.....	490	....	1.42	.....
9	20.9	15.2	10.5 S	275.7	....	....	....	.....	0.90	....	405	.....	1.54
9	21.1	15.5	10.5 S	275.7	....	....	....	.....	.....	....	....	.....	.....
10	16.1	10.4	10.8 S	275.0	....	....	....	.....	.....	....	....	.....	.....
10	16.4	10.7	10.8 S	275.0	....	....	....	.....	0.88	....	350	.....	1.75
10	16.8	11.2	10.8 S	275.0	42	MUBS	134	0.98	.....	441	....	1.54	.....
10	17.1	11.4	10.8 S	275.0	....	....	....	.....	.....	....	....	.....	.....
11	16.3	10.6	10.7 S	274.1	....	....	....	0.93	.....	359	....	1.80	.....
11	16.8	11.1	10.7 S	274.1	....	....	....	.....	0.88	....	312	.....	1.96
11	17.1	11.4	10.7 S	274.1	....	....	....	.....	.....	....	....	.....	.....
12	19.6	13.8	11.2 S	272.3	....	....	....	0.99	.....	397	....	1.73	.....
12	20.2	14.4	11.2 S	272.3	....	....	....	.....	0.78	....	236	.....	2.29
12	20.8	15.0	11.2 S	272.3	....	....	....	1.05	.....	379	....	1.92	.....
12	21.1	15.2	11.2 S	272.3	....	....	....	.....	.....	....	....	.....	.....
13	19.6	13.6	12.7 S	270.1	....	....	....	.....	0.89	....	403	.....	1.53
13	20.2	14.2	12.7 S	270.1	54	MUBS	173	1.03	.....	382	....	1.87	.....
13	20.8	14.8	12.7 S	270.1	....	....	....	.....	0.95	....	355	.....	1.86
13	21.1	15.1	12.7 S	270.1	....	....	....	.....	.....	....	....	.....	.....
14	20.2	14.0	14.6 S	267.5	....	....	....	1.09	.....	380	....	1.99	.....
14	20.8	14.6	14.6 S	267.5	57	MUBS	182	.....	0.92	....	278	.....	2.30
14	21.4	15.2	14.6 S	267.5	....	....	....	1.16	.....	360	....	2.24	.....
14	21.7	15.5	14.6 S	267.5	....	....	....	.....	.....	....	....	.....	.....
15	20.2	13.8	15.8 S	264.9	....	....	....	.....	1.14	....	501	.....	1.58
15	20.8	14.4	15.8 S	264.9	47	MUBS	150	1.21	.....	565	....	1.49	.....
15	21.4	15.1	15.8 S	264.9	....	....	....	.....	1.03	....	457	.....	1.57
15	21.8	15.5	15.8 S	264.9	....	....	....	.....	.....	....	....	.....	.....
16	20.4	13.9	15.2 S	262.1	....	....	....	0.95	.....	525	....	1.26	.....
16	21.0	14.4	15.2 S	262.1	54	MUBS	173	.....	0.95	....	508	.....	1.30
16	21.5	15.0	15.2 S	262.1	....	....	....	1.11	.....	598	....	1.29	.....
16	21.8	15.2	15.2 S	262.1	....	....	....	.....	.....	....	....	.....	.....
17	20.6	13.9	14.7 S	258.9	....	....	....	.....	0.81	....	439	.....	1.28

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10^{-7} esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
13.5	......	2.67	19.8	73	....	...	..	....	..	.....
.....	......	.....	19.6	75	....	...	..	....	..	.....
.....	110	.....	19.4	73	SE	5	10	stcu-nb	3	.....
.....	......	.....	19.9	76	....	...	..	....	..	.....
11.1	......	2.49	20.0	77	....	...	..	....	..	.....
.....	......	.....	20.1	76	....	...	..	....	..	.....
.....	180	.....	20.1	75	SE×S	4	1	frcu	3	.....
.....	520	.....	19.9	76	SE×S	4	10	stcu	3	.....
.....	......	.....	20.6	80	....	...	..	....	..	.....
11.2	......	2.80	20.5	78	....	...	..	....	..	.....
.....	......	.....	20.4	76	....	...	..	....	..	.....
.....	200	.....	20.4	74	SE×S	4	7	ast	3	.....
.....	......	.....	20.2	77	....	...	..	....	..	.....
8.0	......	.....	20.4	74	SE	3	10	stcu	..	.....
.....	......	2.58	20.0	74	....	...	..	....	..	.....
9.4	......	2.74	19.9	73	SE×S	5	10	stcu	..	.....
.....	......	.....	22.8	71	....	...	..	....	..	.....
10.7	......	2.74	22.7	72	....	...	..	....	..	.....
.....	......	.....	22.3	73	SE×S	4	..	....	..	.....
.....	......	.....	22.9	78	....	...	..	....	..	.....
11.1	......	2.84	22.9	78	....	...	..	....	..	.....
.....	......	.....	22.9	77	SE	4	..	....	..	.....
.....	......	.....	25.6	75	....	...	..	....	..	.....
.....	......	2.66	25.7	74	....	...	..	....	..	.....
.....	......	.....	25.6	74	....	...	..	....	..	.....
.....	770	.....	25.7	73	SE×S	3	5	cist-cicu	2	.....
.....	......	.....	24.9	79	....	...	..	....	..	.....
9.0	......	2.91	24.8	80	....	...	..	....	..	.....
.....	......	.....	24.7	81	....	...	..	....	..	.....
.....	560	.....	24.7	80	SE×S	3	3	frcu	3	.....
.....	850	.....	25.3	77	SSE	4	4	cist-frcu	3	.....
.....	......	.....	25.2	81	....	...	..	....	..	.....
9.2	......	2.66	25.1	81	....	...	..	....	..	.....
.....	......	.....	24.9	81	....	...	..	....	..	.....
.....	680	.....	24.9	78	S	4	7	cu-frcu	3	.....
.....	450	.....	25.0	76	SE×S	3	3	acu-cu	3	.....
.....	......	.....	25.2	72	....	...	..	....	..	.....
.....	......	2.79	25.0	71	....	...	..	....	..	.....
.....	......	.....	24.8	70	....	...	..	....	..	.....
.....	590	.....	24.7	67	SSE	1	1	frcu	3	.....
.....	940	.....	26.1	68	SE×S	2	1	ast	3	.....
.....	......	2.86	26.3	69	....	...	..	....	..	.....
8.3	......	2.87	26.5	68	....	...	..	....	..	.....
.....	660	.....	26.6	64	SE×S	1	1	ast	3	.....
.....	......	2.23	26.6	69	....	...	..	....	..	.....
.....	......	2.45	26.6	69	....	...	..	....	..	.....
.....	1080	.....	26.7	68	SSE	2	2	cu	3	.....
.....	......	.....	24.2	77	....	...	..	....	..	.....
.....	......	2.46	24.2	76	....	...	..	....	..	.....
.....	......	.....	24.1	75	....	...	..	....	..	.....
.....	990	.....	24.0	74	SE×S	4	2	frcu	3	.....
.....	......	.....	23.8	78	....	...	..	....	..	.....
11.2	......	2.71	23.6	80	....	...	..	....	..	.....
.....	......	.....	23.4	81	....	...	..	....	..	.....
.....	1270	.....	23.2	81	SSE	4	2	cu	3	.....
.....	......	.....	23.4	77	....	...	..	....	..	.....
12.4	......	2.83	23.2	78	....	...	..	....	..	.....
.....	......	.....	23.0	78	....	...	..	....	..	.....
.....	900	.....	22.9	75	SE×S	4	1	stcu	3	.....
.....	......	.....	24.0	66	....	...	..	....	..	.....
11.5	......	2.70	24.0	68	....	...	..	....	..	.....
.....	......	.....	23.8	73	....	...	..	....	..	.....
.....	1640	.....	25.0	63	ESE	4	3	ast	3	.....
.....	......	.....	24.2	75	....	...	..	....	..	.....
11.4	......	.....	24.1	73	....	...	..	....	..	.....
.....	......	.....	24.0	71	....	...	..	....	..	.....
.....	1810	.....	24.0	71	ESE	5	9	stcu	3	.....
.....	......	.....	24.8	73	....	...	..	....	..	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient			Conductivity		Small ions		Mobility	
					Volts	Sail position	V/m	λ+	λ-	n+	n-	k+	k-
								in 10^{-4} esu		per cc		cm/s/v/cm	
1929													
Feb 17	21.2	14.5	14.7 S	258.9	78	MUBS	250	0.82	.....	481	....	1.18	.....
17	21.9	15.1	14.7 S	258.9	....	....	....	.....	0.65	....	368	.....	1.23
17	22.2	15.5	14.7 S	258.9	....	....	....	.....	.....	....	....	.....	.....
18	18.3	11.4	14.3 S	256.7	....	....	....	.....	.....	....	....	.....	.....
18	18.7	11.7	14.3 S	256.7	....	....	....	0.93	.....	527	....	1.22	.....
18	19.1	12.1	14.3 S	256.7	61	MUBS	195	.....	0.89	....	523	.....	1.18
18	19.3	12.4	14.3 S	256.7	....	....	....	.....	.....	....	....	.....	.....
19	18.0	11.1	13.6 S	254.1	....	....	....	.....	0.98	....	505	.....	1.35
19	18.4	11.5	13.6 S	254.1	65	MUBS	208	1.04	.....	659	....	1.10	.....
19	18.7	11.7	13.6 S	254.1	....	....	....	.....	.....	....	....	.....	.....
20	21.1	13.9	13.0 S	251.7	....	....	....	1.19	.....	625	....	1.32	.....
20	21.6	14.4	13.0 S	251.7	33	MUBS	106	.....	1.22	....	598	.....	1.42
20	22.2	15.0	13.0 S	251.7	....	....	....	1.20	.....	628	....	1.33	.....
20	22.5	15.3	13.0 S	251.7	....	....	....	.....	.....	....	....	.....	.....
21	21.4	14.1	12.5 S	249.6	....	....	....	.....	0.96	....	480	.....	1.39
21	22.0	14.6	12.5 S	249.6	37	MDBPC	144	0.95	.....	470	....	1.40	.....
21	22.5	15.2	12.5 S	249.6	....	....	....	.....	0.91	....	448	.....	1.41
21	22.8	15.5	12.5 S	249.6	....	....	....	.....	.....	....	....	.....	.....
22	21.1	13.6	12.6 S	247.5	....	....	....	0.80	.....	432	....	1.29	.....
22	21.8	14.3	12.6 S	247.5	38	MDBPC	148	.....	0.76	....	357	.....	1.48
22	22.6	15.0	12.6 S	247.5	....	....	....	0.85	.....	510	....	1.16	.....
22	22.8	15.3	12.6 S	247.5	....	....	....	.....	.....	....	....	.....	.....
23	21.3	13.7	12.5 S	244.6	....	....	....	.....	0.91	....	415	.....	1.52
23	22.0	14.3	12.5 S	244.6	36	MDBPC	140	0.87	.....	488	....	1.24	.....
23	22.7	15.0	12.5 S	244.6	....	....	....	.....	0.83	....	431	.....	1.34
23	23.0	15.3	12.5 S	244.6	....	....	....	.....	.....	....	....	.....	.....
24	21.5	13.7	12.7 S	242.2	....	....	....	0.78	.....	456	....	1.19	.....
24	22.2	14.4	12.7 S	242.2	38	MDBPC	148	.....	0.74	....	343	.....	1.50
24	22.9	15.0	12.7 S	242.2	....	....	....	0.82	.....	478	....	1.19	.....
24	23.2	15.3	12.7 S	242.2	....	....	....	.....	.....	....	....	.....	.....
25	21.5	13.5	12.8 S	240.5	....	....	....	.....	0.79	....	340	.....	1.61
25	22.1	14.2	12.8 S	240.5	46	MDBPC	179	0.90	.....	490	....	1.28	.....
25	22.8	14.8	12.8 S	240.5	....	....	....	.....	0.85	....	378	.....	1.57
25	23.2	15.2	12.8 S	240.5	....	....	....	.....	.....	....	....	.....	.....
26	19.2	11.0	13.1 S	238.7	....	....	....	.....	.....	....	....	.....	.....
26	19.6	11.4	13.1 S	238.7	....	....	....	.....	0.84	....	373	.....	1.56
26	20.1	12.0	13.1 S	238.7	50	MUBS	160	0.75	.....	....	....	.....	.....
26	21.0	12.8	13.1 S	238.7	....	....	....	0.84	.....	434	....	1.34	.....
27	19.2	11.0	13.5 S	235.8	....	....	....	0.98	.....	518	....	1.31	.....
27	19.7	11.5	13.5 S	235.8	57	MUBS	182	.....	0.92	....	480	.....	1.33
27	20.0	11.8	13.5 S	235.8	....	....	....	.....	.....	....	....	.....	.....
28	22.0	13.6	15.0 S	233.7	....	....	....	1.20	.....	607	....	1.37	.....
28	22.7	14.2	15.0 S	233.7	47	MUBS	150	.....	1.09	....	508	.....	1.49
28	23.3	14.9	15.0 S	233.7	....	....	....	1.21	.....	674	....	1.25	.....
28	23.7	15.3	15.0 S	233.7	....	....	....	.....	.....	....	....	.....	.....
Mar 1	22.0	13.5	16.7 S	231.8	....	....	....	.....	1.01	....	490	.....	1.43
1	22.6	14.0	16.7 S	231.8	50	MUBS	160	1.02	.....	632	....	1.12	.....
1	23.1	14.6	16.7 S	231.8	....	....	....	.....	1.02	....	536	.....	1.32
1	23.3	14.8	16.7 S	231.8	....	....	....	.....	.....	....	....	.....	.....
2	22.1	13.5	17.0 S	230.1	....	....	....	1.02	.....	509	....	1.39	.....
2	22.7	14.0	17.0 S	230.1	32	MDBPC	124	.....	1.00	....	382	.....	1.82
2	23.2	14.6	17.0 S	230.1	....	....	....	0.97	.....	536	....	1.26	.....
2	23.5	14.8	17.0 S	230.1	....	....	....	.....	.....	....	....	.....	.....
3	22.1	13.8	17.1 S	228.2	....	....	....	0.88	.....	496	....	1.23	.....
3	22.7	13.9	17.1 S	228.2	35	MDBPC	136	.....	0.93	....	453	.....	1.42
3	23.2	14.5	17.1 S	228.2	....	....	....	0.93	.....	563	....	1.15	.....
3	23.5	14.7	17.1 S	228.2	....	....	....	.....	.....	....	....	.....	.....
4	22.3	13.4	17.2 S	226.5	....	....	....	.....	0.94	....	405	.....	1.61
4	22.8	13.9	17.2 S	226.5	28	MDBPC	109	1.04	.....	504	....	1.43	.....
4	23.3	14.5	17.2 S	226.5	....	....	....	.....	1.08	....	476	.....	1.58
4	23.6	14.7	17.2 S	226.5	....	....	....	.....	.....	....	....	.....	.....
5	22.5	13.5	17.1 S	224.5	....	....	....	0.94	.....	561	....	1.16	.....
5	23.1	14.1	17.1 S	224.5	40	MDBPC	156	.....	0.99	....	335	.....	2.05
5	23.7	14.7	17.1 S	224.5	....	....	....	1.02	.....	535	....	1.33	.....
5	0.1	15.1	17.1 S	224.5	....	....	....	.....	.....	....	....	.....	.....
6	23.2	14.1	17.2 S	223.1	....	....	....	.....	0.87	....	344	.....	1.76
6	23.8	14.7	17.2 S	233.1	....	....	e	0.93	.....	490	....	1.32	.....
6	0.4	14.2	17.2 S	223.1	....	....	....	.....	0.99	....	415	.....	1.66

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10-7 esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
12.9	.....	.....	24.5	74	....	...	..	....	..	.....
.....	.....	.....	24.2	76	....	...	..	....	..	.....
.....	1600	.....	23.9	76	ESE	5	1	frcu	3	.....
.....	1880	.....	25.1	75	E×S	4	1	cu	3	.....
.....	.....	3.03	.....	...	....	...	..	....	..	.....
11.8	.....	.....	.....	...	....	...	..	....	..	.....
.....	1880	.....	25.0	69	E×S	4	1	frcu	3	.....
.....	.....	.....	.....	...	....	...	..	....	..	.....
14.0	.....	.....	.....	...	....	...	..	....	..	.....
.....	4450	.....	25.9	73	ESE	4	9	stcu-cunb	3	.....
.....	.....	.....	.....	...	....	...	..	....	..	.....
8.6	.....	2.62	.....	...	....	...	..	....	..	.....
.....	.....	.....	.....	...	....	...	..	....	..	.....
.....	3890	.....	25.5	77	SE×E	3	8	cu-stcu	3	.....
.....	.....	.....	.....	...	....	...	..	....	..	.....
9.0	.....	2.52	.....	...	....	...	..	....	..	.....
.....	.....	.....	.....	...	....	...	..	....	..	.....
.....	3480	.....	25.3	70	E×S	4	4	cu	3	.....
.....	.....	.....	26.0	71	....	...	..	....	..	.....
7.8	.....	2.70	26.0	71	....	...	..	....	..	.....
.....	.....	.....	25.9	71	....	...	..	....	..	.....
.....	3270	.....	25.7	71	E×S	4	3	ci-frcu	3	.....
.....	.....	.....	26.2	70	....	...	..	....	..	.....
8.1	.....	2.75	26.1	71	....	...	..	....	..	.....
.....	.....	.....	26.2	72	....	...	..	....	..	.....
.....	3060	.....	26.0	70	SE×E	4	2	frcu	3	.....
.....	.....	.....	26.9	71	....	...	..	....	..	.....
7.6	.....	2.82	26.9	71	....	...	..	....	..	.....
.....	.....	.....	26.9	71	....	...	..	....	..	.....
.....	4380	.....	26.9	70	E×N	4	8	cu-stcu	3	.....
.....	.....	.....	27.3	70	....	...	..	....	..	.....
10.3	.....	2.89	27.3	71	....	...	..	....	..	.....
.....	.....	.....	27.1	71	....	...	..	....	..	.....
.....	4030	.....	27.0	70	E×S	3	5	acu-frcu	3	.....
.....	4520	.....	26.6	74	E×S	4	8	cist-cu	3	.....
.....	.....	2.83	26.6	75	....	...	..	....	..	.....
8.7	.....	2.76	26.8	74	....	...	..	....	..	r
.....	4590	2.73	26.6	73	E×S	3	9	cu-cunb	3	.....
.....	.....	2.89	27.5	68	....	...	..	....	..	.....
11.5	.....	2.87	27.6	67	....	...	..	....	..	.....
.....	4800	.....	27.8	64	E×S	5	1	ci-frcu	3	.....
.....	.....	.....	27.8	68	....	...	..	....	..	.....
11.5	.....	2.83	27.9	66	....	...	..	....	..	.....
.....	.....	.....	27.7	68	....	...	..	....	..	.....
.....	3960	.....	27.7	67	ESE	4	8	cist	2	.....
.....	.....	.....	29.0	67	....	...	..	....	..	.....
10.9	.....	2.75	29.0	67	....	...	..	....	..	.....
.....	.....	.....	28.4	68	....	...	..	....	..	p
.....	3130	.....	28.1	67	ENE	3	7	cu-cunb	3	.....
.....	.....	.....	28.2	69	....	...	..	....	..	.....
8.3	.....	2.91	28.0	72	....	...	..	....	..	.....
.....	.....	.....	27.9	72	....	...	..	....	..	.....
.....	3480	.....	28.1	70	E	4	3	ci-cu	3	.....
.....	.....	.....	29.0	67	....	...	..	....	..	.....
8.3	.....	2.71	29.0	68	....	...	..	....	..	.....
.....	.....	.....	28.9	68	....	...	..	....	..	.....
.....	3480	.....	28.8	60	E×S	3	4	cu	3	.....
.....	.....	.....	.....	...	....	...	..	....	..	.....
7.4	.....	2.69	.....	...	....	...	..	....	..	.....
.....	.....	.....	.....	...	....	...	..	....	..	.....
.....	4380	.....	28.6	68	E×S	3	3	frcu	3	.....
.....	.....	.....	28.9	69	....	...	..	....	..	.....
10.2	.....	2.73	29.0	69	....	...	..	....	..	.....
.....	.....	.....	28.9	70	....	...	..	....	..	.....
.....	4170	.....	29.0	66	E×N	3	3	ci-cu	3	.....
.....	.....	.....	28.7	71	....	...	..	....	..	.....
.....	.....	2.95	29.0	68	....	...	..	....	..	.....
.....	.....	.....	29.1	67	....	...	..	....	..	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient			Conductivity		Small ions		Mobility	
					Volts	Sail position	V/m	λ+	λ-	n_+	n_-	k_+	k_-
								in 10^{-4} esu		per cc		cm/s/v/cm	
1929													
Mar 6	0.7	15.5	17.2 S	223.1	....	....	....	.....	.....	....	....	.....	.....
7	22.9	13.7	17.4 S	220.9	....	....	....	.....	0.99	....	337	.....	2.04
7	23.5	14.3	17.4 S	220.9	....	....	e	0.98	.....	480	....	1.42	.....
7	0.1	14.9	17.4 S	220.9	....	....	....	.....	0.93	....	343	.....	1.88
7	0.3	15.1	17.4 S	220.9	....	....	....	.....	.....	....	....	.....	.....
9	0.1	14.7	17.7 S	217.8	....	....	....	0.99	.....	488	....	1.41	.....
9	0.6	15.2	17.7 S	217.8	30	MDBPC	117	.....	0.97	....	429	.....	1.57
9	1.2	15.7	17.7 S	217.8	....	....	....	1.01	.....	502	....	1.40	.....
9	1.4	15.9	17.7 S	217.8	....	....	....	.....	.....	....	....	.....	.....
10	19.9	10.3	18.0 S	216.1	....	....	....	.....	0.91	....	458	.....	1.38
10	20.3	10.7	18.0 S	216.1	63	MDBPC	246	1.05	.....	588	....	1.24	.....
10	20.5	10.9	18.0 S	216.1	....	....	....	.....	.....	....	....	.....	.....
11	0.6	14.9	18.2 S	213.9	....	....	....	1.15	.....	....	....	.....	.....
11	1.3	15.6	18.2 S	213.9	....	....	....	.....	0.38	....	....	.....	.....
11	1.8	16.1	18.2 S	213.9	....	....	....	0.17	.....	....	....	.....	.....
12	0.1	14.2	17.8 S	211.7	....	....	....	.....	0.89	....	377	.....	1.64
12	0.6	14.7	17.8 S	211.7	57	MDBPC	222	1.09	.....	569	....	1.33	.....
12	1.1	15.2	17.8 S	211.7	....	....	....	.....	1.00	....	425	.....	1.63
12	1.3	15.4	17.8 S	211.7	....	....	....	.....	.....	....	....	.....	.....
12	3.6	17.7	17.7 S	211.5	....	....	....	.....	.....	....	....	.....	.....
12	4.6	18.7	17.7 S	211.4	....	....	....	.....	.....	....	....	.....	.....
12	5.6	19.7	17.7 S	211.3	....	....	....	.....	.....	....	....	.....	.....
22	1.0	14.9	17.6 S	208.2	....	....	....	1.40	.....	622	....	1.56	.....
22	1.5	15.4	17.6 S	208.2	34	MUBP	98	.....	1.29	.....	511	.....	1.77
22	2.0	15.9	17.6 S	208.2	....	....	....	1.41	.....	632	....	1.55	.....
22	2.2	16.1	17.6 S	208.2	....	....	....	.....	.....	....	....	.....	.....
23	0.2	14.0	17.1 S	207.1	....	....	....	.....	1.27	....	454	.....	1.96
23	0.8	14.6	17.1 S	207.1	43	MUBS	138	1.23	.....	555	....	1.54	.....
23	1.3	15.1	17.1 S	207.1	....	....	....	.....	1.28	....	495	.....	1.81
23	1.7	15.5	17.1 S	207.1	....	....	....	.....	.....	....	....	.....	.....
24	0.2	13.9	16.9 S	206.1	....	....	....	1.16	.....	512	....	1.57	.....
24	0.8	14.5	16.9 S	206.1	34	MUBS	109	.....	1.08	....	465	.....	1.61
24	1.3	15.0	16.9 S	206.1	....	....	....	1.15	.....	606	....	1.32	.....
24	1.5	15.2	16.9 S	206.1	....	....	....	.....	.....	....	....	.....	.....
25	20.9	10.5	16.5 S	204.1	....	....	....	.....	0.94	....	429	.....	1.52
25	21.4	11.0	16.5 S	204.1	52	MUBP	151	0.96	.....	497	....	1.34	.....
25	21.7	11.3	16.5 S	204.1	....	....	....	.....	.....	....	....	.....	.....
26	1.0	14.5	16.1 S	201.3	....	....	....	1.12	.....	....	....	.....	.....
26	1.6	15.0	16.1 S	201.3	....	....	....	.....	1.14	....	....	.....	.....
26	2.1	15.5	16.1 S	201.3	....	....	....	1.09	.....	....	....	.....	.....
26	2.4	15.8	16.1 S	201.3	....	....	....	.....	.....	....	....	.....	.....
27	22.0	11.3	15.7 S	199.4	....	....	....	.....	0.86	....	515	.....	1.16
27	22.5	11.8	15.7 S	199.4	44	MDBPC	172	0.93	.....	441	....	1.46	.....
27	22.9	12.2	15.7 S	199.4	....	....	....	.....	.....	....	....	.....	.....
28	0.9	14.0	15.5 S	197.9	....	....	....	1.05	.....	706	....	1.03	.....
28	1.4	14.6	15.5 S	197.9	41	MUBP	119	.....	0.97	....	473	.....	1.42
28	2.0	15.2	15.5 S	197.9	....	....	....	0.95	.....	512	....	1.29	.....
28	2.4	15.6	15.5 S	197.9	....	....	....	.....	.....	....	....	.....	.....
29	0.9	14.0	15.2 S	196.4	....	....	....	.....	0.90	....	381	.....	1.64
29	1.4	14.5	15.2 S	196.4	....	....	e	1.02	.....	485	....	1.46	.....
29	1.8	14.9	15.2 S	196.4	....	....	....	.....	0.90	....	415	.....	1.51
29	2.2	15.3	15.2 S	196.4	....	....	....	.....	.....	....	....	.....	.....
30	0.3	13.2	14.7 S	194.2	....	....	....	1.01	.....	427	....	1.64	.....
30	0.8	13.7	14.7 S	194.2	....	....	e	.....	1.10	....	459	.....	1.66
30	1.3	14.2	14.7 S	194.2	....	....	....	1.16	.....	561	....	1.43	.....
30	1.5	14.5	14.7 S	194.2	....	....	....	.....	.....	....	....	.....	.....
31	0.8	13.6	14.7 S	191.9	....	....	....	.....	0.96	....	481	.....	1.38
31	1.3	14.1	14.7 S	191.9	....	....	....	1.05	.....	486	....	1.49	.....
31	1.8	14.6	14.7 S	191.9	....	....	....	.....	1.02	....	421	.....	1.68
31	2.0	14.8	14.7 S	191.9	....	....	....	.....	.....	....	....	.....	.....
Apr 1	0.7	13.3	14.4 S	189.8	....	....	....	0.93	.....	416	....	1.54	.....
1	1.3	13.9	14.4 S	189.8	....	....	....	.....	0.93	....	362	.....	1.78
1	1.8	14.5	14.4 S	189.8	....	....	....	0.96	.....	434	....	1.53	.....
1	2.2	14.8	14.4 S	189.8	....	....	....	.....	.....	....	....	.....	.....
22	2.0	14.6	12.5 S	188.4	....	....	....	1.15	.....	647	....	1.23	.....
22	2.6	15.1	12.5 S	188.4	....	....	....	.....	1.08	....	....	.....	.....
22	3.2	15.8	12.5 S	188.4	....	....	....	0.67	.....	....	....	.....	.....
23	2.0	14.6	11.0 S	188.5	....	....	....	.....	0.97	....	486	.....	1.39

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10^{-7} esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind Dir.	Wind Force	Clouds Amt.	Clouds Type	Visibility 1-3	Weather notes
.....	2360	.....	30.3	54	NE×E	1	7	cu-cunb	3	.....
.....	......	.....	29.0	67	....	...	..	....	..	.....
.....	......	2.86	29.1	67	....	...	..	....	..	.....
.....	......	.....	29.2	67	....	...	..	....	..	.....
.....	3340	.....	30.3	59	CALM	0	3	cu-cunb	3	.....
.....	......	.....	28.9	69	....	...	..	....	..	.....
7.7	......	2.85	28.8	69	....	...	..	....	..	.....
.....	......	.....	28.7	70	....	...	..	....	..	.....
.....	2430	.....	28.7	60	E	2	8	acu-cunb	3	.....
.....	......	2.97	29.4	71	....	...	..	....	..	.....
16.1	......	2.75	29.3	71	....	...	..	....	..	.....
.....	2290	.....	29.1	71	ENE	3	7	acu-cu	3	.....
.....	......	.....	25.9	82	....	...	..	....	..	s
.....	......	2.91	25.2	84	....	...	..	....	..	r
.....	......	.....	24.8	85	....	...	..	....	..	r
.....	......	.....	27.1	78	....	...	..	....	..	.....
15.1	......	2.81	27.4	77	....	...	..	....	..	.....
.....	......	.....	27.6	76	....	...	..	....	..	.....
.....	2850	.....	27.9	72	N×W	2	9	ast-cunb	2	.....
.....	2990	.....	28.0	71	NW×N	3	7	cu-nb	2	.....
.....	1880	.....	27.9	71	NW×N	3	7	cunb-nb	..	.....
.....	2780	.....	27.8	72	NW×N	3	..	....	..	.....
.....	......	.....	28.1	76	....	...	..	....	..	.....
8.8	......	2.83	28.1	76	....	...	..	....	..	.....
.....	......	.....	28.2	75	....	...	..	....	..	.....
.....	2640	.....	28.2	73	NW	2	3	ci-stcu	3	.....
.....	......	.....	29.7	68	....	...	..	....	..	.....
11.5	......	2.72	29.4	70	....	...	..	....	..	.....
.....	......	.....	29.2	71	....	...	..	....	..	.....
.....	1950	.....	29.1	71	NE×E	1	1	frcu	3	.....
.....	......	.....	28.5	74	....	...	..	....	..	.....
8.1	......	2.76	28.2	76	....	...	..	....	..	.....
.....	......	.....	28.1	78	....	...	..	....	..	.....
.....	2090	.....	28.1	77	SE×S	3	7	ci-cu	3	.....
.....	......	2.44	29.1	77	....	...	..	....	..	.....
9.6	......	2.40	29.3	76	....	...	..	....	..	.....
.....	3540	.....	29.6	74	E×N	4	8	ci-cu	2	.....
.....	......	.....	29.0	...	....	...	..	....	..	q
.....	......	2.93	29.0	...	....	...	..	....	..	q
.....	......	.....	28.8	...	....	...	..	....	..	q
.....	2430	.....	28.8	77	E×S	4	7	ci-cunb	3	.....
.....	......	2.97	28.9	80	....	...	..	....	..	.....
10.3	......	2.91	28.9	80	....	...	..	....	..	.....
.....	1460	.....	29.0	79	NE×E	4	5	ci-cu	3	.....
.....	......	.....	29.7	70	....	...	..	....	..	.....
7.8	......	2.84	29.7	72	....	...	..	....	..	.....
.....	......	.....	29.7	72	....	...	..	....	..	.....
.....	3540	.....	29.7	67	NE×E	2	7	cu-cunb	3	.....
.....	......	.....	30.4	70	....	...	..	....	..	.....
.....	......	.....	29.7	72	....	...	..	....	..	.....
.....	......	.....	29.1	74	....	...	..	....	..	.....
.....	1880	.....	29.1	73	CALM	0	3	cu-cunb	3	.....
.....	......	.....	30.0	69	....	...	..	....	..	.....
.....	......	.....	28.9	75	....	...	..	....	..	.....
.....	......	.....	28.1	79	....	...	..	....	..	.....
.....	1740	.....	27.9	79	S×W	2	7	cu-stcu	3	.....
.....	......	.....	29.1	76	....	...	..	....	..	.....
.....	......	.....	29.1	76	....	...	..	....	..	.....
.....	......	.....	29.0	75	....	...	..	....	..	.....
.....	1460	.....	29.0	74	N×E	3	5	cu-cunb	3	.....
.....	......	.....	.....	....	....	...	..	....	..	.....
.....	......	.....	.....	....	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	1250	.....	29.0	74	NW×N	2	7	ci-cu	3	.....
.....	......	.....	28.6	76	....	...	..	....	..	q
.....	......	.....	27.7	78	....	...	..	....	..	q
.....	......	.....	25.8	87	....	...	..	....	..	r
.....	......	.....	29.1	79	....	...	..	....	..	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient Volts	Sail position	V/m	Conductivity λ_+ (in 10^{-4} esu)	λ_-	Small ions n_+ (per cc)	n_-	Mobility k_+ (cm/s/v/cm)	k_-
1929													
Apr 23	2.5	15.1	11.0 S	188.5	45	MUBP	130	1.07	.....	663	....	1.12	.....
23	3.0	15.6	11.0 S	188.5	....	....	....	.....	0.96	....	554	.....	1.20
23	3.2	15.8	11.0 S	188.5	....	....	....	.....	.....	....	....	.....	.....
24	2.1	14.7	8.4 S	188.8	....	....	....	0.84	.....	....	....	.....	.....
24	2.7	15.3	8.4 S	188.8	....	....	....	.....	0.88	....	449	.....	1.36
24	3.2	15.8	8.4 S	188.8	....	....	....	1.06	.....	530	....	1.39	.....
24	3.4	16.0	8.4 S	188.8	....	....	....	.....	.....	....	....	.....	.....
25	1.3	13.8	7.4 S	188.1	....	....	....	.....	0.92	....	543	.....	1.17
25	1.8	14.4	7.4 S	188.1	47	MUBS	150	0.87	.....	582	....	1.04	.....
25	2.4	15.0	7.4 S	188.1	....	....	....	.....	0.83	....	509	.....	1.13
25	2.7	15.2	7.4 S	188.1	....	....	....	.....	.....	....	....	.....	.....
26	1.4	13.9	6.5 S	187.6	....	....	....	0.66	.....	....	....	.....	.....
26	2.0	14.5	6.5 S	187.6	....	....	....	.....	0.95	....	....	.....	.....
26	2.6	15.1	6.5 S	187.6	....	....	....	0.94	.....	....	....	.....	.....
26	2.8	15.3	6.5 S	187.6	....	....	....	.....	.....	....	....	.....	.....
27	0.9	13.4	5.0 S	187.6	....	....	....	.....	1.11	....	440	.....	1.75
27	1.3	13.8	5.0 S	187.6	47	MUBP	136	1.05	.....	514	....	1.42	.....
27	1.8	14.3	5.0 S	187.6	....	....	....	.....	1.07	....	508	.....	1.46
27	2.0	14.5	5.0 S	187.6	....	....	....	.....	.....	....	....	.....	.....
28	1.3	13.8	3.6 S	187.3	....	....	....	0.99	.....	494	....	1.39	.....
28	1.8	14.3	3.6 S	187.3	37	MUBP	107	.....	0.92	....	371	.....	1.72
28	2.4	14.8	3.6 S	187.3	....	....	....	0.97	.....	492	....	1.37	.....
28	2.8	15.2	3.6 S	187.3	....	....	....	.....	.....	....	....	.....	.....
29	1.0	13.4	1.6 S	186.5	....	....	....	.....	0.81	....	392	.....	1.44
29	1.6	14.0	1.6 S	186.5	43	MUBP	125	0.95	.....	481	....	1.36	.....
29	2.1	14.5	1.6 S	186.5	....	....	....	.....	0.88	....	419	.....	1.46
29	2.5	14.9	1.6 S	186.5	....	....	....	.....	.....	....	....	.....	.....
30	23.1	11.5	0.4 N	186.0	....	....	....	.....	0.74	....	400	.....	1.28
30	23.6	12.0	0.4 N	186.0	49	MUBP	142	0.85	.....	470	....	1.26	.....
30	23.8	12.2	0.4 N	186.0	....	....	....	.....	.....	....	....	.....	.....
May 1	21.7	10.1	2.3 N	185.0	....	....	....	.....	.....	....	....	.....	.....
1	22.4	10.8	2.4 N	185.0	....	....	....	1.31	.....	....	....	.....	.....
1	22.9	11.2	2.4 N	185.0	51	MUBP	148	.....	1.18	....	....	.....	.....
2	22.8	11.0	4.5 N	183.5	....	....	....	.....	.....	....	....	.....	.....
2	4.2	16.4	4.5 N	183.5	....	....	....	0.80	.....	....	....	.....	.....
2	4.7	16.9	4.5 N	183.5	....	....	....	.....	0.92	....	....	.....	.....
3	1.4	13.5	6.7 N	182.1	....	....	....	.....	0.73	....	452	.....	1.12
3	2.1	14.3	6.7 N	182.1	47	MUBP	136	0.98	.....	555	....	1.23	.....
3	2.8	14.9	6.7 N	182.1	....	....	....	.....	0.87	....	473	.....	1.27
3	3.2	15.3	6.7 N	182.1	....	....	....	.....	.....	....	....	.....	.....
4	1.5	13.6	8.3 N	180.9	....	....	....	1.06	.....	561	....	1.31	.....
4	2.0	14.1	8.3 N	180.9	36	MUBP	104	.....	0.96	....	456	.....	1.46
4	2.6	14.6	8.3 N	180.9	....	....	....	0.99	.....	....	....	.....	.....
4	3.2	15.2	8.3 N	180.9	....	....	....	.....	.....	....	....	.....	.....
5	1.6	13.6	11.1 N	179.2	....	....	....	.....	1.07	....	468	.....	1.59
5	2.2	14.1	11.1 N	179.2	50	MUBP	145	1.21	.....	550	....	1.53	.....
5	2.7	14.7	11.1 N	179.2	....	....	....	.....	1.14	....	484	.....	1.63
5	3.2	15.1	11.1 N	179.2	....	....	....	.....	.....	....	....	.....	.....
Crossed International Date Line													
7	1.6	13.4	13.7 N	177.1	....	....	....	1.21	.....	683	....	1.23	.....
7	2.1	13.9	13.7 N	177.1	57	MUBP	165	.....	1.01	....	503	.....	1.39
7	2.7	14.5	13.7 N	177.1	....	....	....	1.17	.....	569	....	1.43	.....
7	3.1	14.9	13.7 N	177.1	....	....	....	.....	.....	....	....	.....	.....
8	1.8	13.4	15.5 N	174.5	....	....	....	.....	1.13	....	570	.....	1.38
8	2.3	13.9	15.5 N	174.5	38	MUBP	110	1.18	.....	682	....	1.20	.....
8	2.8	14.4	15.5 N	174.5	....	....	....	.....	1.10	....	621	.....	1.23
8	3.2	14.8	15.5 N	174.5	....	....	....	.....	.....	....	....	.....	.....
9	23.7	11.1	16.5 N	171.8	....	....	....	.....	1.15	....	617	.....	1.29
9	0.2	11.6	16.5 N	171.8	45	MUBP	130	1.25	.....	686	....	1.25	.....
9	0.5	11.9	16.5 N	171.8	....	....	....	.....	.....	....	....	.....	.....
10	23.0	10.4	18.3 N	169.2	....	....	....	1.18	.....	576	....	1.42	.....
10	23.4	10.8	18.3 N	169.2	49	MUBP	142	.....	1.05	....	539	.....	1.35
10	23.7	11.0	18.3 N	169.2	....	....	....	.....	.....	....	....	.....	.....
11	22.1	9.2	19.3 N	166.6	....	....	....	1.24	.....	610	....	1.41	.....
11	22.6	9.7	19.3 N	166.6	44	MUBP	128	.....	1.28	....	686	.....	1.30
11	23.1	10.2	19.3 N	166.6	....	....	....	1.34	.....	832	....	1.12	.....
11	23.4	10.5	19.3 N	166.6	....	....	....	.....	.....	....	....	.....	.....
12	2.7	13.6	20.3 N	163.4	....	....	....	.....	1.25	....	628	.....	1.38

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10^{-7} esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
8.8	......	3.00	29.1	79	....	...	..	....	..	.....
.....	......	.....	29.1	79	....	...	..	....	..	.....
.....	2990	.....	29.1	77	SSE	4	8	cu-cunb	2	.....
.....	......	.....	27.1	85	....	...	..	....	..	r
.....	......	2.73	27.5	83	....	...	..	....	..	.....
.....	......	.....	28.1	82	....	...	..	....	..	.....
.....	1600	.....	28.1	81	ENE	3	4	acu-stcu	3	.....
.....	......	.....	31.0	69	....	...	..	....	..	.....
8.7	......	.....	30.7	70	....	...	..	....	..	.....
.....	......	.....	30.0	74	....	...	..	....	..	.....
.....	2920	.....	29.8	72	NE×N	1	7	cu-stcu	3	.....
.....	......	.....	28.1	79	....	...	..	....	..	r
.....	......	.....	27.8	80	....	...	..	....	..	r
.....	......	.....	27.8	80	....	...	..	....	..	r
.....	1810	.....	27.1	82	NW×N	1	7	cu-nb	3	.....
.....	......	.....	30.2	69	....	...	..	....	..	.....
9.7	......	.....	30.3	68	....	...	..	....	..	.....
.....	......	.....	29.4	68	....	...	..	....	..	.....
.....	1530	.....	29.0	75	CALM	0	10	cu-nb	3	.....
.....	......	.....	28.8	75	....	...	..	....	..	.....
6.8	......	2.94	28.7	75	....	...	..	....	..	.....
.....	......	.....	28.6	76	....	...	..	....	..	.....
.....	710	.....	28.6	74	E×N	3	2	frcu	3	.....
.....	......	.....	28.1	80	....	...	..	....	..	.....
7.5	......	2.92	28.0	81	....	...	..	....	..	.....
.....	......	.....	28.0	80	....	...	..	....	..	.....
.....	770	.....	28.0	78	E×N	4	3	cu-frcu	3	.....
.....	......	2.81	27.7	80	....	...	..	....	..	.....
7.5	......	2.74	27.8	78	....	...	..	....	..	.....
.....	990	.....	27.9	76	E×S	5	0	....	3	.....
.....	1530	.....	27.0	85	ENE	4	3	cu-cunb	3	.....
.....	......	3.00	27.8	82	....	...	..	....	..	r
12.3	......	2.90	27.9	81	....	...	..	....	..	r
.....	2290	.....	28.5	82	NE×E	4	8	cu-cunb	3	.....
.....	......	.....	27.3	85	....	...	..	....	..	r
.....	......	2.85	26.3	91	....	...	..	....	..	r
.....	......	.....	27.6	81	....	...	..	....	..	.....
8.1	......	3.04	27.2	84	....	...	..	....	..	.....
.....	......	.....	27.6	81	....	...	..	....	..	.....
.....	1670	.....	27.8	80	NE×E	5	9	cu-cunb	3	.....
.....	......	.....	27.9	79	....	...	..	....	..	.....
6.8	......	3.36	27.9	79	....	...	..	....	..	.....
.....	......	.....	27.3	80	....	...	..	....	..	r
.....	260	.....	26.9	80	NE×E	4	10	cu-cunb	2	.....
.....	......	.....	27.2	78	....	...	..	....	..	.....
11.2	......	3.06	27.1	79	....	...	..	....	..	.....
.....	......	.....	26.9	78	....	...	..	....	..	.....
.....	280	.....	26.9	79	ENE	6	4	frcu	3	.....
.....	......	.....	26.9	79	....	...	..	....	..	.....
12.1	......	2.97	26.8	79	....	...	..	....	..	.....
.....	......	.....	26.6	80	....	...	..	....	..	.....
.....	1670	.....	25.4	81	E×N	5	6	cu	2	.....
.....	......	.....	26.4	78	....	...	..	....	..	.....
8.4	......	2.94	26.4	78	....	...	..	....	..	.....
.....	......	.....	26.3	79	....	...	..	....	..	.....
.....	1390	.....	26.2	77	ENE	5	6	cist-cu	3	.....
.....	......	3.14	26.1	81	....	...	..	....	..	.....
10.4	......	3.21	26.2	81	....	...	..	....	..	.....
.....	2090	.....	26.2	82	E×N	5	5	cu	3	.....
.....	......	3.06	26.4	74	....	...	..	....	..	.....
10.6	......	2.95	26.5	73	....	...	..	....	..	.....
.....	2220	.....	26.7	73	E×N	5	7	cist-frcu	3	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
11.0	......	3.08	.....	...	....	...	..	....	..	.....
.....	......	.....	.....	...	....	...	..	....	..	.....
.....	2090	.....	26.0	73	NE×E	4	3	ci-cu	3	.....
.....	......	.....	26.6	72	....	...	..	....	.	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient			Conductivity		Small ions		Mobility	
					Volts	Sail position	V/m	λ_+	λ_-	n_+	n_-	k_+	k_-
								in 10^{-4} esu		per cc		cm/s/v/cm	
1929													
May 12	3.2	14.1	20.3 N	163.4	32	MUBP	93	1.29	.....	719	....	1.24	.....
12	3.7	14.6	20.3 N	163.4	....	....	....	.....	1.31	....	712	.....	1.28
12	4.0	14.8	20.3 N	163.4	....	....	....	.....	.....	....	....	.....	.....
13	2.6	13.3	20.2 N	160.9	....	....	....	1.24	.....	735	....	1.17	.....
13	3.1	13.8	20.2 N	160.9	35	MUBP	102	.....	1.25	....	725	.....	1.20
13	3.6	14.4	20.2 N	160.9	....	....	....	1.27	.....	972	....	1.11	.....
13	3.9	14.6	20.2 N	160.9	....	....	....	.....	.....	....	....	.....	.....
14	2.7	13.3	19.4 N	158.2	....	....	....	.....	1.04	....	570	.....	1.27
14	3.3	13.8	19.4 N	158.2	47	MUBS	150	1.11	.....	693	....	1.11	.....
14	3.9	14.4	19.4 N	158.2	....	....	....	.....	1.03	....	624	.....	1.15
14	4.2	14.8	19.4 N	158.2	....	....	....	.....	.....	....	....	.....	.....
15	3.2	13.6	18.5 N	155.8	....	....	....	1.32	.....	750	....	1.22	.....
15	3.8	14.2	18.5 N	155.8	30	MUBS	96	.....	1.19	....	644	.....	1.28
15	4.3	14.7	18.5 N	155.8	....	....	....	1.33	.....	729	....	1.27	.....
15	4.7	15.1	18.5 N	155.8	....	....	....	.....	.....	....	....	.....	.....
16	3.6	13.8	17.3 N	153.2	....	....	....	.....	1.19	....	676	.....	1.22
16	4.1	14.4	17.3 N	153.2	28	MUBS	90	1.21	.....	723	....	1.16	.....
16	4.7	14.9	17.3 N	153.2	....	....	....	.....	1.18	....	664	.....	1.23
16	5.1	15.4	17.3 N	153.2	....	....	....	.....	.....	....	....	.....	.....
17	0.8	10.8	16.2 N	151.1	....	....	....	.....	0.90	....	510	.....	1.23
17	1.3	11.2	16.2 N	151.1	32	MUBS	102	1.04	.....	532	....	1.36	.....
18	0.3	10.3	15.0 N	148.4	....	....	....	1.09	.....	623	....	1.22	.....
18	0.7	10.6	15.0 N	148.4	33	MUBS	106	.....	1.07	....	599	.....	1.24
18	0.9	10.9	15.0 N	148.4	....	....	....	.....	.....	....	....	.....	.....
18	3.7	13.5	14.8 N	148.0	....	....	....	.....	.....	....	....	.....	.....
18	6.1	15.9	14.7 N	147.8	....	....	....	.....	.....	....	....	.....	.....
19	21.3	7.1	14.1 N	146.2	....	....	....	.....	.....	....	....	.....	.....
19	3.5	13.2	14.0 N	145.8	....	....	....	1.28	.....	688	....	1.29	.....
19	4.0	13.7	14.0 N	145.8	31	MUBS	99	.....	1.19	....	688	.....	1.20
19	4.6	14.3	14.0 N	145.8	....	....	....	1.14	.....	730	....	1.08	.....
19	4.9	14.6	14.0 N	145.8	....	....	....	.....	.....	....	....	.....	.....
26	4.4	14.0	16.4 N	144.1	....	....	....	1.10	.....	579	....	1.32	.....
26	5.0	14.6	16.4 N	144.1	64	MUBP	186	.....	0.85	....	433	.....	1.36
26	5.5	15.1	16.4 N	144.1	....	....	....	1.00	.....	553	....	1.25	.....
26	5.8	15.4	16.4 N	144.1	....	....	....	.....	.....	....	....	.....	.....
27	1.7	11.3	18.5 N	144.0	....	....	....	.....	1.02	....	446	.....	1.59
27	2.2	11.8	18.5 N	144.0	56	MUBP	162	1.21	.....	581	....	1.37	.....
27	2.5	12.1	18.5 N	144.0	....	....	....	.....	.....	....	....	.....	.....
28	1.2	10.8	21.3 N	144.2	....	....	....	1.34	.....	712	....	1.31	.....
28	1.6	11.2	21.3 N	144.2	59	MUBP	171	.....	1.16	....	586	.....	1.37
28	2.0	11.6	21.3 N	144.2	....	....	....	.....	.....	....	....	.....	.....
29	3.8	13.4	23.6 N	144.0	....	....	....	1.28	.....	659	....	1.35	.....
29	4.4	14.0	23.6 N	144.0	59	MUBP	171	.....	1.14	....	566	.....	1.40
29	5.0	14.6	23.6 N	144.0	....	....	....	1.27	.....	680	....	1.30	.....
29	5.4	15.0	23.6 N	144.0	....	....	....	.....	.....	....	....	.....	.....
30	1.3	10.9	25.2 N	144.1	....	....	....	.....	.....	....	....	.....	.....
30	2.0	11.6	25.2 N	144.1	....	....	....	.....	.....	....	....	.....	.....
30	2.1	11.7	25.2 N	144.1	....	....	....	.....	.....	....	....	.....	.....
30	3.9	13.5	25.4 N	144.2	....	....	....	.....	1.31	....	673	.....	1.35
30	4.4	14.0	25.4 N	144.2	34	MUBP	99	1.31	.....	746	....	1.22	.....
30	4.9	14.5	25.4 N	144.2	....	....	....	.....	1.32	....	697	.....	1.32
30	5.3	15.0	25.4 N	144.2	....	....	....	.....	.....	....	....	.....	.....
31	3.8	13.4	26.5 N	144.4	....	....	....	1.04	.....	660	....	1.10	.....
31	4.3	13.9	26.5 N	144.4	42	MUBP	122	.....	1.07	....	565	.....	1.32
31	4.8	14.5	26.5 N	144.4	....	....	....	1.07	.....	635	....	1.17	.....
31	5.3	14.9	26.5 N	144.4	....	....	....	.....	.....	....	....	.....	.....
June 1	3.8	13.4	28.7 N	143.9	....	....	....	.....	0.90	....	454	.....	1.38
1	4.3	13.9	28.7 N	143.9	46	MUBS	147	1.06	.....	683	....	1.08	.....
1	4.8	14.4	28.7 N	143.9	....	....	....	.....	1.00	....	485	.....	1.43
1	5.3	14.9	28.7 N	143.9	....	....	....	.....	.....	....	....	.....	.....
2	3.8	13.4	30.3 N	144.1	....	....	....	0.94	.....	351	....	1.86	.....
2	4.5	14.1	30.3 N	144.1	58	MUBS	186	.....	0.58	....	220	.....	1.83
2	5.3	14.9	30.3 N	144.1	....	....	....	0.73	.....	298	....	1.70	.....
2	5.7	15.3	30.3 N	144.1	....	....	....	.....	.....	....	....	.....	.....
3	1.2	10.9	31.0 N	144.3	....	....	....	.....	.....	....	....	.....	.....
3	2.0	11.6	31.0 N	144.3	....	....	....	.....	.....	....	....	.....	.....
3	3.9	13.6	31.3 N	144.2	....	....	....	.....	0.27	....	126	.....	1.48
3	5.0	14.6	31.3 N	144.2	88	MUBS	282	0.34	.....	177	....	1.33	.....

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10-7esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
8.0	......	3.00	26.6	72	....	...	..	....	..	.....
.....	......	.....	26.4	71	....	...	..	....	..	.....
.....	2850	.....	26.3	79	ENE	3	7	ast-stcu	3	.....
.....	......	.....	26.4	75	....	...	..	....	..	.....
8.5	......	3.10	26.5	74	....	...	..	....	..	.....
.....	......	.....	26.5	74	....	...	..	....	..	.....
.....	3200	.....	26.4	74	ENE	4	3	cu	3	.....
.....	......	.....	27.0	74	....	...	..	....	..	.....
10.7	......	2.93	26.9	74	....	...	..	....	..	.....
.....	......	.....	26.8	76	....	...	..	....	..	.....
.....	2500	.....	26.8	73	ESE	5	4	ci-frcu	3	.....
.....	......	.....	27.0	79	....	...	..	....	..	.....
8.1	......	2.96	27.0	79	....	...	..	....	..	.....
.....	......	.....	27.0	79	....	...	..	....	..	.....
.....	2430	.....	27.0	78	SE×S	4	2	frcu-cunb	3	.....
.....	......	.....	27.8	79	....	...	..	....	..	.....
7.2	......	2.89	27.7	79	....	...	..	....	..	.....
.....	......	.....	27.5	78	....	...	..	....	..	.....
.....	3270	.....	27.6	77	ESE	4	6	cicu-frcu	3	.....
.....	......	2.68	27.5	77	....	...	..	....	..	.....
6.6	3270	2.77	27.7	74	ESE	4	8	ast-stcu	2	.....
.....	......	3.10	28.4	72	....	...	..	....	..	.....
7.6	......	3.04	28.4	72	....	...	..	....	..	.....
.....	13100	.....	28.7	70	E	4	8	cist-cu	2	.....
.....	12100	.....	28.2	77	E	4	10	ast-frcu	2	.....
.....	11720	.....	28.0	78	E	4	10	ast-cu	2	.....
.....	2500	.....	27.9	77	E	4	7	cu-frcu	3	.....
.....	......	.....	29.0	74	....	...	..	....	..	.....
7.9	......	2.90	28.9	74	....	...	..	....	..	.....
.....	......	.....	28.7	75	....	...	..	....	..	.....
.....	5000	.....	28.4	76	E×N	4	6	ast-cu	2	.....
.....	......	.....	28.9	74	....	...	..	....	..	.....
11.8	......	3.16	28.6	75	....	...	..	....	..	.....
.....	......	.....	28.4	76	....	...	..	....	..	.....
.....	4170	.....	28.3	76	E	4	2	cu-frcu	3	.....
.....	......	3.09	28.9	73	....	...	..	....	..	.....
12.0	......	2.97	28.9	74	....	...	..	....	..	.....
.....	3680	.....	28.9	74	E	4	6	ci-cu	3	.....
.....	......	2.92	29.1	72	....	...	..	....	..	.....
14.2	......	2.92	29.1	72	....	...	..	....	..	.....
.....	15620	.....	29.0	71	E	4	2	ci-frcu	3	.....
.....	......	.....	28.1	77	....	...	..	....	..	.....
13.8	......	3.00	28.1	77	....	...	..	....	..	.....
.....	......	.....	28.0	78	....	...	..	....	..	.....
.....	17260	.....	27.8	75	SE×S	4	1	frcu	3	.....
.....	......	2.86	28.2	76	....	...	..	....	..	.....
.....	14490	.....	27.7	73	SSE	3	3	ci	3	.....
.....	17260	.....	27.7	73	SSE	3	3	ci	3	.....
.....	......	.....	28.7	75	....	...	..	....	..	.....
8.6	......	3.10	29.1	73	....	...	..	....	..	.....
.....	......	.....	29.1	74	....	...	..	....	..	.....
.....	21720	.....	29.1	71	SSE	3	3	ci	3	.....
.....	......	.....	27.7	82	....	...	..	....	..	.....
8.6	......	2.83	27.7	82	....	...	..	....	..	.....
.....	......	.....	27.4	82	....	...	..	....	..	.....
.....	12980	.....	27.1	79	S	2	8	ci-cist	3	.....
.....	......	.....	25.3	87	....	...	..	....	..	.....
9.8	......	2.91	25.3	87	....	...	..	....	..	.....
.....	......	.....	25.2	86	....	...	..	....	..	.....
.....	10840	.....	25.0	83	SW	4	10	ast	2	.....
.....	......	.....	20.8	84	....	...	..	....	..	.....
8.8	......	3.02	20.7	82	....	...	..	....	..	.....
.....	......	.....	20.9	81	....	...	..	....	..	.....
.....	8690	.....	20.8	77	NW×N	3	9	ast	2	.....
.....	......	3.08	20.7	82	....	...	..	....	..	.....
.....	10460	.....	20.9	79	....	...	8	ci-cist	2	.....
.....	......	.....	20.8	86	....	...	..	....	..	.....
5.6	8440	.....	20.7	86	W×S	4	3	ci	2	z

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient Volts	Sail position	V/m	Conductivity λ+ (in 10⁻⁴ esu)	λ-	Small ions n+ (per cc)	n-	Mobility k+ (cm/s/v/cm)	k-
1929													
June 3	6.2	15.8	31.3 N	144.2	....	....	....	.....	0.25	....	149	.....	1.17
4	4.1	13.6	32.8 N	142.1	....	....	....	0.32	.....	145	....	1.53	.....
4	5.0	14.5	32.8 N	142.1	106	MUBS	339	.....	0.25	....	125	.....	1.39
4	5.9	15.4	32.8 N	142.1	....	....	....	0.32	.....	164	....	1.35	.....
5	23.9	9.4	33.8 N	141.3	....	....	....	.....	.....	....	....	.....	.....
5	0.7	10.1	33.8 N	141.3	....	....	....	.....	.....	....	....	.....	.....
5	4.0	13.4	34.1 N	141.0	....	....	....	.....	0.48	....	207	.....	1.61
5	4.8	14.2	34.1 N	141.0	45	MUBS	144	0.66	.....	313	....	1.46	.....
5	5.5	14.9	34.1 N	141.0	....	....	....	.....	0.60	....	259	.....	1.61
25	5.9	15.3	34.8 N	141.2	....	....	....	.....	.....	....	....	.....	.....
26	4.4	13.9	36.1 N	142.3	....	....	....	0.45	.....	257	....	1.21	.....
26	5.1	14.6	36.1 N	142.3	92	MUBP	267	.....	0.40	....	266	.....	1.05
26	5.8	15.3	36.1 N	142.3	....	....	....	0.50	.....	314	....	1.11	.....
27	4.1	13.7	36.7 N	143.8	....	....	....	.....	0.42	....	235	.....	1.24
27	4.9	14.5	36.7 N	143.8	62	MUBP	180	0.51	.....	311	....	1.14	.....
27	5.7	15.3	36.7 N	143.8	....	....	....	.....	0.46	....	270	.....	1.18
28	9.0	18.7	36.8 N	145.4	....	....	....	.....	.....	....	....	.....	.....
28	9.7	19.4	36.8 N	145.4	....	....	....	0.33	.....	....	....	.....	.....
28	10.3	20.0	36.8 N	145.4	93	MUBP	270	.....	0.25	....	....	.....	.....
29	4.0	13.7	37.9 N	145.5	....	....	....	.....	0.36	....	265	.....	0.94
29	4.6	14.3	37.9 N	145.5	95	MUBP	276	0.47	.....	306	....	1.07	.....
29	5.2	14.9	37.9 N	145.5	....	....	....	.....	0.36	....	243	.....	1.03
30	3.8	13.6	38.2 N	147.1	....	....	....	0.58	.....	326	....	1.24	.....
30	4.5	14.3	38.2 N	147.1	85	MUBP	246	.....	0.47	....	246	.....	1.32
30	5.1	15.0	38.2 N	147.1	....	....	....	0.54	.....	382	....	0.98	.....
30	7.6	17.5	38.3 N	147.3	....	....	....	.....	.....	....	....	.....	.....
July 1	3.7	13.6	38.8 N	147.8	....	....	....	.....	0.41	....	172	.....	1.67
1	4.4	14.2	38.8 N	147.8	95	MUBP	276	0.61	.....	375	....	1.13	.....
1	5.0	14.9	38.8 N	147.8	....	....	....	.....	0.51	....	293	.....	1.21
2	3.5	13.4	39.9 N	149.6	....	....	....	0.56	.....	498	....	0.78	.....
2	4.1	14.1	39.9 N	149.6	110	MUBP	319	.....	0.38	....	220	.....	1.20
2	4.9	14.8	39.9 N	149.6	....	....	....	0.62	.....	529	....	0.81	.....
3	0.1	10.2	40.3 N	151.0	....	....	....	.....	.....	....	....	.....	.....
3	1.8	12.0	40.4 N	151.1	....	....	....	.....	0.72	....	480	.....	1.04
3	2.3	12.4	40.4 N	151.1	71	MUBP	206	0.81	.....	574	....	0.98	.....
3	2.5	12.6	40.4 N	151.1	....	....	....	.....	.....	....	....	.....	.....
4	1.3	11.4	41.4 N	153.3	....	....	....	0.75	.....	....	....	.....	.....
4	1.8	11.9	41.4 N	153.3	59	MUBP	171	.....	0.63	....	....	.....	.....
4	2.2	12.3	41.4 N	153.3	....	....	....	.....	.....	....	....	.....	.....
5	3.6	14.0	42.8 N	155.9	....	....	....	0.42	.....	....	....	.....	.....
5	4.3	14.7	42.8 N	155.9	118	MUBP	342	.....	0.28	....	....	.....	.....
5	5.1	15.5	42.8 N	155.9	....	....	....	0.44	.....	....	....	.....	.....
6	3.2	13.7	43.9 N	158.3	....	....	....	.....	0.46	....	....	.....	.....
6	3.7	14.2	43.9 N	158.3	70	MUBP	203	0.66	.....	....	....	.....	.....
6	4.1	14.7	43.9 N	158.3	....	....	....	.....	0.67	....	....	.....	.....
7	2.8	13.5	45.7 N	159.8	....	....	....	0.60	.....	....	....	.....	.....
7	3.2	13.9	45.7 N	159.8	36	MUBP	104	.....	1.02	....	....	.....	.....
7	3.7	14.3	45.7 N	159.8	....	....	....	1.18	.....	....	....	.....	.....
8	3.1	14.0	47.0 N	163.3	....	....	....	0.32	.....	108	....	2.06	.....
8	3.9	14.8	47.0 N	163.3	134	MUBP	389	.....	0.50	....	249	.....	1.39
8	4.4	15.3	47.0 N	163.3	....	....	....	0.65	.....	295	....	1.53	.....
9	2.6	13.7	47.0 N	166.9	....	....	....	.....	0.60	....	406	.....	1.03
9	3.4	14.5	47.0 N	166.9	45	MUBP	130	0.64	.....	345	....	1.29	.....
9	4.1	15.2	47.0 N	166.9	....	....	....	.....	0.61	....	339	.....	1.25
10	2.6	13.9	46.7 N	169.7	....	....	....	1.15	.....	630	....	1.27	.....
10	3.1	14.4	46.7 N	169.7	41	MUBP	119	.....	1.03	....	461	.....	1.55
10	3.6	15.0	46.7 N	169.7	....	....	....	1.09	.....	655	....	1.15	.....
11	2.1	13.6	45.9 N	171.9	....	....	....	.....	0.93	....	587	.....	1.10
11	2.6	14.1	45.9 N	171.9	57	MUBP	165	1.08	.....	768	....	0.98	.....
11	3.1	14.6	45.9 N	171.9	....	....	....	.....	0.70	....	395	.....	1.23
12	2.1	13.6	45.4 N	173.0	....	....	....	0.50	.....	....	....	.....	.....
12	2.7	14.3	45.4 N	173.0	124	MUBP	360	.....	0.40	....	....	.....	.....
12	3.3	14.9	45.4 N	173.0	....	....	....	0.61	.....	....	....	.....	.....
13	23.7	11.3	46.3 N	174.1	....	....	....	.....	.....	....	....	.....	.....
13	2.0	13.6	46.5 N	174.4	....	....	....	0.51	.....	....	....	.....	.....
13	2.5	14.1	46.5 N	174.4	76	MUBP	220	.....	0.76	....	....	.....	.....
13	2.9	14.6	46.5 N	174.4	....	....	....	0.77	.....	....	....	.....	.....
14	23.0	10.9	48.0 N	177.9	....	....	....	.....	.....	....	....	.....	.....

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10-7 esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
.....	......	.....	20.9	87	....	...	..	....	..	.....
.....	......	.....	21.9	87	....	...	..	....	..	.....
6.4	5980	3.03	21.9	86	SW×W	3	8	ci-cist	2	z
.....	......	.....	22.0	88	....	...	..	....	..	.....
.....	......	3.13	23.4	83	....	...	..	....	..	.....
.....	4520	.....	23.8	82	W×S	4	10	ast-cu	3	.....
.....	......	.....	23.5	81	....	...	..	....	..	.....
5.8	4520	.....	23.4	79	WSW	4	6	ci-frcu	3	z
.....	......	.....	23.6	83	....	...	..	....	..	.....
.....	2080	3.10	23.5	77	E	2	7	cu	3	.....
.....	......	.....	21.9	87	....	...	..	....	..	.....
7.8	4100	3.31	21.6	84	SE×S	2	10	ast	2	.....
.....	......	.....	21.4	87	....	...	..	....	..	.....
.....	......	.....	21.5	85	....	...	..	....	..	.....
5.7	3270	3.10	21.9	82	S	2	9	ast-acu	2	.....
.....	......	.....	22.0	85	....	...	..	....	..	.....
.....	3270	3.17	19.6	89	E×N	2	0	....	2	z
.....	......	.....	19.3	90	....	...	..	....	..	.....
5.2	......	.....	19.1	90	....	...	..	....	..	.....
.....	......	.....	18.0	78	....	...	..	....	..	.....
7.6	4240	3.02	18.0	76	E×S	3	0	....	3	z
.....	......	.....	18.0	77	....	...	..	....	..	.....
.....	......	.....	18.6	88	....	...	..	....	..	.....
8.4	3540	3.97	18.3	90	SE	2	1	ast	3	z
.....	......	.....	18.1	90	....	...	..	....	..	.....
.....	......	3.10	17.0	90	....	...	..	....	..	.....
.....	......	.....	17.8	78	....	...	..	....	..	.....
9.8	......	2.97	17.6	78	....	...	..	....	..	.....
.....	4660	.....	17.7	68	SE×E	3	2	acu	3	.....
.....	......	.....	15.9	79	....	...	..	....	..	.....
10.3	3060	2.92	15.9	78	SE×S	3	2	ci-ast	3	.....
.....	......	.....	15.9	79	....	...	..	....	..	.....
.....	......	2.93	15.0	77	....	...	..	....	..	.....
.....	......	3.24	14.4	84	....	...	..	....	..	.....
10.5	......	3.10	14.3	82	....	...	..	....	..	.....
.....	2290	.....	13.9	82	S×E	3	10	stcu	3	.....
.....	......	2.90	11.5	88	....	...	..	....	..	m
7.9	......	2.86	11.6	89	....	...	..	....	..	m
.....	2080	.....	11.7	85	SSE	4	10	stcu	3	.....
.....	......	.....	11.2	94	....	...	..	....	..	f-d
8.1	2500	2.92	10.9	93	SE×S	5	10	stcu	1	f-d
.....	......	.....	10.9	95	....	...	..	....	..	f-d
.....	......	.....	10.3	97	....	...	..	....	..	f-d
8.3	3540	3.03	10.2	94	SSE	4	10	st	0	f-d
.....	......	.....	10.4	97	....	...	..	....	..	f-d
.....	......	.....	9.2	96	....	...	..	....	..	f-r
6.6	......	3.16	9.2	97	....	...	..	....	..	f-r
.....	......	.....	9.3	97	....	...	..	....	..	f-r
.....	......	.....	8.6	90	....	...	..	....	..	f
12.7	4450	3.00	7.3	89	WSW	3	..	....	0	f
.....	......	.....	7.5	92	....	...	..	....	..	f
.....	......	.....	8.1	93	....	...	..	....	..	f
5.4	3060	2.96	7.8	88	W	4	10	st	1	f
.....	......	.....	7.6	93	....	...	..	....	..	r
.....	......	.....	8.1	92	....	...	..	....	..	m-z
8.5	3060	3.07	7.6	88	NNE	3	10	st	2	m-z
.....	......	.....	7.9	88	....	...	..	....	..	m-z
.....	......	.....	7.9	90	....	...	..	....	..	m-f
10.4	4380	3.05	7.8	86	NE	4	10	stcu	3	m-f
.....	......	.....	7.9	90	....	...	..	....	..	m-f
.....	......	.....	9.9	93	....	...	..	....	..	f
11.5	1670	2.91	9.7	89	SE	2	10	st	2	f
.....	......	.....	10.0	92	....	...	..	....	..	f
.....	......	3.04	10.4	98	....	...	..	....	..	f
.....	......	...	10.8	98	....	...	..	....	..	r-f
10.3	......	2.97	10.8	96	S×E	4	10	nb	..	r-f
.....	......	.....	10.7	98	....	...	..	....	..	m-f
.....	......	3.07	10.0	98	....	...	..	....	..	m-f

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient			Conductivity		Small ions		Mobility	
					Volts	Sail position	V/m	λ_+	λ_-	n_+	n_-	k_+	k_-
								in 10^{-4} esu		per cc		cm/s/v/cm	
1929													
July 14	1.8	13.7	48.2 N	178.5	....	....	....	.....	0.43	....	....	.....	.....
14	2.4	14.3	48.2 N	178.5	143	MUBP	415	0.47	.....	....	....	.....	.....
14	3.0	14.9	48.2 N	178.5	....	....	....	.....	0.33	....	....	.....	.....
Crossed International Date Line													
14	2.2	14.4	49.4 N	183.9	....	....	....	0.36	.....	....	....	.....	.....
14	2.8	15.0	49.4 N	183.9	225	MUBP	652	.....	0.23	....	....	.....	.....
14	3.3	15.6	49.4 N	183.9	....	....	....	0.28	.....	....	....	.....	.....
15	1.0	13.6	50.6 N	187.8	....	....	....	.....	0.60	....	....	.....	.....
15	1.5	14.0	50.6 N	187.8	100	MUBP	290	0.77	.....	....	....	.....	.....
15	1.9	14.4	50.6 N	187.8	....	....	....	.....	0.62	....	....	.....	.....
16	1.6	14.5	51.6 N	193.5	....	....	....	0.98	.....	....	....	.....	.....
16	2.2	15.1	51.6 N	193.5	81	MUBP	235	.....	0.80	....	....	.....	.....
16	2.7	15.6	51.6 N	193.5	....	....	....	1.01	.....	....	....	.....	.....
17	1.1	14.4	52.5 N	199.0	....	....	....	.....	0.60	....	364	.....	1.14
17	1.8	15.1	52.5 N	199.0	79	MUBP	229	0.84	.....	....	....	.....	.....
17	2.4	15.7	52.5 N	199.0	....	....	....	.....	0.74	....	....	.....	.....
18	0.4	14.1	52.5 N	205.0	....	....	....	0.75	.....	....	....	.....	.....
18	1.1	14.7	52.5 N	205.0	76	MUBP	220	.....	0.66	....	....	.....	.....
18	1.7	15.4	52.5 N	205.0	....	....	....	0.85	.....	....	....	.....	.....
19	0.4	14.4	51.8 N	210.1	....	....	....	.....	0.90	....	....	.....	.....
19	0.9	14.9	51.8 N	210.1	78	MUBP	226	0.94	.....	....	....	.....	.....
19	1.5	15.5	51.8 N	210.1	....	....	....	.....	0.72	....	....	.....	.....
20	23.4	13.6	50.0 N	214.3	....	....	....	1.27	.....	....	....	.....	.....
20	0.0	14.3	50.0 N	214.3	74	MUBP	215	.....	1.02	....	....	.....	.....
20	0.6	14.9	50.0 N	214.3	....	....	....	1.25	.....	....	....	.....	.....
21	21.5	12.0	48.0 N	217.3	....	....	....	.....	0.83	....	....	.....	.....
21	21.9	12.5	48.0 N	217.3	76	MUBP	220	0.98	.....	520	....	1.31	.....
21	22.2	12.8	48.0 N	217.3	....	....	....	.....	.....	....	....	.....	.....
22	20.7	11.3	46.1 N	220.2	....	....	....	1.11	.....	708	....	1.09	.....
22	21.1	11.7	46.1 N	220.2	38	MDBPC	148	.....	1.19	....	616	.....	1.34
22	21.3	11.9	46.1 N	220.2	....	....	....	.....	.....	....	....	.....	.....
23	23.2	14.1	44.1 N	222.6	....	....	....	1.32	.....	885	....	1.04	.....
23	23.7	14.5	44.1 N	222.6	64	MDBPC	250	.....	1.13	....	660	.....	1.19
23	0.2	15.1	44.1 N	222.6	....	....	....	1.25	.....	793	....	1.09	.....
23	0.7	15.4	44.1 N	222.6	....	....	....	.....	.....	....	....	.....	.....
24	22.2	13.2	42.4 N	225.0	....	....	....	.....	1.20	....	635	.....	1.31
24	22.8	13.8	42.4 N	225.0	59	MUBP	171	1.27	.....	717	....	1.23	.....
24	23.3	14.3	42.4 N	225.0	....	....	....	.....	1.08	....	533	.....	1.41
25	22.3	13.5	40.6 N	227.9	....	....	....	1.08	.....	650	....	1.15	.....
25	22.9	14.1	40.6 N	227.9	44	MDBPC	172	.....	0.95	....	434	.....	1.52
25	23.5	14.7	40.6 N	227.9	....	....	....	1.12	.....	644	....	1.21	.....
26	22.0	13.4	39.5 N	230.7	....	....	....	.....	0.88	....	420	.....	1.44
26	22.6	14.0	39.5 N	230.7	63	MUBS	202	1.00	.....	528	....	1.31	.....
26	23.2	14.6	39.5 N	230.7	....	....	....	.....	0.85	....	422	.....	1.40
27	21.8	13.5	38.7 N	234.5	....	....	....	0.68	.....	424	....	1.11	.....
27	22.6	14.3	38.7 N	234.5	84	MUBS	269	.....	0.54	....	262	.....	1.43
27	23.4	15.1	38.7 N	234.5	....	....	....	0.61	.....	358	....	1.18	.....
28	18.1	9.9	38.0 N	237.0	....	....	....	.....	0.22	....	....	.....	.....
28	18.9	10.7	38.0 N	237.0	190	MUBS	608	0.24	.....	100	....	1.67	.....
28	19.2	11.0	38.0 N	237.0	....	....	....	.....	.....	....	....	.....	.....
28	19.5	11.3	38.0 N	237.0	....	....	....	.....	.....	....	....	.....	.....
Sep 5	22.3	14.0	35.7 N	235.2	....	....	....	.....	0.44	....	208	.....	1.47
5	22.9	14.6	35.7 N	235.2	105	MUBP	304	.....	.....	438	....	.....	.....
5	23.5	15.2	35.7 N	235.2	....	....	....	.....	0.47	....	258	.....	1.26
6	22.7	14.3	33.6 N	233.4	62	MUBP	180	1.12	.....	568	....	1.37	.....
7	18.9	10.4	32.5 N	232.2	....	....	....	.....	.....	....	....	.....	.....
7	22.6	14.1	32.3 N	232.0	47	MUBP	136	1.09	.....	503	....	1.51	.....
8	22.5	13.9	31.5 N	231.1	....	....	....	.....	0.93	....	367	.....	1.76
9	23.0	14.3	30.3 N	228.9	96	MUBP	278	.....	0.27	....	149	.....	1.26
10	23.1	14.3	29.2 N	227.3	101	MUBP	293	.....	.....	224	....	.....	.....
11	23.3	14.4	28.1 N	225.5	71	MUBP	206	.....	.....	266	....	.....	.....
11	4.1	19.1	28.0 N	225.3	57	MUBP	165	.....	.....	....	327	.....	.....
12	23.2	14.2	27.7 N	224.3	42	MUBS	134	.....	0.41	....	243	.....	1.17
13	23.6	14.4	26.9 N	221.9	....	....	....	.....	.....	....	183	.....	.....
14	23.3	14.0	26.7 N	220.8	....	....	....	.....	.....	265	....	.....	.....
15	23.5	14.1	26.4 N	219.3	38	MUBS	122	0.59	.....	294	....	1.39	.....
16	1.1	15.6	26.2 N	217.8	....	....	....	.....	0.68	....	299	.....	1.58
17	0.3	14.7	25.0 N	216.2	58	MUBS	186	0.76	.....	396	....	1.33	.....

observations on the Carnegie, cruise VII, 1928-1929--Continued

Air-earth current density i, in 10-7 esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
.....	......	.....	10.1	96	....	...	..	....	..	m-f
11.8	......	3.03	9.8	96	S×W	5	10	nb	..	r
.....	......	.....	9.9	96	....	...	..	....	..	r-f
.....	......	.....	9.5	95	....	...	..	....	..	m-f
12.0	......	2.90	9.6	96	....	...	..	....	..	m-f
.....	......	.....	9.5	98	....	...	..	....	..	f
.....	......	.....	10.1	93	....	...	..	....	..	z
13.3	......	3.12	9.9	91	S×E	6	..	....	..	z
.....	......	.....	10.1	93	....	...	..	....	..	r-s
.....	......	.....	10.2	94	....	...	..	....	..	.....
14.1	3410	3.10	10.0	94	S	6	10	st	2	z
.....	......	.....	10.2	93	....	...	..	....	..	.....
.....	......	.....	10.9	92	....	...	..	....	..	f
11.5	4030	2.96	10.6	91	SSW	6	9	ast	2	f
.....	......	.....	10.7	92	....	...	..	....	..	m-s
.....	......	.....	10.5	94	....	...	..	....	..	f
10.7	2020	3.04	10.2	93	SW×W	5	10	st	2	f
.....	......	.....	10.4	94	....	...	..	....	..	f
.....	......	.....	11.2	95	....	...	..	....	..	r-f
13.2	2220	3.02	10.9	95	W×S	5	10	st	2	f
.....	......	.....	11.2	95	....	...	..	....	..	f
.....	......	.....	12.1	92	....	...	..	....	..	d
16.3	1950	3.04	11.8	91	WSW	6	8	acu	2	m
.....	......	.....	11.7	91	....	...	..	....	..	m
.....	......	2.91	12.1	83	....	...	..	....	..	m
13.3	......	2.84	12.1	84	....	...	..	....	..	z
.....	3060	.....	11.9	88	W×N	6	7	stcu	3	z
.....	......	3.31	12.4	85	....	...	..	....	..	.....
11.3	......	3.10	12.6	83	....	...	..	....	..	.....
.....	1950	.....	12.8	78	W×N	4	9	stcu-nb	3	.....
.....	......	.....	14.0	75	....	...	..	....	..	.....
20.2	......	2.96	14.0	76	....	...	..	....	..	.....
.....	......	.....	13.9	76	....	...	..	....	..	.....
.....	2850	.....	13.8	79	W	4	4	frcu	3	.....
.....	......	.....	15.2	78	....	...	..	....	..	.....
13.7	2150	3.11	15.1	79	SSW	5	10	stcu-nb	3	.....
.....	......	.....	15.1	80	....	...	..	....	..	.....
.....	......	.....	17.4	84	....	...	..	....	..	z
11.8	2360	2.96	17.2	87	W×N	4	10	stcu-nb	3	z
.....	......	.....	17.6	84	....	...	..	....	..	z
.....	......	.....	17.2	77	....	...	..	....	..	.....
12.6	3340	2.99	17.0	80	NE×N	5	10	stcu-nb	3	.....
.....	......	.....	17.1	79	....	...	..	....	..	.....
.....	......	.....	16.7	84	....	...	..	....	..	.....
10.6	2710	2.88	16.6	85	NNW	5	10	stcu-nb	2	.....
.....	......	.....	16.6	85	....	...	..	....	..	.....
.....	......	.....	13.2	89	....	...	..	....	..	f
9.3	......	.....	13.2	90	....	...	..	....	..	f
.....	3200	.....	13.0	91	CALM	0	..	....	0	f
.....	......	3.60	13.3	90	....	...	..	....	..	f
.....	......	.....	18.6	72	....	...	..	....	..	.....
9.7[d]	8190	.....	18.8	73	NW×N	4	8	stcu	3	.....
.....	......	.....	18.7	70	....	...	..	....	..	.....
12.8	10210	2.94	18.9	86	NW×N	4	9	stcu-nb	3	.....
.....	......	2.46	20.4	67	....	...	..	....	..	.....
9.4	4240	3.00	20.9	72	NW	2	10	stcu	3	.....
.....	3270	3.01	21.8	67	N×W	2	9	acu	3	.....
5.3	2360	3.15	22.0	71	N	3	3	cu	3	z
.....	2150	3.04	22.7	66	NE	3	8	acu-cu	3	z
.....	1740	2.81	23.8	61	NE×E	2	4	acu	3	z
.....	......	.....	22.7	65	....	...	..	....	..	.....
3.8	2430	2.99	24.0	60	S×E	2	1	frcu	3	.....
.....	1390	2.75	25.5	64	SE×S	1	1	frcu	3	.....
.....	2150	2.88	25.0	75	CALM	0	5	acu-cu	3	.....
4.6	1880	2.79	25.3	73	S×E	3	9	acu-stcu	3	.....
.....	1670	3.04	24.8	73	SE×E	3	1	frcu	3	.....
9.0	1320	2.88	26.0	67	E×N	3	1	frcu	3	.....

Table 1. Final results of daily atmospheric-electric

Local date	GMT h	LMT h	Latitude °	Longitude east °	Potential-gradient Volts	Sail position	V/m	Conductivity λ+ (in 10⁻⁴ esu)	λ-	Small ions n+ (per cc)	n-	Mobility k+ (cm/s/v/cm)	k-
1929													
Sep 18	23.0	13.3	24.0 N	214.2	49	MDBPC	191	0.74	.....	392	....	1.31	.....
18	23.6	13.9	24.0 N	214.1	....	....	....	.....	.....	....	....	.....	.....
18	23.8	14.0	24.0 N	214.1	....	....	....	.....	.....	....	....	.....	.....
18	0.3	14.6	24.0 N	214.1	42	MDBPC	164	.....	.....	....	348	.....	.....
18	1.0	15.3	23.9 N	214.0	42	MDBPC	164	0.54	.....	273	....	1.37	.....
18	2.1	16.4	23.9 N	213.8	....	....	....	.....	.....	....	....	.....	.....
19	0.3	14.4	23.3 N	211.0	49	MDBPC	191	.....	0.72	....	355	.....	1.41
20	0.3	14.2	22.8 N	208.4	37	MDBPC	144	.....	0.91	....	368	.....	1.72
21	0.4	14.2	22.2 N	206.2	47	MDBPC	183	1.03	.....	448	....	1.60	.....
22	0.3	13.9	21.7 N	204.2	37	MUBS	118	1.16	.....	710	....	1.14	.....
Oct 3	0.5	13.8	23.7 N	200.4	53	MUBP	154	.....	1.08	....	559	.....	1.34
4	1.1	14.4	26.8 N	199.4	47	MUBP	136	1.14	.....	542	....	1.46	.....
5	0.5	13.8	29.5 N	198.8	50	MUBP	145	.....	1.10	....	499	.....	1.53
6	23.6	12.8	31.7 N	199.0	60	MUBP	174	.....	0.91	....	406	.....	1.56
7	0.9	14.1	32.9 N	199.3	42	MUBP	122	.....	0.94	....	384	.....	1.70
8	1.0	14.4	34.3 N	200.2	40	MUBP	116	1.47	.....	794	....	1.28	.....
9	0.9	14.4	34.0 N	203.5	52	MUBP	151	.....	0.95	....	573	.....	1.15
10	0.6	14.3	33.6 N	205.8	....	MDBS	e	0.64	.....	357	....	1.24	.....
11	0.5	14.4	33.6 N	208.8	46	MUBP	133	.....	1.07	....	592	.....	1.26
12	23.5	13.7	33.3 N	212.5	....	....	....	.....	.....	....	....	.....	.....
12	2.5	16.7	33.3 N	212.7	30	MDBPC	117	1.17	.....	745	....	1.09	.....
13	0.6	14.9	33.5 N	214.9	43	MUBS	138	1.42	.....	603	....	1.63	.....
14	20.5	10.9	33.6 N	216.8	48	MUBP	139	1.22	.....	576	....	1.47	.....
15	0.5	15.1	31.5 N	219.4	....	....	....	1.29	.....	602	....	1.47	.....
16	0.6	15.3	28.6 N	220.9	28	MUBP	81	.....	1.19	....	403	.....	2.05
17	22.5	13.3	27.3 N	222.0	41	MUBP	119	.....	1.09	....	432	.....	1.75
18	23.5	14.4	25.9 N	222.8	30	MUBS	96	1.43	.....	468	....	2.12	.....
19	23.5	14.3	24.9 N	222.3	26	MUBS	83	.....	1.28	....	449	.....	1.98
20	22.5	13.3	23.0 N	221.6	36	MUBS	115	1.46	.....	430	....	2.36	.....
21	22.5	13.3	21.1 N	221.4	39	MUBS	125	.....	1.24	....	341	.....	2.53
22	19.5	10.3	18.5 N	222.0	39	MUBS	125	.....	1.09	....	309	.....	2.45
23	0.5	15.4	15.8 N	223.1	32	MUBS	102	.....	1.11	....	311	.....	2.48
24	23.5	14.4	13.4 N	223.3	72	MDBPC	281	.....	0.66	....	309	.....	1.50
25	23.1	14.0	12.6 N	222.4	....	....	....	.....	.....	....	....	.....	.....
26	23.5	14.3	11.2 N	221.2	20	MDBPC	78	1.04	.....	471	....	1.53	.....
27	23.5	14.2	9.9 N	220.1	37	MUBS	118	.....	0.98	....	362	.....	1.88
28	23.5	14.1	8.5 N	219.2	29	MUBS	93	1.04	.....	549	.....	1.32	.....
29	23.5	14.1	7.7 N	218.5	41	MUBS	131	.....	1.21	....	602	.....	1.40
30	23.5	14.0	7.0 N	217.3	....	....	....	.....	.....	....	....	.....	.....
31	23.5	13.9	6.6 N	216.6	33	MUBS	106	.....	1.13	....	384	.....	2.04
Nov 1	23.5	13.9	5.8 N	215.3	....	....	....	.....	.....	....	....	.....	.....
2	0.5	14.7	4.9 N	213.0	....	....	....	.....	.....	....	....	.....	.....
3	0.5	14.5	4.2 N	210.6	43	MUBS	138	.....	0.67	....	307	.....	1.51
4	0.5	14.4	2.8 N	210.0	45	MUBS	144	0.76	.....	268	....	1.97	.....
5	23.5	13.5	0.9 N	208.4	45	MUBS	144	0.72	.....	285	....	1.75	.....
6	0.5	14.3	2.2 S	207.6	52	MUBS	166	0.92	.....	319	....	2.00	.....
7	0.5	14.2	5.1 S	206.4	36	MUBS	115	.....	0.93	....	461	.....	1.40
8	0.5	14.2	6.8 S	204.7	34	MDBPC	133	0.82	.....	374	....	1.52	.....
9	0.5	14.1	8.2 S	202.9	54	MUBP	157	.....	0.71	.....	429	.....	1.15
11	0.5	13.9	9.4 S	200.9	37	MDBPC	144	0.69	.....	394	....	1.22	.....
13	0.5	13.6	11.1 S	197.8	26	MUBP	75	1.01	.....	491	....	1.43	.....
14	0.5	13.6	11.6 S	196.5	26	MDBPC	101	.....	0.80	....	389	.....	1.43
15	0.5	13.5	12.1 S	195.0	30	MDBPC	117	.....	.....	578	....	.....	.....
16	1.5	14.2	13.0 S	192.8	53	MUBP	154	.....	1.06	....	418	.....	1.76
17	1.5	14.2	13.7 S	191.4	....	....	....	0.98	.....	541	....	1.26	.....

[a]Ion-pairs produced per cubic centimeter per second in penetrating radiation apparatus 1 are tabulated as observed, without correction for residual ionization.

[b]Values of potential gradient associated with this letter have been obtained from the recorder apparatus, each value being the mean for the period during which conductivity measurements were being made.

[c]Beginning with the value of potential gradient associated with this reference letter, recorder values are used exclusively throughout the remainder of the table.

observations on the Carnegie, cruise VII, 1928-1929--Concluded

Air-earth current density i, in 10-7 esu	Nuclei per cc	Pen. rad. ion-pairs per cc/sec	Temperature °C	Rel. hum. per cent	Wind		Clouds		Visibility	Weather notes
					Dir.	Force	Amt.	Type	1-3	
9.0	2220	.....	25.7	67	ENE	4	1	frcu	..	.....
.....	......	3.16	25.7	66	....	...	..	....	..	.....
.....	......	2.61	25.7	66	....	...	..	....	..	.....
.....	......	.....	25.5	67	....	...	..	....	..	.....
5.6	......	2.99	25.2	69	....	...	..	....	..	.....
.....	......	2.65	25.0	70	....	...	..	....	..	.....
9.6	1880	2.73	26.7	62	E×N	4	8	ast	3	.....
9.2	1180	2.82	26.8	70	E×N	4	3	cu	3	.....
12.0	1460	2.81	27.2	71	E	4	8	ci-cu	3	.....
8.7	1530	2.89	28.5	68	SE×E	3	7	cicu-cu	3	.....
11.7	2150	2.83	27.3	65	E×S	5	7	cist-cu	3	.....
9.9	1530	2.76	26.5	67	E×N	5	3	ci-cu	3	.....
11.2	2080	2.67	25.7	69	E×N	5	4	cu-cunb	3	.....
11.1	1180	2.82	25.2	77	E×S	4	9	cist-ast	3	.....
8.0	1250	2.87	24.4	78	ENE	1	3	cu-cunb	3	.....
10.9	1040	3.07	23.0	86	SSE	2	9	acu-cunb	3	.....
10.1	970	3.06	24.0	79	SSW	5	3	frcu	3	.....
.....	1320	2.57	23.5	63	NW×N	1	6	cist	3	.....
10.0	1250	2.75	25.0	80	SW	5	5	cu-cunb	3	.....
.....	......	3.03	19.9	93	....	...	..	....	..	.....
8.7	1390	2.97	21.0	91	SW×W	4	10	st-nb	2	.....
12.5	830	2.93	21.1	68	NW×N	2	7	ci-cu	3	.....
10.8	970	2.65	22.8	79	SW×S	4	10	stcu	3	.....
.....	690	2.67	20.9	84	N×W	4	10	stcu-nb	3	.....
6.8	1180	2.42	21.9	87	NE×E	5	10	stcu-nb	3	.....
9.1	760	2.73	24.7	70	S×W	1	1	frcu	3	.....
8.7	970	2.57	23.1	68	SE	2	1	frcu	3	.....
7.4	900	2.54	22.0	83	E×N	2	1	frcu	3	.....
10.7	1180	2.38	23.3	77	ESE	4	7	cist-cu	3	.....
10.8	700	2.59	23.1	78	E×S	4	9	cist-stcu	3	.....
9.5	630	2.70	25.4	67	E×N	5	8	ast-cu	3	.....
7.9	970	2.48	25.0	72	ENE	4	4	ast	3	.....
13.0	2920	2.65	26.8	82	NE×N	3	10	stcu	2	.....
.....	......	2.55	23.0	90	....	...	..	....	..	q
5.2	1040	2.67	28.8	63	NW×N	1	7	cu-cunb	3	.....
8.1	900	2.69	28.0	72	E×S	1	6	cu-cunb	3	.....
6.2	970	2.75	28.0	73	E	2	4	cu	3	.....
11.1	1180	2.68	28.1	74	E	3	3	cu-cunb	3	q
.....	......	2.77	26.5	83	....	...	..	....	..	r
8.4	970	2.69	26.2	77	CALM	0	7	ast-cunb	3	.....
.....	......	2.63	25.9	86	....	...	..	....	..	r
.....	760	2.65	27.0	79	S	4	10	stcu-nb	2	.....
6.5	1880	2.65	27.6	72	SSE	2	9	stcu-st	2	.....
7.0	630	2.65	26.9	76	SE×S	3	7	cu	3	.....
6.6	970	2.78	27.0	77	SE×E	5	4	cu	3	.....
9.7	1670	2.62	27.1	75	E	5	2	cist-frcu	3	.....
7.5	1880	2.69	27.8	68	NE×E	4	7	cunb	2	.....
7.0	970	2.65	27.9	70	ENE	4	3	frcu-cu	3	.....
7.8	1740	2.66	29.9	68	NE×N	4	4	cu	3	.....
6.3	1250	2.68	29.0	70	NE×E	2	7	acu-cu	3	.....
4.8	2080	2.69	29.0	65	NE×N	4	8	ast-frcu	3	.....
5.7	1810	2.75	31.9	66	NE×E	1	3	ci-frcu	3	.....
.....	1880	2.72	30.0	65	NE×E	2	3	cicu-cu	3	.....
11.4	1600	2.55	31.1	61	NE	1	3	frcu	3	.....
.....	1250	2.76	30.9	62	CALM	0	4	cu	3	.....

[d]Values of air-earth current density computed for the three months September to November, 1929, are based on measured values of only one sign of conductivity for each day, the appropriate value for the other sign being computed on the assumption that $\lambda_+/\lambda_- = 1.10$. (This value is slightly lower than the grand average of λ_+/λ_- obtained from 250 daily values in the period May 15, 1928 to July 28, 1929, which is 1.16.)

VI. ATMOSPHERIC-ELECTRIC DIURNAL-VARIATION RESULTS

EXPLANATORY NOTES AND COMMENTS

Measurement of the several atmospheric-electric elements through a twenty-four-hour period was scheduled for once each week while at sea, in order to obtain information on the character of the diurnal variation of the various elements. During fifty-three weeks at sea, between May 11, 1928 and November 18, 1929, thirty-two diurnal-variation series were undertaken, or about two series in every three weeks. Actually the thirty-two series were obtained in forty-six weeks, no series being attempted in the first seven weeks, or until July 30, 1928, as the whole ship's program was being organized and systematized during this initial period. The observational procedure in a diurnal-variation series was to measure each element once each hour through a period beginning approximately at noon, local mean time, and ending at noon on the following day. Two observers worked in shifts of six hours observing and six hours rest.

Of the thirty-two series begun, several were not completed because instrumental difficulties developed or bad weather made observing impossible. The series begun on October 8, 1928 was discontinued so early that all data obtained on that occasion were placed in section V rather than in the present table. There are, therefore, only thirty-one complete and partial series tabulated here. The nuclei measurements were completed through the twenty-four-hour period on only sixteen occasions, with one additional series lacking only four values; the small-ion measurements on twenty occasions; and the conductivity on twenty-seven. Recorder values of potential-gradient were available for twenty-four complete series, and for all incomplete series except the first, for which eye readings were used.

Each diurnal-variation series is tabulated under local dates, and latitude and longitude are given for the average position for the twenty-four-hour period. Thus the position for each series is approximately that for twenty-four hours, LMT, of the first date given for the series. The atmospheric-electric elements tabulated are: potential-gradient, in volts per meter; conductivity, of the sign given at the head of the column; small-ion concentration, of the sign at the head of the column; computed small-ion mobility; nuclei concentration; computed air-earth current density.

Potential-Gradient.--Values of potential-gradient were taken from the photographic records for a period ranging from ten to twenty minutes in each hour, coinciding with the period during which the conductivity and small-ion measurements were made. Frequently the value of potential-gradient for this short interval differs considerably from the mean hourly value which may be found in section VII for the particular hour and date, owing to the fluctuations which occur in the potential-gradient even on comparatively quiet days. Comparison of the twenty-four values in any series in the present table with the corresponding twenty-four hourly mean values in section VII will give some indication of the extent to which the period is disturbed, as the more disturbed periods show larger and more frequent differences. The eye-reading values of potential-gradient used for the series of July 30-31, 1928 were obtained fifteen to twenty-five minutes earlier than the values of the other elements with which they are associated in the series; some question may therefore be raised as to the validity of the computed air-earth current values which have been tabulated for the group, and for the sake of homogeneity in studies of the material in this table perhaps they should be ignored.

Conductivity and Small-Ion Concentration.--Unlike the procedure for the daily observations of conductivity and small-ion concentration, under which the measurements of positive and negative values of these elements were alternated, the procedure for the diurnal-variation measurements required that only one sign be measured, and that this be done at hourly intervals through the twenty-four-hour period. The time required for one measurement in each hour ranged from ten to twenty minutes, the conductivity and small-ion concentration being obtained simultaneously. The small-ion measurements were subject to more frequent interruption than the conductivity, however, because the occurrence of rain or spray on any occasion made necessary the closing of the roof aperture through which the ion-counter intake projected.

Computed Small-Ion Mobility.--From the simultaneous measurements of conductivity and small-ion concentration, values of small-ion mobility were computed for the present table as in section V. For the last two diurnal-variation series which are given, obtained October 21-22 and November 4-5, 1929, the mobility values are conspicuously higher than for any of the other series obtained on the cruise. These two series fall in the period October 16 to November 6, 1929, when high mobility values were consistently obtained from the daily measurements of conductivity and small ions, as stated in connection with section V. No explanation has been found for these high values.

Nuclei Concentration.--The values of nuclei concentration shown in the table, except for the last four series, generally were not obtained at the particular times with which they are associated. The times given are the mean times for the conductivity and small-ion measurements, and as the nuclei measurements were not begun until after these had been completed, their mean times actually are from fifteen to thirty minutes later than the times tabulated. The magnitude of this time difference was as indicated because the conductivity and ion measurements required ten to twenty minutes for completion, while the nuclei measurements required ten to fifteen, and five minutes or more were consumed in changing from one type of measurement to the other. For the last four series, when both potential gradient and conductivity were being recorded, the eye-reading measurements of small ions and nuclei were made simultaneously, and with potential gradient and conductivity recorder values taken to correspond in time with these eye-reading measurements, the tabulated values for each hour in these series represent simultaneous measurements.

Air-Earth Current Density.--As in section V, each value of air-earth current density was computed from the sum of the positive and negative conductivities and the corresponding value of potential gradient. For the present table, however, since only one sign of conductivity was measured during any one diurnal-variation series, it was necessary to compute the value of the other sign. The formula used for this computation is $\lambda_+/\lambda_- = 1.10$. Of these 645 values of computed air-earth current density in the present table, 142 were obtained in the Atlantic Ocean in seven series between July 30 and September 16, 1928. Three of the series, August 14-15, August 17-18, and August 24-25, having a total of 58 values, have 34 values or 60 per cent of the total, lying between 3.5 and 5.0×10^{-7} esu. Such low values were not encountered on any other part of the cruise; there are only eight other scattered values as small as these in the entire table, and several of them are associated with disturbed weather conditions. That part of the Atlantic Ocean in which the 34 low values were obtained, sustains a large steamship traffic, and it may be that pollution from the ships is a cause for low air-earth current density in the region. Discussion of this possibility will be undertaken in a later section of this volume. Except for the low Atlantic values just mentioned, and omitting a few extreme values, the range in the table is 5.0 to 15.0×10^{-7} esu.

Meteorological Notes and Data.--Appropriate meteorological notes and measurements were made every hour during a diurnal-variation series, but on most occasions the variations throughout the twenty-four-hour period in any of the several meteorological elements, except perhaps cloud types and cloud amount, appeared to be too small to warrant detailed tabulation. Instead, a summary of the meteorological data and notes has been made below each series of atmospheric-electric measurements, when such notes and data have been available. The meteorological symbols and notations used in section V, and defined in the explanatory note for that section, have been used in the present section also.

Several of the series lack the meteorological notes and data because the meteorological work was a part of the program of nuclei observations, and when nuclei data are lacking the meteorological data likewise are lacking. Special note has been made of particularly disturbed weather conditions under any series where one or more of the atmospheric-electric elements obviously has been disturbed by those conditions, and where specific note was made by the observer of the disturbed meteorological element. For more detailed meteorological information reference may be made to Meteorology-I of this series of publications of Carnegie results, which deals with the meteorological data of cruise VII (Carnegie Institution of Washington Publication 544, 1943).

Table 2. Diurnal-variation measurements of atmospheric-electric elements

July 30-31, 1928. Latitude 58°.8 N; Longitude 326°.0 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
16.5	14.2	96	1.04	600	1.20	......	6.3[a]
17.5	15.2	102	1.10	609	1.25	......	7.1
18.5	16.2	89	0.94	405	1.61	......	5.3
19.5	17.2	....	1.11	600	1.28	......	.....
20.5	18.2	....	1.02	561	1.26	......	.....
21.5	19.3	191	0.85	542	1.09	......	10.3
22.5	20.3	152	0.88	489	1.25	......	8.5
23.5	21.2	172	0.93	513	1.26	......	10.2
0.5	22.2	172	1.17	561	1.45	......	12.8
1.5	23.3	....	1.15	488	1.26	......	.....
2.6	0.3	....	1.03	496	1.44	......	.....
3.6	1.3	....	1.03	588	1.22	......	.....
4.6	2.3	....	1.02	491	1.44	......	.....
5.6	3.3	....	1.02	503	1.41	......	.....
6.6	4.3	....	0.99	491	1.40	......	.....
7.5	5.3	....	1.04	478	1.51	......	.....
8.6	6.3	....	0.97	466	1.44	......	.....
9.5	7.3	....	1.07	526	1.41	......	.....
10.6	8.3	122	0.92	498	1.28	......	7.2
11.6	9.4	112	1.15	574	1.39	......	8.2
12.6	10.3	106	1.18	563	1.45	......	8.0
13.5	11.3	122	1.17	593	1.37	......	9.1
14.6	12.3	109	1.09	554	1.36	......	7.6
15.6	13.3	106	0.98	517	1.31	......	6.6

[a]Air-earth current density computed from potential-gradient and the sum of positive and negative conductivities, assuming $\lambda_+ = 1.10\ \lambda_-$

August 7-8, 1928. Latitude 44°.5 N; Longitude 313°.0 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_-	n_-	k_-		
14.9	11.8	144	0.60	417	1.00	......	6.0
16.3	13.2	140	0.65	379	1.19	......	6.3
17.2	14.1	154	0.63	393	1.11	......	6.8
18.2	15.1	140	0.83	457	1.26	......	8.1
19.4	16.3	136	0.86	470	1.27	......	8.2
20.4	17.2	139	0.80	444	1.25	......	7.8
21.4	18.2	139	0.88	529	1.16	......	8.6
22.3	19.2	131	0.91	533	1.19	......	8.3
23.3	20.2	111	0.93	590	1.09	......	7.2
0.3	21.2	94	1.01	627	1.12	......	6.6
1.4	22.2	83	0.99	637	1.08	......	5.8
2.4	23.2	76	1.06	642	1.15	......	5.6
3.4	0.3	81	1.06	641	1.15	......	6.0
4.4	1.3	90	1.09	638	1.18	......	6.9
5.2	2.1	97	1.02	601	1.18	......	6.9
6.2	3.1	97	0.99	617	1.11	......	6.7
7.3	4.1	83	1.02	622	1.14	......	5.9
8.2	5.1	78	1.11	636	1.21	......	6.1
9.3	6.1	97	0.98	625	1.09	......	6.7
10.3	7.1	97	1.03	623	1.15	......	7.0
11.4	8.3	99	0.96	574	1.16	......	6.6
12.4	9.3	111	0.95	526	1.25	......	7.4
13.4	10.3	111	0.94	486	1.34	......	7.3
14.6	11.4	106	0.98	420	1.62	......	7.3

August 14-15, 1928. Latitude 34°.8 N; Longitude 316°.7 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
18.6	15.7	121	0.68	517	0.91	......	5.2
19.8	16.9	155	0.57	467	0.85	......	5.6
21.0	18.1	155	0.57	490	0.81	......	5.6
21.8	18.9	178	0.53	340	1.08	......	6.0
23.0	20.1	144	0.63	453	0.97	......	5.8
0.3	21.4	129	0.64	418	1.06	......	5.2
1.4	22.5	115	0.55	465	0.82	......	4.0
2.2	23.3	118	0.61	502	0.84	......	4.6
3.3	0.4	119	0.66	515	0.89	......	5.0
4.2	1.3	133	0.63	....	.....	......	5.3

Observations discontinued because of rain.

August 17-18, 1928. Latitude 28°.9 N; Longitude 319°.9 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
15.6	12.9	90	0.83	535	1.08	......	4.8
16.9	14.2	99	0.84	591	0.99	......	5.3
17.8	15.1	84	0.85	519	1.14	......	4.5
18.7	16.0	88	0.83	525	1.10	......	4.7
19.8	17.1	99	0.84	553	1.05	......	5.3
20.8	18.1	101	0.81	584	0.96	......	5.2
21.8	19.1	133	0.79	667	0.82	......	6.7
22.8	20.1	127	0.77	629	0.85	......	6.2
23.8	21.1	101	0.82	591	0.96	......	5.3
0.7	22.0	108	0.80	527	1.05	......	5.5
1.7	23.0	90	0.76	512	1.03	......	4.4
2.8	0.1	83	0.73	475	1.07	......	3.8
3.7	1.1	80	0.72	463	1.08	......	3.7
4.8	2.2	84	0.72	519	0.96	......	3.9
5.9	3.2	85	0.73	464	1.09	......	3.9
6.8	4.1	97	0.73	514	0.99	......	4.5
7.8	5.1	88	0.74	527	0.98	......	4.1
8.8	6.2	108	0.77	509	1.05	......	5.3
9.7	7.0	105	0.79	508	1.08	......	5.3
10.7	8.0	107	0.81	476	1.18	......	5.5
11.9	9.2	102	0.81	466	1.21	......	5.3
12.9	10.3	102	0.68	473	1.00	......	4.4
13.6	11.0	102	0.74	446	1.15	......	4.8
14.8	12.1	70	0.81	438	1.28	......	3.6

Table 2. Diurnal-variation measurements of atmospheric-electric elements--Continued

August 24-25, 1928. Latitude 15°.5 N; Longitude 321°.9 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_-	n_-	k_-		
15.3	12.8	56	0.91	499	1.27	......	3.6
16.3	13.7	64	0.94	548	1.19	......	4.2
17.1	14.6	73	0.89	470	1.31	730	4.6
18.1	15.6	81	1.00	460	1.51	530	5.7
19.3	16.8	90	0.81	415	1.35	......	5.1
20.3	17.8	85	0.83	420	1.37	......	4.9
21.1	18.6	88	0.84	531	1.10	2560	5.2
22.1	19.6	89	0.80	438	1.27	590	5.0
23.3	20.6	78	0.85	467	1.26	......	4.6
0.1	21.5	76	0.87	463	1.30	730	4.6
1.1	22.6	71	0.86	450	1.33	......	4.3
2.1	23.6	64	0.87	474	1.27	620	3.9
3.2	0.6	66	0.90	515	1.21	890	4.2
4.1	1.6	68	0.88	378	1.62	520	4.2
5.2	2.7	71	0.81	465	1.21	......	4.0
6.3	3.8	74	0.85	471	1.25	......	4.4
7.2	4.6	72	0.79	391	1.40	......	4.0
8.1	5.6	78	0.73	450	1.13	480	4.0
9.1	6.6	81	0.72	406	1.23	......	4.1
10.2	7.6	74	0.73	443	1.14	870	3.8
11.2	8.6	70	0.94	478	1.36	600	4.6
12.2	9.6	72	0.82	355	1.60	640	4.1
13.1	10.6	78	0.91	416	1.52	530	5.0
14.0	11.5	80	0.85	425	1.39	......	4.7

Temp. range: 28.9-26.0 °C. Rel. hum. range: 73-93 per cent. Wind: SE to NE, 1-2. Visibility: 3. Clouds: ci-cu-stcu-cunb, 1-8. Shower 4.3h-4.4h GMT.

September 13-14, 1928. Latitude 13°.2 N; Longitude 306°.7 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_-	n_-	k_-		
15.5	11.9	117	0.99	476	1.44	......	8.1
16.5	12.9	117	0.99	450	1.53	......	8.1
17.5	14.0	107	1.01	457	1.53	......	7.6
18.5	15.0	129	0.94	432	1.51	......	8.5
19.5	16.0	146	0.90	409	1.53	......	9.2
20.5	16.9	147	0.91	480	1.32	......	9.4
21.5	18.0	132	0.95	455	1.45	......	8.8
22.6	19.0	146	0.89	431	1.43	......	9.1
23.5	20.0	120	0.94	435	1.50	......	7.9
0.5	20.9	120	0.95	448	1.47	......	8.0
1.5	22.0	119	0.92	441	1.45	......	7.7
2.5	23.0	120	0.93	424	1.52	......	7.8
3.5	23.9	117	0.98	471	1.44	......	8.0
4.5	0.9	120	0.99	454	1.51	......	8.3
5.5	1.9	124	0.91	396	1.60	......	7.9
6.5	3.0	120	0.95	478	1.38	......	8.0
7.5	4.0	134	0.89	437	1.41	......	8.3
8.5	5.0	120	0.96	433	1.54	......	8.1
9.5	5.9	120	0.97	468	1.44	......	8.2
10.6	7.0	120	0.99	538	1.28	......	8.3
11.5	8.0	104	1.04	552	1.31	......	7.6
12.5	8.9	104	1.03	537	1.33	......	7.5
13.5	9.9	108	0.97	550	1.22	......	7.3
14.4	10.9	129	0.99	535	1.28	......	6.9

September 5-6, 1928. Latitude 11°.6 N; Longitude 318°.2 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
15.7	12.8	110	1.11	658	1.17	......	7.8
16.5	13.7	108	1.19	661	1.25	......	8.2
17.6	14.8	108	1.18	640	1.28	......	8.1
18.5	15.7	107	1.23	699	1.22	......	8.4
19.4	16.6	107	1.20	725	1.15	......	8.2
20.2	17.4	121	1.10	740	1.03	......	8.5
21.3	18.5	119	1.16	680	1.18	......	8.8
22.2	19.4	118	1.19	663	1.25	......	8.9
23.1	20.3	115	1.24	675	1.28	......	9.1
0.0	21.2	108	1.23	647	1.32	......	8.5
1.1	22.3	101	1.19	632	1.31	......	7.6
2.1	23.3	108	1.21	632	1.33	......	8.3
3.1	0.3	108	1.26	663	1.32	......	8.7
4.0	1.2	92	1.30	650	1.39	......	7.6
5.1	2.3	91	1.14	612	1.29	......	6.6
6.0	3.2	91	1.14	613	1.29	......	6.6
7.1	4.3	96	1.12	601	1.29	......	6.8
8.0	5.2	106	1.11	582	1.32	......	7.5
9.2	6.4	96	1.13	591	1.33	......	6.9
10.1	7.3	90	1.12	587	1.32	......	6.4
11.2	8.5	87	1.13	578	1.36	......	6.3
12.1	9.3	96	1.14	588	1.35	......	7.0
13.2	10.4	90	1.13	586	1.34	......	6.5
14.1	11.3	97	1.16	614	1.31	......	7.2

November 13-14, 1928. Latitude 1°.6 S; Longitude 266°.3 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
18.4	12.1	141	1.11	564	1.36	280	10.0
19.4	13.2	157	1.12	502	1.55	320	11.2
20.3	14.0	163	1.11	507	1.52	360	11.5
21.1	14.9	186	1.14	492	1.31	460	13.5
22.0	15.8	128	1.13	576	1.36	480	9.2
23.2	16.9	173	1.12	....	.....	480	12.3
24.0	17.8	38	1.07	....	.....	.....	2.6
0.9	18.7	141	1.09	....	.....	680	9.8
2.0	19.7	38	1.13	....	.....	340	2.7
3.0	20.8	106	1.16	....	.....	230	7.8
4.0	21.8	118	1.15	....	.....	250	8.7
5.0	22.7	118	1.21	....	.....	300	9.1
6.0	23.7	147	1.20	....	.....	210	11.2
7.0	0.7	106	1.11	....	.....	200	7.5
8.0	1.7	99	1.09	....	.....	430	6.9
9.0	2.8	118	1.20	....	.....	340	9.0
10.0	3.8	118	1.20	....	.....	410	9.0
11.2	5.0	106	1.26	....	.....	780	8.5
12.0	5.7	125	1.24	....	.....	910	9.9
13.0	6.7	128	1.27	....	.....	440	10.4
14.0	7.8	125	1.41	....	.....	460	11.2
15.0	8.7	118	1.44	....	.....	280	10.8
16.0	9.8	163	1.31	....	.....	370	14.0
17.1	10.9	173	1.26	....	.....	.....	13.9

Temp. range: 21.1-18.0 °C. Rel. hum. range: 72-83 per cent. Wind: SE to SSE, 1-3, except first four hours calm. Clouds: ast-cu-cunb-nb, 10, except last three hours frcu-stcu, 1-7. Visibility: 3. Drizzling 23.5h, 0.2h, 1.4h GMT.

Table 2. Diurnal-variation measurements of atmospheric-electric elements--Continued

November 21-22, 1928. Latitude 10°.6 S; Longitude 250°.7 E

GMT h	LMT h	Pot'l. grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_-	n_-	k_-		
18.8	11.5	106	1.01	....	.....	550	7.5
19.8	12.6	106	0.96	....	.....	710	7.1
20.9	13.6	77	1.04	....	.....	520	5.6
22.0	14.7	93	1.06	....	.....	480	6.9
23.0	15.7	86	1.13	....	.....	730	6.8
24.0	16.7	77	1.05	....	.....	640	5.6
1.0	17.7	70	1.06	....	.....	690	5.2
2.0	18.7	70	1.10	....	.....	820	5.4
2.9	19.7	70	1.11	....	.....	640	5.4
4.0	20.7	74	1.13	....	.....	710	5.8
5.0	21.7	70	1.11	....	.....	730	5.4
6.1	22.8	74	1.11	....	.....	660	5.7
7.1	23.8	74	1.04	....	.....	770	5.4
8.1	0.8	74	1.01	....	.....	410	5.2
9.1	1.8	74	0.98	....	.....	230	5.1
10.1	2.8	80	0.97	....	.....	250	5.4
11.1	3.9	80	0.97	....	.....	.....	5.4
12.0	4.7	83	0.92	....	.....	410	5.3
13.0	5.8	106	0.96	....	.....	610	7.1
14.1	6.9	106	0.97	....	.....	410	7.2
15.2	7.9	106	1.00	....	.....	620	7.4
16.1	8.8	115	0.98	....	.....	680	7.9
17.0	9.7	122	0.96	....	.....	480	8.2
18.1	10.8	112	0.97	....	.....	....	7.6

Temp. range: 24.0-22.8 °C. Rel. hum. range: 68-82 per cent. Wind: ESE, 4-5. Clouds: acu-ast-cu-stcu-frcu, 1-8. Visibility: 3. Few drops rain 21.2h GMT, Nov. 21.

November 27-28, 1928. Latitude 24°.0 S; Longitude 245°.1 E

GMT h	LMT h	Pot'l. grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
18.9	11.3	154	1.34	....	.....	120	13.1
19.8	12.1	147	1.37	....	.....	210	12.8
21.0	13.3	125	1.40	....	.....	210	11.1
22.0	14.4	93	1.39	....	.....	140	8.2
23.0	15.4	93	1.44	....	.....	140	8.5
0.1	16.4	74	1.39	....	.....	340	6.5
1.0	17.3	74	1.33	....	.....	370	6.3
2.0	18.4	67	1.31	....	.....	280	5.6
3.0	19.3	83	1.31	....	.....	480	6.9
4.0	20.4	93	1.29	....	.....	390	7.6
5.1	21.4	93	1.29	....	.....	280	7.6
6.0	22.3	106	1.31	....	.....	250	8.8
7.0	23.4	109	1.29	....	.....	340	8.9
8.0	0.3	115	1.29	....	.....	280	9.4
9.0	1.4	109	1.34	....	.....	270	9.3
10.0	2.3	102	1.33	....	.....	270	8.6
11.1	3.4	96	1.43	....	.....	270	8.7
12.1	4.4	102	1.24	....	.....	....	8.1
12.9	5.3	109	1.41	....	.....	280	9.8
14.0	6.4	115	1.35	....	.....	270	9.9
15.0	7.3	125	1.37	....	.....	210	10.9
16.0	8.3	134	1.29	....	.....	300	11.0
17.0	9.3	154	1.30	....	.....	270	12.7
18.0	10.4	154	1.34	....	.....	520	13.1

Temp. range: 20.7-19.9 °C. Rel. hum. range: 76-93 per cent. Wind: E to SE, 1-4. Clouds: cu-frcu-stcu-cunb-nb, 1-10. Visibility: 3. Rain 1.2h-1.3h and 12.5h-12.8h GMT.

December 3-4, 1928. Latitude 31°.6 S; Longitude 248°.5 E

GMT h	LMT h	Pot'l. grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_-	n_-	k_-		
18.7	11.3	125	1.05	471	1.55	1600	9.2
19.5	12.0	134	1.04	421	1.72	1200	9.7
20.8	13.3	125	1.07	450	1.65	2000	9.4
21.9	14.4	109	1.11	498	1.55	2700	8.5
23.0	15.6	102	1.12	488	1.59	3200	8.0
24.0	16.6	86	1.16	554	1.45	4600	7.0
0.8	17.4	86	1.09	517	1.46	3400	6.6
2.1	18.6	86	1.11	537	1.43	2800	6.7
3.0	19.6	86	1.14	530	1.49	5000	6.9
4.0	20.6	86	1.15	543	1.47	4500	6.9
5.0	21.6	99	1.13	522	1.50	2800	7.8
6.0	22.6	109	1.13	507	1.55	2800	8.6
7.0	23.6	109	1.08	544	1.38	2000	8.2
8.0	0.6	122	1.11	536	1.44	1800	9.5
9.0	1.6	122	1.08	549	1.37	1800	9.2
10.0	2.6	125	1.07	518	1.43	2500	9.4
11.0	3.6	125	1.13	541	1.45	1800	9.9
12.0	4.6	134	1.15	564	1.41	3200	10.8
13.0	5.6	134	1.10	556	1.37	2300	10.3
14.0	6.6	157	1.02	507	1.40	4300	11.2
14.8	7.4	157	1.05	489	1.49	2000	11.5
16.0	8.6	163	0.98	360	1.89	1600	11.2
17.0	9.6	163	0.98	363	1.87	2500	11.2
18.1	10.6	163	0.98	357	1.90	1800	11.2

Temp. range: 23.0-21.8 °C. Rel. hum. range: 73-85 per cent. Wind: NW to NNW, 3-4. Visibility: 3. Clouds: cist-ast-frcu-stcu, 5-10.

December 18-19, 1928. Latitude 32°.3 S; Longitude 252°.1 E

GMT h	LMT h	Pot'l. grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
18.5	11.4	195	1.15	349	2.29	......	14.3
19.4	12.3	179	1.01	361	1.94	......	11.5
20.5	13.3	179	1.07	423	1.76	......	12.2
21.4	14.2	173	1.10	451	1.69	......	12.1
22.5	15.3	150	1.11	487	1.58	......	10.6
23.5	16.3	147	1.12	507	1.53	......	10.5
0.5	17.3	138	1.12	473	1.64	......	9.8
1.2	18.0	131	1.08	469	1.60	......	9.0
2.3	19.1	131	1.05	462	1.58	......	8.8
3.3	20.1	131	1.04	442	1.63	......	8.7
4.4	21.2	150	1.02	430	1.65	......	9.8
5.4	22.2	163	1.00	425	1.63	......	10.4
6.5	23.3	163	0.98	437	1.56	......	10.2
7.4	0.2	166	1.00	428	1.62	......	10.6
8.5	1.3	157	0.97	473	1.42	......	9.7
9.7	2.5	176	0.99	502	1.37	......	11.1
10.4	3.2	150	1.04	443	1.63	......	10.0
11.4	4.2	166	1.03	458	1.56	......	10.9
12.6	5.4	189	0.98	452	1.50	......	11.8
13.4	6.2	195	0.99	441	1.56	......	12.3
14.6	7.4	205	1.01	442	1.59	......	13.2
15.6	8.4	205	1.02	424	1.67	......	13.3
16.5	9.3	208	1.04	435	1.66	......	13.8
17.4	10.2	205	1.01	427	1.64	......	13.2

Temp. range: 22.2-19.6 °C. Rel. hum. range: 66-84 per cent. Wind: N×W to NE×N, 1-4. Visibility: --. Clouds: ci-cist-ast-cu-stcu, 0-10.

Table 2. Diurnal-variation measurements of atmospheric-electric elements--Continued

December 26-27, 1928. Latitude 40°.4 S; Longitude 263°.0 E

GMT h	LMT h	Pot'l grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
18.8	12.3	346	0.72	371	1.35	......	15.9
19.9	13.4	275	0.78	387	1.40	......	13.7
20.9	14.4	227	0.84	429	1.36	......	12.1
21.8	15.3	202	1.06	477	1.54	......	13.6
22.7	16.3	192	0.96	466	1.43	......	11.7
23.8	17.4	170	1.01	396	1.77	......	10.9
1.1	18.6	150	0.98	398	1.71	......	9.4
1.9	19.4	157	1.01	462	1.52	......	10.1
2.9	20.4	176	0.89	573	1.08	......	10.0
3.8	21.4	195	0.84	512	1.14	......	10.4
4.8	22.4	211	0,89	516	1.20	......	12.0
5.8	23.4	230	0.79	468	1.17	......	11.6
6.9	0.4	192	0.88	532	1.15	......	10.8
7.8	1.4	166	0.99	528	1.30	......	10.5
8.9	2.4	154	1.01	558	1.26	......	9.9
9.9	3.4	157	0.93	515	1.25	......	9.3
10.9	4.4	150	1.07	606	1.23	......	10.2
11.8	5.3	157	1.10	658	1.16	......	11.0
12.8	6.3	144	1.08	679	1.10	......	9.9
13.8	7.3	157	1.11	711	1.08	......	11.1
15.0	8.5	208	.....	561	.....	......	.....
16.0	9.6	314	0.76	649	0.81	......	15.2
16.9	10.4	330	0.70	530	0.92	......	14.7
17.7	11.3	227	0.92	591	1.08	......	13.3

Temp. range: 19.0-15.2 °C. Rel. hum. range: 73-98 per cent.
Wind: NW to N×W, 1-3. Visibility: --.
Clouds: ci-ast-cu-stcu, 0-7.

January 1-2, 1929. Latitude 32°.0 S; Longitude 271°.1 E

GMT h	LMT h	Pot'l grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
17.4	11.5	174	0.99	606	1.13	......	11.0
18.3	12.4	183	1.02	512	1.38	......	11.9
19.3	13.3	96	1.05	564	1.29	......	6.4
20.3	14.3	99	0.92	518	1.23	......	5.8
21.3	15.3	104	1.03	546	1.31	......	6.8
22.3	16.4	125	0.89	484	1.28	......	7.1
23.3	17.4	102	0.77	488	1.10	......	5.0
0.3	18.4	136	0.97	606	1.11	......	8.4
1.8	19.8	168	0.92	582	1.10	......	9.9
2.6	20.6	128	0.97	594	1.13	......	7.9
3.4	21.5	145	0.99	592	1.16	......	9.1
4.5	22.5	125	0.88	551	1.11	......	7.0
5.4	23.4	125	0.98	568	1.20	......	7.8
6.2	0.3	125	0.94	575	1.13	......	7.5
7.2	1.3	148	0.90	535	1.17	......	8.5
8.4	2.5	142	0.98	574	1.18	......	8.9
9.4	3.5	136	0.99	556	1.24	......	8.6
10.4	4.5	125	1.01	599	1.19	......	8.0
11.3	5.4	130	1.05	583	1.25	......	8.7
12.4	6.4	130	0.94	555	1.18	......	7.8
13.2	7.2	128	1.04	568	1.27	......	8.5
14.1	8.2	136	1.05	533	1.37	......	9.1
15.2	9.3	151	1.01	522	1.35	......	9.7
16.2	10.3	165	1.03	534	1.34	......	10.8

Temp. range: 23.3-19.6 °C. Rel. hum. range: 63-75 per cent.
Wind: Calm first 11 sets, then SE to SSW, 1
Visibility: --. Clouds: cu-frcu-stcu, 0-8.

January 10-11, 1929. Latitude 20°.4 S; Longitude 280°.0 E

GMT h	LMT h	Pot'l grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
17.1	11.8	197	0.65	341	1.32	......	8.1
18.2	12.8	206	0.61	346	1.22	......	8.0
19.3	14.0	206	0.59	337	1.22	......	7.8
20.3	15.0	212	0.50	280	1.24	......	6.8
21.3	16.0	218	0.48	275	1.21	......	6.7
22.3	17.0	218	0.48	268	1.24	......	6.7
23.2	17.9	186	0.51	290	1.22	......	6.0
0.3	19.0	157	0.62	327	1.32	......	6.2
1.3	20.0	148	0.66	350	1.31	......	6.2
2.2	20.9	145	0.75	383	1.36	......	6.9
3.3	21.9	136	0.76	423	1.25	......	6.6
4.2	22.8	130	0.78	402	1.35	......	6.5
5.3	23.9	130	0.78	413	1.31	......	6.5
6.2	0.8	139	0.79	421	1.30	......	7.0
7.2	1.9	130	0.80	421	1.32	......	6.6
8.3	3.0	160	0.77	414	1.29	......	7.8
9.2	3.8	142	0.81	426	1.32	......	7.3
10.2	4.9	162	0.80	418	1.33	......	8.3
11.2	5.9	151	0.81	431	1.30	......	7.8
12.2	6.8	180	0.79	425	1.29	......	9.1
13.0	7.7	183	0.75	422	1.23	......	8.7
14.1	8.8	194	0.76	398	1.33	......	9.4
15.2	9.8	232	0.73	393	1.29	......	10.7
16.2	10.9	232	0.75	397	1.31	......	11.1

Temp. range: 20.7-18.9 °C. Rel. hum. range: 70-81 per cent.
Wind: ESE to SE×S, 3-5. Visibility: --.
Clouds: cu-stcu-nb, 10

February 10-11, 1929. Latitude 10°.6 S; Longitude 274°.7 E

GMT h	LMT h	Pot'l grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
16.8	11.2	134	0.98	441	1.54	660	8.4
17.8	12.1	147	0.89	447	1.38	940	8.3
19.1	13.4	141	0.92	433	1.46	970	8.3
20.0	14.3	182	0.84	389	1.50	1210	9.7
21.0	15.3	109	0.94	475	1.37	780	6.5
21.9	16.2	125	0.92	379	1.68	590	7.3
22.9	17.2	122	0.90	425	1.47	210	7.0
23.9	18.2	....	0.95	401	1.64	170	.....
1.2	19.5	....	0.94	371	1.76	750	.....
2.2	20.5	....	0.96	363	1.83	640	.....
3.3	21.6	....	0.92	393	1.62	770	.....
4.2	22.5	....	0.98	371	1.83	560	.....
5.3	23.6	....	0.99	368	1.87	500	.....
6.3	0.6	....	0.92	384	1.66	560	.....
7.3	1.6	....	0.91	377	1.68	490	.....
8.3	2.6	....	0.92	353	1.81	440	.....
9.3	3.6	....	0.91	329	1.92	1080	.....
10.1	4.4	....	0.92	364	1.75	800	.....
11.1	5.4	....	0.94	392	1.66	870	.....
12.1	6.4	....	0.92	393	1.62	1440	.....
13.0	7.3	....	0.93	371	1.74	1030	.....
14.1	8.4	....	0.88	382	1.60	1250	.....
15.2	9.5	....	0.93	385	1.68	940	.....
16.3	10.6	....	0.93	359	1.80	1080	.....

Temp. range: 27.7-24.2 °C. Rel. hum. range: 56-76 per cent.
Wind: Calm or SSE to SW, 1-3. Visibility: 3.
Clouds: ast-frcu-stcu, 0-9.

Table 2. Diurnal-variation measurements of atmospheric-electric elements--Continued

February 18-19, 1929. Latitude 14°.0 S; Longitude 255°.5 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_-	n_-	k_-		
19.1	12.1	176	0.89	523	1.18	1880	11.0
20.3	13.4	189	0.90	488	1.28	1110	11.9
21.3	14.4	160	0.99	541	1.27	1250	11.1
22.2	15.3	160	1.03	534	1.33	1740	11.5
23.1	16.1	144	1.06	556	1.32	1670	10.7
24.0	17.0	125	1.03	547	1.31	1950	9.0
1.0	18.0	122	1.00	560	1.24	......	8.5
2.0	19.0	115	1.10	626	1.22	2090	8.9
2.9	20.0	109	1.07	633	1.17	2850	8.2
4.0	21.0	106	1.13	735	1.07	2360	8.4
5.0	22.1	112	1.09	610	1.24	2020	8.5
6.1	23.1	134	1.06	570	1.29	2090	10.0
7.2	0.2	141	1.08	598	1.25	3340	10.7
8.2	1.2	147	1.06	564	1.30	3820	10.9
9.2	2.2	131	1.09	551	1.37	3410	10.0
10.3	3.3	157	1.01	542	1.29	3200	11.1
11.2	4.3	147	1.05	534	1.37	1600	10.8
12.3	5.3	147	1.05	562	1.30	2920	10.8
13.3	6.4	166	0.95	510	1.29	2150	11.1
14.2	7.2	157	1.03	589	1.21	3750	11.3
15.4	8.4	173	1.10	574	1.33	4450	13.3
16.3	9.3	150	1.21	594	1.41	3750	12.7
17.1	10.1	170	1.20	594	1.40	3480	14.3
18.0	11.1	173	0.98	505	1.35	4450	11.9

Temp. range: 26.0-23.4 °C. Rel. hum. range: 69-82 per cent.
Wind: E×S to SE×E, 4. Visibility: 3.
Clouds: cu-frcu, 1-4.

February 26-27, 1929. Latitude 13°.1 S; Longitude 237°.4 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
20.1	12.0	106	0.75	....	.....	4590	5.1
21.0	12.8	166	0.84	434	1.34	......	8.9
21.9	13.8	147	0.85	466	1.27	4030	7.9
22.8	14.6	166	0.88	467	1.31	3270	9.3
23.8	15.6	141	0.75	478	1.09	3480	6.7
0.8	16.6	125	0.81	473	1.19	3130	6.5
1.9	17.7	138	0.86	483	1.24	3480	7.5
3.0	18.8	112	0.86	536	1.11	2220	6.1
4.0	19.8	102	0.85	520	1.13	1180	5.5
4.9	20.8	112	0.87	523	1.15	2150	6.2
5.9	21.8	109	0.92	517	1.23	1670	6.4
6.9	22.7	112	0.92	513	1.24	1390	6.6
7.9	23.8	112	0.94	546	1.19	1880	6.7
9.0	0.8	138	0.88	515	1.19	2640	7.7
9.9	1.7	129	0.83	485	1.19	2850	6.8
11.2	3.0	133	0.91	486	1.30	2430	7.7
12.2	4.0	164	0.90	491	1.27	1180	9.4
13.2	5.1	160	0.95	517	1.27	2430	9.7
14.2	6.0	168	0.90	530	1.18	2780	9.6
15.2	7.0	168	0.79	436	1.26	2150	8.5
16.1	8.0	179	0.66	401	1.14	2990	7.5
17.2	9.0	176	0.97	505	1.33	2920	10.9
18.1	10.0	205	0.97	483	1.39	3890	12.6
19.2	11.0	208	0.98	518	1.31	4800	13.0

Temp. range: 27.8-26.1 °C. Rel. hum. range: 64-75 per cent.
Wind: E to E×S, 3-5. Visibility: 3.
Clouds: ci-cist-cu-frcu-cunb, 1-9.
Showers Feb. 26, 20.0h and Feb. 27, 10.2h GMT.

March 10-11, 1929. Latitude 18°.0 S; Longitude 215°.5 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
20.3	10.7	214	1.05	588	1.24	2290	14.3
21.1	11.5	218	1.03	582	1.23	2020	14.3
22.0	12.3	230	1.03	572	1.25	2360	15.1
23.0	13.4	207	1.03	578	1.24	1390	13.6
0.2	14.5	....	1.13	530	1.48	1810	.....
1.3	15.6	157	1.20	573	1.45	2850	12.0
2.3	16.7	163	1.29	679	1.32	2220	13.4
3.3	17.7	67	1.27	485	1.82	......	5.4
4.5	18.9	29	1.21	....	.....	......	2.2
5.3	19.7	81	1.14	626	1.26	......	5.9
6.4	20.8	99	1.17	558	1.46	1810	7.4

Observations discontinued because of bad weather; rain from 3.0h GMT.

March 25-26, 1929. Latitude 16°.5 S; Longitude 203°.7 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
21.4	11.0	157	0.96	497	1.34	3540	9.6
22.5	12.1	151	0.80	446	1.24	2990	7.7
0.1	13.7	142	0.90	460	1.36	2090	8.1
1.1	14.7	....	0.93	491	1.31	1810	.....
2.1	15.7	....	1.01	500	1.40	3610	.....
3.2	16.8	....	0.72	432	1.16	1810	.....
4.2	17.8	148	0.90	512	1.22	1250	8.5
5.5	19.0	179	0.80	448	1.24	1670	9.1

Observations discontinued because of bad weather.

March 27-28, 1929. Latitude 15°.7 S; Longitude 199°.1 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
22.5	11.8	176	0.93	441	1.46	1460	10.4
0.2	13.4	125	0.92	520	1.23	1320	7.3
1.2	14.4	....	1.00	403	1.72	970	.....
2.2	15.5	....	0.92	....	.....	1390	.....
3.2	16.5	94	1.04	....	.....	1460	6.2
4.2	17.5	109	1.16	553	1.46	1250	8.1
5.4	18.6	99	1.12	611	1.27	630	7.1
6.2	19.5	104	1.13	635	1.23	850	7.5
7.2	20.4	96	1.10	618	1.23	1200	6.7
8.1	21.4	102	1.17	636	1.28	1030	7.6
9.2	22.4	138	0.93	....	.....	610	8.2
10.1	23.4	....	1.11	592	1.30	490	.....
11.1	0.4	....	1.07	510	1.46	520	.....

Observations discontinued because of thunder, lightning, and rain.
Temp. range: 29.0-27.2 °C. Rel. hum. range: 77-82 per cent.
Wind: N×E to ENE, 2-4. Visibility: 3.
Clouds: ci-cu-cunb, 4-10.

Table 2. Diurnal-variation measurements of atmospheric-electric elements--Continued

April 30-May 1, 1929. Latitude 1°6 N; Longitude 185°4 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
23.6	12.0	148	0.85	470	1.26	990	8.0
0.3	12.7	....	.....	....	.....	......	.....
1.1	13.4	128	0.88	526	1.16	750	7.2
2.3	14.7	116	0.90	508	1.23	780	6.7
3.3	15.7	116	0.89	522	1.18	710	6.6
4.4	16.8	122	0.89	527	1.17	2090	6.9
5.3	17.6	125	0.91	514	1.23	1940	7.2
6.5	18.8	128	0.89	470	1.31	920	7.3
7.4	19.8	148	0.91	432	1.46	2570	8.6
8.5	20.8	154	0.95	433	1.52	2090	9.3
9.5	21.9	160	0.96	440	1.51	1950	9.8
10.4	22.8	154	1.01	383	1.83	2780	9.9
11.4	23.8	151	0.99	382	1.80	2290	9.5
12.5	0.8	151	0.92	386	1.65	1600	8.9
13.4	1.8	151	0.95	398	1.66	770	9.1
14.5	2.8	154	0.95	....	.....	......	9.3
15.6	4.0	148	1.00	....	.....	2050	9.4
16.6	5.0	162	1.02	....	.....	2020	10.5
17.6	6.0	148	0.99	....	.....	1810	9.3
18.5	6.9	....	0.96	....	.....	2500	.....
19.4	7.8	145	1.09	....	.....	1880	10.1
20.5	8.8	151	1.18	....	.....	1810	11.3
21.4	9.8	130	1.16	....	.....	1530	9.6
22.4	10.8	154	1.31	....	.....	......	12.8

Temp. range: 27.9-26.2 °C. Rel. hum. range: 75-87 per cent.
Wind: NE×E to E×S, 2-5. Visibility: 3.
Clouds: Cloudless for 12 sets, then cu-stcu-cunb, 3-10.
Occasional showers 14.9h to 21.3h GMT.

May 9-10, 1929. Latitude 17°5 N; Longitude 170°5 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
0.2	11.6	125	1.25	686	1.25	2090	10.0
1.1	12.5	130	1.20	694	1.20	1740	9.9
2.1	13.4	125	1.22	633	1.34	760	9.7
3.0	14.4	151	1.21	699	1.20	1040	11.6
4.0	15.4	145	1.20	689	1.21	970	11.1
5.0	16.4	133	1.20	717	1.16	900	10.2
6.1	17.4	128	1.20	727	1.15	630	9.8
7.2	18.5	130	1.16	706	1.14	350	9.6
8.1	19.5	128	1.14	....	.....	3610	9.3
9.0	20.4	125	1.22	....	.....	2430	9.7
10.0	21.4	122	1.18	....	.....	3130	9.1
11.0	22.4	113	1.27	....	.....	2290	9.2
12.1	23.4	139	1.06	....	.....	1950	9.4
13.1	0.4	145	1.04	....	.....	2090	9.6
14.0	1.4	145	0.98	....	.....	2220	9.0
15.1	2.4	162	0.97	....	.....	3410	10.0
16.1	3.5	174	0.89	....	.....	3540	9.9
17.1	4.5	174	1.00	....	.....	5420	11.1
18.1	5.4	174	1.01	....	.....	4170	11.2
19.1	6.5	165	1.02	516	1.37	1110	10.7
20.1	7.4	180	1.06	539	1.37	700	12.1
21.0	8.3	151	1.13	562	1.40	2150	10.9
22.0	9.4	142	1.14	582	1.36	2850	10.3
23.0	10.4	136	1.18	576	1.42	2220	10.2

Temp. range: 26.9-25.2 °C. Rel. hum. range: 73-85 per cent.
Wind: ENE to E×N, 5. Visibility: 3.
Clouds: ci-cist-cu-frcu-stcu, 2-10.

May 17-18, 1929. Latitude 15°5 N; Longitude 149°6 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
1.3	11.2	99	1.04	532	1.36	3270	6.6
2.3	12.3	99	1.10	574	1.33	2780	6.9
3.3	13.3	99	1.10	599	1.27	2150	6.9
4.2	14.2	96	1.07	593	1.25	2850	6.5
5.3	15.3	96	1.11	613	1.26	3750	6.8
6.4	16.3	93	1.10	586	1.30	4240	6.5
7.3	17.2	93	1.07	607	1.22	4800	6.3
8.4	18.4	86	1.13	643	1.22	3200	6.2
9.4	19.4	86	1.14	590	1.34	4240	6.2
10.4	20.3	67	1.14	578	1.37	4310	4.9
11.4	21.4	67	1.11	545	1.41	2990	4.7
12.4	22.3	67	1.07	520	1.43	3960	4.6
13.4	23.3	77	1.14	558	1.42	3890	5.6
14.4	0.4	86	1.05	463	1.57	3610	5.8
15.3	1.3	86	1.07	545	1.36	3960	5.8
16.6	2.6	96	1.00	492	1.41	4870	6.1
17.5	3.4	99	1.00	527	1.32	5280	6.3
18.5	4.5	90	1.03	552	1.30	2780	5.9
19.3	5.3	86	1.02	542	1.31	3130	5.6
20.3	6.3	90	1.08	598	1.25	3750	6.2
21.3	7.3	90	1.06	580	1.27	4590	6.1
22.3	8.3	106	1.08	581	1.29	7100	7.3
23.3	9.2	102	1.07	587	1.27	9580	6.9
0.3	10.3	99	1.09	623	1.22	13100	6.9

Temp. range: 28.7-26.8 °C. Rel. hum. range: 70-82 per cent.
Wind: E to SE×E, 4-5. Visibility: 2-3.
Clouds: cist-ast-cu-frcu, 1-10.

May 27-28, 1929. Latitude 20°0 N; Longitude 144°0 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
2.2	11.8	160	1.21	581	1.37	3680	12.3
3.2	12.8	148	1.23	611	1.37	9450	11.6
4.2	13.8	139	1.25	634	1.37	7690	11.1
5.2	14.8	148	1.16	604	1.33	10330	11.0
6.2	15.8	148	1.13	595	1.32	8130	10.7
7.3	16.9	148	1.09	591	1.28	12100	10.3
8.3	17.9	151	1.07	605	1.23	18900	10.3
9.3	18.9	148	1.05	545	1.34	15840	9.9
10.4	20.0	148	1.06	559	1.32	15750	10.0
11.3	20.9	139	1.07	537	1.38	16590	9.5
12.2	21.8	139	1.12	575	1.35	13660	9.9
13.2	22.8	151	1.15	618	1.29	12930	11.1
14.3	23.9	157	1.13	640	1.22	14880	11.3
15.2	0.8	157	1.19	630	1.31	11710	11.9
16.2	1.8	110	1.21	654	1.28	15370	8.5
17.3	2.9	171	1.19	663	1.25	18060	12.9
18.2	3.8	188	1.17	645	1.26	17570	14.0
19.3	4.9	186	1.15	624	1.28	24640	13.6
20.2	5.8	188	1.15	601	1.33	20010	13.8
21.2	6.8	168	1.22	636	1.33	22940	13.0
22.3	7.9	188	1.31	658	1.38	17570	15.7
23.2	8.8	183	1.31	657	1.38	23420	15.2
0.2	9.8	174	1.29	673	1.33	15370	14.3
1.2	10.8	174	1.34	712	1.31	15620	14.8

Temp. range: 29.0-27.9 °C. Rel. hum. range: 71-79 per cent.
Wind: E×N to E×S, 4. Visibility: 2-3.
Clouds: ci-cu-frcu-stcu, 1-7.

Table 2. Diurnal-variation measurements of atmospheric-electric elements--Continued

July 3-4, 1929. Latitude 40°.8 N; Longitude 151°.9 E

GMT h	LMT h	Pot'l-grad. V/m	Con-duc-tivity in 10^{-4} esu	Small ions per cc	Mobil-ity cm/s per v/cm	Nu-clei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
2.3	12.4	191	0.81	574	0.98	2290	9.9
3.3	13.4	197	0.80	574	0.97	3680	10.0
4.2	14.3	203	0.78	560	0.97	3340	10.1
5.2	15.3	203	0.70	487	1.00	4380	9.1
6.3	16.4	223	0.58	415	0.97	4380	8.3
7.3	17.4	223	0.58	393	1.02	3680	8.3
8.3	18.4	203	0.58	376	1.07	1740	7.5
9.4	19.5	203	0.63	411	1.06	2220	8.1
10.3	20.4	186	0.73	470	1.08	2500	8.6
11.2	21.4	174	0.78	473	1.15	3340	8.6
12.2	22.4	165	0.76	518	1.02	2850	8.0
13.3	23.5	160	0.77	513	1.04	3610	7.8
14.3	0.4	151	0.78	524	1.03	2640	7.5
15.3	1.4	174	0.75	502	1.04	2500	8.3
16.3	2.4	197	0.64	402	1.11	3270	8.0
17.3	3.4	186	0.71	500	0.99	2360	8.4
18.3	4.4	148	0.72	382	1.31	1810	6.8
19.3	5.4	148	0.71	....	.....	1600	6.7
20.3	6.5	160	0.76	....	.....	970	7.7
21.3	7.4	148	0.86	469	1.27	1880	8.1
22.4	8.5	148	0.72	....	.....	2500	6.8
23.3	9.5	148	0.74	....	.....	3060	6.9
0.3	10.4	215	0.79	....	.....	2500	10.8
1.3	11.4	171	0.75	....	.....	2080	8.2

Temp. range: 14.0-11.0 °C. Rel. hum. range: 75-91 per cent.
Wind: SE to S×E, 1-4. Visibility: 3.
Clouds: cu-stcu-cunb, 7-10.
After 18h GMT overcast, threatening, disturbed.

October 5-6, 1929. Latitude 30°.8 N; Longitude 198°.6 E

GMT h	LMT h	Pot'l-grad. V/m	Con-duc-tivity in 10^{-4} esu	Small ions per cc	Mobil-ity cm/s per v/cm	Nu-clei per cc	Air-earth current density in 10^{-7} esu
			λ_-	n_-	k_-		
0.5	13.8	145	1.10	499	1.53	2080	11.2
1.5	14.8	142	1.10	474	1.61	1390	10.9
2.5	15.8	136	1.10	446	1.71	1530	10.5
3.6	16.8	139	1.06	433	1.70	970	10.3
4.5	17.7	130	1.08	535	1.40	1530	9.8
5.5	18.7	125	1.08	490	1.53	1810	9.5
6.5	19.7	128	1.08	588	1.28	1460	9.7
7.5	20.8	151	1.06	527	1.40	1740	11.2
8.5	21.7	145	1.04	513	1.41	1040	10.5
9.5	22.7	142	1.01	486	1.44	1460	10.0
10.5	23.7	157	0.99	457	1.50	1460	10.9
11.5	0.7	168	0.93	414	1.56	1530	10.9
12.5	1.7	174	0.89	395	1.56	1460	10.8
13.5	2.8	180	0.87	360	1.68	1320	11.0
14.5	3.8	180	0.87	365	1.66	1530	11.0
15.5	4.8	206	0.85	332	1.78	1320	12.2
16.5	5.7	209	0.87	367	1.65	1040	12.7
17.5	6.7	232	0.87	403	1.50	690	14.2
18.6	7.8	241	0.85	385	1.53	1040	14.3
19.6	8.8	241	0.85	371	1.59	1040	14.3
20.5	9.7	241	0.83	388	1.48	620	14.0
21.5	10.8	203	0.89	399	1.55	760	12.7
22.5	11.7	186	0.89	414	1.49	630	11.6
23.6	12.8	174	0.91	406	1.56	1180	11.1

Temp. range: 25.7-23.7 °C. Rel. hum. range: 69-82 per cent.
Wind: NE×E to ESE, 3-5. Visibility: 3.
Clouds: ci-cist-cu-cunb, 1-9.

July 21-22, 1929. Latitude 47°.0 N; Longitude 218°.8 E

GMT h	LMT h	Pot'l-grad. V/m	Con-duc-tivity in 10^{-4} esu	Small ions per cc	Mobil-ity cm/s per v/cm	Nu-clei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
21.9	12.5	194	0.98	520	1.31	3060	12.1
22.8	13.4	223	0.87	485	1.25	2570	12.3
23.7	14.3	249	0.80	459	1.21	2500	12.7
0.8	15.4	229	0.79	584	0.94	2990	11.5
1.7	16.3	200	0.77	528	1.01	3410	9.8
2.7	17.3	177	0.86	763	0.78	1950	9.7
3.7	18.3	183	0.90	777	0.80	1530	10.5
4.7	19.3	160	0.91	....	.....	1250	9.3
5.7	20.3	125	1.06	....	.....	1180	8.4
6.8	21.4	70	1.13	....	.....	1600	5.0
7.7	22.3	160	1.23	....	.....	800	12.5
8.8	23.4	52	1.25	....	.....	1950	4.1
9.8	0.4	139	1.27	....	.....	1950	11.3
10.7	1.3	145	1.43	....	.....	2020	13.2
11.8	2.4	139	1.32	....	....	610	11.7
12.7	3.3	160	1.31	....	.....	450	13.3
13.7	4.3	145	1.45	....	.....	830	13.4
14.8	5.4	139	1.47	....	.....	880	13.1
15.7	6.3	154	1.46	....	.....	990	14.3
16.7	7.3	125	1.31	....	.....	800	10.4
17.9	8.5	93	1.28	....	.....	1010	7.6
18.8	9.4	160	1.36	764	1.24	950	13.9
19.7	10.3	212	1.22	737	1.15	1090	16.5
20.7	11.3	136	1.11	708	1.09	1950	9.6

Temp. range: 12.8-10.9 °C. Rel. hum. range: 78-95 per cent.
Wind: WNW, 4-6. Visibility: 1-3.
Clouds: cu-stcu-cunb-nb, 7-10.
Occasional light rains 4h to 18h GMT.

October 13-14, 1929. Latitude 33°.5 N; Longitude 215°.3 E

GMT h	LMT h	Pot'l-grad. V/m	Con-duc-tivity in 10^{-4} esu	Small ions per cc	Mobil-ity cm/s per v/cm	Nu-clei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
21.5	11.9	163	1.44	613	1.63	1530	14.9
22.5	12.9	125	1.44	602	1.66	1250	11.5
23.5	13.9	154	1.44	593	1.68	970	14.1
0.5	14.9	131	1.42	603	1.63	830	11.8
1.5	15.9	93	1.33	662	1.39	1250	7.9
2.5	16.9	83	1.25	604	1.44	760	6.6
3.5	17.9	96	1.25	680	1.28	1250	7.6
4.5	18.9	86	1.36	680	1.39	420	7.5
5.5	19.9	83	1.28	682	1.30	620	6.8
6.4	20.8	94	1.28	586	1.52	700	7.6
7.5	21.9	94	1.25	531	1.63	830	7.5
8.5	22.9	82	1.28	554	1.60	760	6.7
9.4	23.8	82	1.30	555	1.63	560	6.8
10.4	0.8	86	1.25	587	1.48	560	6.9
11.4	1.8	90	1.25	551	1.58	900	7.2
12.5	2.9	105	1.25	562	1.54	......	8.4
13.5	3.9	130	1.39	646	1.49	......	11.5
14.5	4.9	136	1.42	647	1.52	......	12.3
15.4	5.8	119	1.42	640	1.54	......	10.7
16.5	6.9	139	1.36	711	1.33	1110	12.0
17.5	7.9	130	1.28	604	1.47	1390	10.6
18.5	8.9	165	1.25	597	1.45	900	13.1
19.5	9.9	46	1.25	621	1.40	760	3.7
20.5	10.9	139	1.22	576	1.47	970	10.8

Temp. range: 22.8-20.1 °C. Rel. hum. range: 67-69 per cent.
Wind: SW×S to NW×N, 1-4. Visibility: 3.
Clouds: ci-cu-frcu-stcu, 1-10. Disturbed 19-20h GMT.

Table 2. Diurnal-variation measurements of atmospheric-electric elements--Concluded

October 21-22, 1929. Latitude 19°9 N; Longitude 221°7 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_-	n_-	k_-		
20.5	11.3	147	1.24	359	2.40	630	12.7
21.5	12.3	134	1.26	346	2.53	700	11.8
22.5	13.3	122	1.24	341	2.53	700	10.6
23.5	14.3	122	1.26	369	2.37	1320	10.8
0.5	15.3	....	1.26	405	2.16	1460	.....
1.5	16.3	....	1.21	406	2.07	830	.....
2.6	17.4	....	1.16	385	2.09	630	.....
3.6	18.4	....	1.16	351	2.29	1180	.....
4.6	19.4	....	1.11	347	2.22	1810	.....
5.5	20.3	....	1.07	338	2.20	1530	.....
6.5	21.3	115	1.07	327	2.27	1180	8.6
7.5	22.3	122	1.07	331	2.24	760	9.2
8.6	23.3	118	1.05	297	2.45	630	8.7
9.5	0.3	118	1.05	326	2.24	830	8.7
10.5	1.3	122	1.02	313	2.26	900	8.7
11.7	2.4	109	1.05	361	2.02	830	8.0
12.6	3.4	115	1.02	360	1.97	......	8.2
13.6	4.4	125	1.05	407	1.79	420	9.2
14.6	5.4	131	1.05	371	1.96	280	9.6
15.6	6.3	74	1.11	404	1.91	140	5.7
16.5	7.3	131	1.11	408	1.89	280	10.2
17.5	8.3	141	1.09	375	2.02	830	10.8
18.5	9.3	134	1.07	354	2.10	760	10.0
19.5	10.3	125	1.09	309	2.45	630	9.5

Temp. range: 25.8-22.9 °C. Rel. hum. range: 66-82 per cent.
Wind: ENE to E×S, 4-5. Visibility: 2-3.
Clouds: ci-cist-acu-cu-stcu, 4-10. Rain 15-16h GMT.

November 4-5, 1929. Latitude 1°8 N; Longitude 209°1 E

GMT h	LMT h	Pot'l-grad. V/m	Conductivity in 10^{-4} esu	Small ions per cc	Mobility cm/s per v/cm	Nuclei per cc	Air-earth current density in 10^{-7} esu
			λ_+	n_+	k_+		
0.5	14.5	144	0.76	268	1.97	630	7.0
1.5	15.4	134	0.76	302	1.74	560	6.5
2.5	16.4	144	0.79	301	1.82	700	7.2
3.5	17.5	144	0.79	295	1.86	560	7.2
4.5	18.5	118	0.82	279	2.04	1530	6.2
5.6	19.5	170	0.79	266	2.06	1250	8.6
6.5	20.5	182	0.79	246	2.23	970	9.2
7.5	21.5	166	0.76	237	2.22	1600	8.0
8.5	22.5	166	0.76	235	2.24	1810	8.0
9.5	23.5	182	0.76	229	2.30	2020	8.8
10.5	0.5	176	0.79	241	2.27	1740	8.9
11.5	1.4	176	0.82	220	2.59	1320	9.2
12.5	2.4	182	0.79	275	1.99	560	9.2
13.5	3.4	189	0.82	270	2.11	560	9.9
14.5	4.5	182	0.85	282	2.09	560	9.8
15.5	5.5	186	0.76	266	1.98	630	9.0
16.5	6.5	163	0.82	272	2.09	490	8.5
17.5	7.4	170	0.76	290	1.82	420	8.2
18.5	8.5	173	0.76	292	1.80	700	8.4
19.5	9.5	182	0.72	311	1.61	900	8.4
20.5	10.5	163	0.72	318	1.57	700	7.5
21.5	11.5	154	0.76	341	1.55	970	7.4
22.5	12.4	141	0.76	318	1.66	1250	6.8
23.5	13.5	144	0.72	285	1.75	970	6.6

Temp. range: 27.0-26.0 °C. Rel. hum. range: 76-82 per cent.
Wind: SE×E to SE×S, 3-5. Visibility: 3.
Clouds: cu-frcu, 1-7. Disturbed 4-5h GMT

VII. ATMOSPHERIC POTENTIAL-GRADIENT RESULTS

EXPLANATORY NOTES AND COMMENTS

Section VII contains hourly mean values, on Greenwich Mean Time, of the atmospheric potential-gradient expressed in volts per meter. These values in volts per meter have been obtained from values of volts recorded at the stern rail of the ship with Günther and Tegetmeyer recorder No. 4946 or 4947, by the use of appropriate reduction factors. For the period from August 10, 1928, to October 11, 1928, the factor 0.7 was used for all mainsail and boom positions, whereas for the period November 6, 1928, to November 18, 1929, the factors 2.9, 3.2, and 3.7 were used for port, starboard, and crutch positions, respectively, of the boom with the mainsail up or down. The cause for the change in factors between October 11 and November 6, 1928 already has been discussed in the section devoted to instruments.

Between August 7, 1928 and November 18, 1929 the ship was at sea for 317 days. The photographic record of potential gradient was lost or was unusable on 50 of these days, and on 86 additional days record was obtained for only part of the twenty-four-hour period, owing to instrumental difficulties or bad weather. Complete days totaling 181 have been tabulated in the present table, and all available values for the 86 partial days.

Instrumental Difficulties.--Instrumental difficulties responsible for the loss of photographic record which were most frequently encountered were as follows: 1. Defective insulation; 2. Hourly zero-marks not recorded; 3. Photographic record unreadable because of inadequate illumination; 4. Electrometer fibers moving too rapidly to make a legible record during disturbed weather conditions; 5. Lens of electrometer telescope loose and record illegible; 6. Recorder lamp burned out; 7. Recorder drum not rotating; 8. Apparatus shut down for repair or adjustment.

Other less frequent difficulties which caused loss of record were: 1. Photographic paper exhausted; 2. Photographic paper fogged; 3. Collector rod displaced by wind (applies only August to October, 1928); 4. Sensitivity of electrometer uncertain; 5. Defective auxiliary-potential batteries making recorded values uncertain.

Interpolated Values.--Interpolated hourly values have been placed in brackets. Values have been interpolated for periods of one to three hours only on days regarded as particularly quiet and undisturbed. No interpolating has been done over periods of bad weather.

Electric Character.--Electric character-figures are tabulated for all days for which these figures can be determined. The character-figure is intended to indicate the degree of disturbance on any day, but actually it indicates only the duration of negative potential. Three figures are used as follows:

0 = A day with no negative potential-gradient
1 = A day with an aggregate of two hours of negative potential or less
2 = A day with an aggregate of more than two hours of negative potential

Because negative potentials are encountered in disturbed weather, and disturbed weather generally causes large and rapid fluctuations in potential-gradient which often make the record illegible, on some disturbed days there is uncertainty sometimes as to whether the character-figure should be 1 or 2. In such cases both figures are given, as 1-2. It must be emphasized that very disturbed days are encountered which show high and variable positive values and no negative potential-gradient; these are "zero" days as well as the very quiet days on which only small variations are seen, and the system of characterization therefore does not cover the entire range of disturbed conditions. Notably, there were many days in July 1929 when fog, mist, or haze, and possibly very light rain, occurred and yet no negative potential-gradient was recorded, while extremely high positive values existed for long intervals. Although classified as "zero" days, these days belong in the category of very disturbed days.

Sail and Boom Position.--It will be noted that the position of the mainsail and boom has not been tabulated for the months of August to October, 1928. During this period the bent collector rod was used on the potential-gradient recorder and reduction-factor determinations indicated that the recorded values of potential-gradient did not change significantly with change in the sail and boom position. After the short straight collector rod was adopted on November 6, 1929, the boom and sail position became significant, and the present table includes a symbol for each day thereafter. The symbols have the following meanings:

P = Mainsail up and boom to port
S = Mainsail up and boom to starboard
C = Mainsail down and boom in port crutch
D = Day divided into several intervals for which different positions were used

Mean Daily Value of Potential-Gradient.--After careful inspection of the photographic records of potential-gradient and the study of weather notes, certain days were selected from the complete days as typical of the least disturbed, fair-weather conditions encountered on the cruise. There were eighty-two such days, and the mean value for each of these days has been tabulated.

Remarks.--Under this heading note is made of various conditions affecting the potential-gradient, such as bad weather and running of the main engine. The occurrence of negative potential is noted in every case. When certain hours on certain days are disturbed and no explanation can be found, the word "disturbed" is inserted, with the time of the disturbed period. For the weather notes the same symbols have been employed as were utilized for sec. V, and the explanations for the various symbols will not be repeated here. In the interpretation of the notes, the punctuation is significant. Where two parts of a note are separated by a comma, the events described are concurrent. For example, "rain, neg. PG 10-12h," indicates that both rain and negative potential-gradient occurred between 10 and 12 hours. When the note reads "rain; neg. PG 10-12h," where the semicolon replaces the comma, the indication is that rain occurred at various other times than 10 to 12 hours, as well as during that period. The semicolon is used throughout where the events are not completely simultaneous in the time. The exact periods during which negative potentials prevailed are not given in the notes, because the method of recording caused some uncertainty as to the extent of these periods; only the hours in which negative potentials occurred are noted.

Table 3. Hourly mean values on Greenwich Mean Time of potential-

Date	GM noon position		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15
	Lat.	Long. E															
1928	°	°															
Aug 7	46.2 N	312.1	199	186	123	119	121	106	97	108	121	121	121	121	119	127	140
8	43.6 N	313.0	93	88	83	83	88	97	97	85	87	102	97	99	106	111	116
9	42.3 N	312.7	108	108	97	64	59	69	62	56	70	71	63	....	....	....	....
10	40.1 N	311.4	....	....	106	99	112	116	121	129	....	....	....	....	....	....	....
11	38.7 N	311.2	85	74	76	64	85	111	88	92	91	88	91	92	[90]	88	98
12	37.2 N	311.5	134	116	115	113	120	127	130	148	146	136	134	146	144	159	159
13	36.8 N	313.4	184	178	172	158	146	112	102	88	91	104	105	137	149	139	159
14	35.4 N	315.3	132	121	118	108	102	105	....	....	....	....	....	....	....	....	116
15	33.7 N	317.6	134	116	116	124	120	105	120	130	131	132	137	127	153	166	166
16	31.5 N	318.7	144	132	122	129	130	131	144	....	....	....	154	164	153	172	130
17	29.8 N	319.4	113	98	94	73	88	100	112	87	90	90	102	104	104	102	91
18	28.2 N	320.3	105	98	87	84	85	97	94	95	104	99	106	108	102	99	76
19	25.8 N	321.1	99	98	102	92	90	97	90	90	....	....	....	87	77	77	83
20	24.0 N	320.4	91	85	78	76	68	73	74	77	77	85	....	....	....	....	....
22	19.2 N	321.6	....	....	....	....	....	....	....	....	....	....	....	....	76	94	108
23	16.8 N	322.1	97	75	90	92	90	94	94	106	109	108	102	106	[109]	101	101
24	15.8 N	322.1	73	73	69	64	61	64	57	66	68	64	56	56	59	61	52
25	15.0 N	321.9	74	69	63	66	[67]	69	74	71	85	[78]	71	69	74	82	77
29	10.8 N	322.6	130	102	102	127	....	....	....	....	....	....	....	112	104	94	....
31	8.2 N	323.8	116	107	93	80	85	65	85	106	94	94	93	94	97	96	106
Sep 1	9.2 N	323.4	148	62	....	99	24	110	110	99	108	99	97	99	94	92	101
2	9.7 N	323.4	88	86	85	82	80	86	77	83	88	99	97	92	101	93	107
3	11.0 N	322.9	....	62	73	74	....	....	83	85	99	87	93	....	....	....	....
5	11.6 N	319.3	120	108	111	114	114	116	107	111	111	105	107	99	[95]	92	102
6	11.7 N	317.6	99	102	108	92	101	92	91	104	99	89	89	96	90	97	106
7	11.3 N	315.8	80	83	82	91	80	105	106	110	94	93	93	97	97	[102	107]
8	11.6 N	314.9	100	99	104	102	102	119	117	117	130	119	117	117	122	105	104
9	11.7 N	314.1	104	105	99	92	92	94	94	92	95	94	....	....	....	....	....
10	11.9 N	312.6	....	102	90	89	87	78	78	90	97	92	64	80	107	108	113
11	13.2 N	310.4	107	95	92	92	125	104	99	111	107	107	97	95	95	97	97
12	13.2 N	309.6	64	62	74	71	71	72	76	76	80	90	90	102	95	100	[100
13	13.2 N	307.8	85	87	84	92	102	104	104	107	122	122	119	124	118	111	108
14	13.1 N	306.0	124	119	120	120	120	124	122	134	120	137	120	107	105	112	120
15	12.9 N	303.8	122	111	105	105	97	111	102	104	104	99	104	99	117	113	127
16	13.0 N	301.8	95	104	108	116	107	105	100	102	95	90	90	99	100	97	104
17	13.2 N	300.5	89	85	72	42	64	64	87	105	90	84	89	92	....	....	....
Oct 4	15.0 N	294.2	....	....	....	....	43	50	58	60	62	68	91	....	....	....	....
5	15.3 N	291.9	....	139	119	119	43	83	116	122	129	119	114	119	114	111	122
6	15.2 N	289.3	97	94	99	101	120	....	....	101	99	96	94	97	104	102	112
7	14.8 N	286.5	83	80	78	73	73	73	74	81	84	88	107	91	90	90	99
8	13.6 N	283.8	78	78	81	86	90	92	91	90	83	90	86	83	92	90	91
9	11.8 N	281.8	81	83	84	91	91	81	81	96	96	86	84	....	50	84	99
10	10.5 N	280.9	....	....	....	....	71	66	63	....	....	....	....	....	....	73	92
11	9.4 N	280.1	117	155	160	155	148	141	140	....	....	....	....	....	....	....	....
Nov 6	0.9 N	278.8	213	209	209	203	158	188	191	197	188	197	148	151	151	142	128
7	0.3 S	278.3	171	168	151	102	162	151	107	129	113	164	190	190	157	157	180
8	1.6 S	277.9	87	81	102	102	102	102	87	96	110	107	106	100	106	167	....
9	1.4 S	275.6	135	135	142	119	80	38	90	119	135	167	167	158	190	196	209
10	1.6 S	273.2	129	122	113	135	129	142	148	135	142	....	....	....	151	....	....
11	1.8 S	271.4	118	106	112	112	118	118	118	106	118	134	134	122	147	157	163
12	1.5 S	269.1	118	118	112	112	112	118	112	112	112	112	112	125	128	157	163
13	1.5 S	267.1	150	128	141	128	134	147	147	147	141	112	134	134	141	141	141
14	1.6 S	266.0	77	70	83	112	118	128	112	77	112	118	106	118	125	125	134
15	2.4 S	264.4	106	106	106	106	106	112	118	125	125	118	106	118	125	147	157
16	3.0 S	262.3	134	150	163	147	....	....	....	....	....	....	....	....	....	163	112
17	3.2 S	260.4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
18	3.8 S	258.1	80	70	70	67	74	80	86	93	93	90	96	99	106	102	[109]
19	4.5 S	255.3	80	77	74	80	83	80	93	99	106	106	106	102	102	122	125
20	6.3 S	253.6	93	86	80	83	83	93	86	90	86	86	93	102	106	106	115
21	8.8 S	251.9	77	86	77	77	74	74	77	77	77	77	74	77	77	77	86
22	11.1 S	250.4	70	70	67	70	70	70	74	77	74	70	80	70	96	102	106
23	13.8 S	248.4	93	106	106	106	106	125	122	118	112	106	96	99	106	125	106
24	15.9 S	247.3	93	77	96	96	96	99	90	106	99	102	106	106	125	70	125
25	18.7 S	246.1	102	102	96	99	106	106	106	106	99	96	102	102	99	109	109
26	21.1 S	245.8	93	93	96	90	90	93	96	96	93	93	106	115	125	128	90
27	23.0 S	245.3	93	106	96	109	109	96	102	90	48	90	93	106	125	125	96
28	24.2 S	244.9	74	64	67	83	93	106	109	115	115	106	102	109	106	109	118
29	26.1 S	244.6	93	102	93	96	102	115	112	115	115	112	118	134	109	109	118
30	27.8 S	244.8	90	93	83	102	109	115	93	93	102	93	102	125	134	118	....

gradient in volts per meter on cruise VII of the Carnegie

15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	Elec. char.	Sail and boom	Mean	Remarks All times given are in GMT
141	142	152	136	139	140	131	121	111	0	..	....	high values 0-2h
119	....	91	99	133	142	....	162	113	0	..	....	
....	....	....	....	....	....	....	....	....	..	..	....	
92	95	92	100	99	91	105	99	60	..	..	....	r, m 15-17h; disturbed 20-24h
88	88	111	124	139	148	155	153	157	0	..	103	disturbed 3-6h
148	139	148	181	178	191	213	198	194	0	..	151	
....	....	....	....	....	....	....	154	143	..	..	....	q 5-10h
115	118	115	120	146	162	167	155	144	..	..	....	q after 6h
171	169	184	190	195	223	151	168	165	0	..	....	occasional q and d
130	124	125	121	120	134	99	120	113	0	..	....	q 13-16h, 20-22h
97	97	88	100	102	99	118	105	104	0	..	98	q 3-10h
74	70	83	99	113	127	129	129	115	0	..	99	distant q
78	94	85	88	97	106	102	104	102	1	..	....	q, neg. P.G. 8-11h
....	....	....	....	....	....	....	....	....	1	..	....	occasional q; neg. P.G. 10-12h
106	94	82	90	104	108	102	101	73	..	..	....	threatening weather; occasional q
97	95	87	90	82	90	92	85	78	0	..	95	
56	[66	77	87]	97	85	88	85	77	0	..	69	
90	66	85	111	63	113	118	174	111	0	..	....	disturbed 18-24h; engine 22-24h
127	115	160	124	....	127	78	....	....	1	..	....	occasional q; neg. P.G. 19-20h
101	....	153	191	188	176	88	153	142	1-2	..	....	occasional q; neg. P.G. 5-7h, 21-22h
97	96	76	....	....	90	....	....	49	2	..	....	r, neg. P.G. 1-5h, 17-23h
15	74	....	....	47	106	111	96	....	2	..	....	r, neg. P.G. 15-20h, 23-24h
....	....	....	....	....	....	....	....	....	1	..	....	r, 0-6h, 9-11h; neg. P.G. 0-1h
110	108	[108]	107	107	121	119	115	115	0	..	109	
115	138	....	161	....	111	93	88	82	1	..	....	q 16-20h; neg. P.G. 17-18h
112	112	125	140	140	125	125	116	105	0	..	105	
105	105	102	111	113	127	120	105	105	0	..	111	
120	112	116	112	134	119	100	....	....	1	..	....	q, neg. P.G. 22-24h
....	....	....	102	107	107	108	105	97	1	..	....	q 10-12h; neg. P.G. 11-12h
122	[115]	100	95	90	90	92	78	72	0	..	99	q 4-10h
97]	87	87	90	92	102	95	92	89	0	..	86	
117	117	113	129	146	147	132	135	120	0	..	114	
100	105	113	127	142	127	132	124	124	0	..	131	
127	125	134	137	130	129	125	108	105	0	..	114	
104	100	112	108	100	104	102	105	105	0	..	102	
....	....	....	....	....	....	....	....	....	..	..	....	
....	....	....	101	130	....	....	....	....	1-2	..	....	q 10-24h; neg. P.G. 12-17h
144	119	146	157	157	123	120	114	101	1	..	....	l, q 0-8h, 15-21h, neg. P.G. 4-6h
102	112	120	117	116	120	106	88	88	1	..	....	l, neg. P.G. 5-7h
97	101	102	114	102	97	94	83	78	0	..	89	
112	97	101	97	120	....	35	66	80	1	..	....	r, neg. P.G. 20-22h
83	125	159	.....	....	64	117	117	....	1-2	..	....	r, neg. P.G. 11-12h, 17-21h, 23-24h
111	158	192	153	134	125	134	144	86	1-2	..	....	thunderstorms 0-4h, 7-13h; some neg. P.G.
....	....	....	....	....	....	....	....	....	..	..	....	
....	252	249	188	162	177	203	223	116	0	D	....	z 6-12h; disturbed 6-12h, 15-24h
174	180	151	177	203	264	223	110	96	0	D	....	disturbed 3-9h, 16-20h; d 22-24h
....	....	....	....	....	....	....	....	148	..	D	....	disturbed 0-8h, with some d
213	203	232	238	242	225	219	190	142	1	S	....	disturbed 3-7h; neg. P.G. 5-6h
....	....	196	203	203	180	164	164	158	..	S	....	
163	[170	176	179]	186	186	163	150	141	0	S	141	
150	134	128	128	134	128	134	147	150	0	S	127	
150	128	163	141	157	179	170	147	90	0	S	141	disturbed 15-20h
163	186	179	186	173	157	128	128	106	1	S	....	z, disturbed 0-4h; neg. P.G. at 2h
150	150	150	173	173	186	150	147	150	0	S	134	
....	....	....	163	170	150	....	....	....	1	S	....	d at 10.5h; neg. P.G. 15-16h
....	....	99	106	106	99	96	106	86	..	S	....	
118	125	122	125	122	122	115	112	106	0	S	99	
138	147	154	154	138	131	125	112	106	0	S	110	
118	125	128	134	125	118	106	106	90	0	S	102	
102	96	86	106	102	83	86	90	83	0	S	83	
112	118	115	118	115	115	112	106	93	0	S	90	
106	125	128	125	128	122	115	106	90	0	S	112	
125	144	141	138	131	131	125	109	86	1	S	....	q all day; neg. P.G. 6-7h, 13-14h, 23-24h
115	128	131	141	141	118	112	106	106	0	S	110	d 2-3h
102	166	93	154	122	109	106	102	106	0	S	....	disturbed 14-20h
128	122	118	154	154	144	125	102	90	1	S	....	d, neg. P.G. 8-9h
134	141	154	154	138	134	128	112	106	0	S	112	
147	118	128	150	154	144	138	118	102	0	S	....	r at 10h; q 8-16h
....	134	118	147	138	141	144	125	115	1	D	....	d 6-9h; q, neg. P.G. 14-16h

Table 3. Hourly mean values on Greenwich Mean Time of potential-

Date	GM noon position Lat.	GM noon position Long. E	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15
1928	°	°															
Dec 1	29.0 S	245.2	109	115	125	125	109	118	129	138	128	128	125	144	144	147	160
2	30.2 S	245.6	147	144	147	150	150	160	163	163	170	166	163	173	173	179	179
3	31.3 S	246.8	106	102	99	109	112	118	128	131	122	131	138	157	144	157	157
4	31.6 S	249.1	86	86	86	93	86	96	109	122	122	125	134	134	134	150	157
5	29.5 S	251.2	....	122	128	131	131	160	166	176	179	182	144	173	182	189	195
13	27.9 S	250.8	106	102	112	118	122	125	118	141	141	131	128	134	138	138	147
14	29.0 S	251.0	125	122	118	93	134	122	138	128	131	102	131	125	131	134	115
17	31.9 S	250.2	.....	165	157	107	160	157	165	162	142	154	180	168	....	....	....
18	31.7 S	250.8	147	141	125	128	141	153	160	157	157	160	154	150	144	157	186
19	32.3 S	252.5	144	131	131	141	154	160	163	166	157	166	157	176	189	205	205
20	33.7 S	253.2	131	86	70	147	170	150	102	77	112	115	115	125	147	147	144
21	34.8 S	254.2	138	125	122	125	141	144	157	163	166	160	157	170	173	166	166
23	38.1 S	256.6	214	144	144	144	195	147	182	186	227	230	262	205	227	266	266
24	39.7 S	258.6	154	170	163	189	176	144	198	131	160	170	138	144	160	179	186
25	40.2 S	260.4	154	128	125	134	131	160	154	99	147	154	163	160	163	186	189
26	40.4 S	262.4	141	141	141	144	144	144	147	147	150	173	198	202	202	250	275
27	40.2 S	263.3	170	160	173	182	205	227	208	176	160	154	150	154	154	154	205
28	38.7 S	265.5	138	141	144	144	144	144	144	144	147	144	170	195	218	227	224
29	37.2 S	266.6	96	128	118	93	109	109	61	125	84	186	232	171	154	165	203
30	34.8 S	268.0	136	151	154	154	157	151	128	154	154	154	168	180	191	206	191
31	32.8 S	269.7	128	....	133	136	130	157	151	139	136	136	162	160	145	142	....
1929																	
Jan 1	32.2 S	270.8	....	....	....	130	116	110	125	133	148	148	160	168	194	183	177
2	32.0 S	271.2	136	154	139	139	128	125	130	151	145	136	125	130	133	139	142
3	31.9 S	271.7	102	106	106	99	96	96	102	109	112	106	102	102	102	109	112
5	31.3 S	273.2	93	80	77	70	77	74	74	74	93	112	109	112	112	112	134
6	29.5 S	274.3	90	90	99	102	107	72	113	110	122	142	145	160	168	174	180
7	27.3 S	275.9	171	165	160	128	130	128	113	133	136	125	125	151	180	154	162
9	23.6 S	278.5	130	125	102	96	96	104	96	99	119	113	99	102	125	136	136
10	21.6 S	279.5	128	128	113	87	110	130	125	130	142	136	139	148	171	186	194
11	19.7 S	280.4	157	148	145	136	136	136	145	145	160	154	162	165	188	186	208
12	17.0 S	281.3	142	128	122	130	128	139	136	139	142	148	174	191	197	200	215
13	14.6 S	282.0	168	154	136	151	156	162	148	130	125	128	151	180	203	226	209
14	12.7 S	282.6	136	136	128	133	136	139	139	142	139	125	139	154	168	197	....
Feb 7	10.6 S	280.4	122	122	112	131	145	154	151	142	151	145	136	145	154	157	151
8	10.0 S	278.1	112	109	109	112	112	115	115	115	118	125	125	122	141	150	160
10	10.7 S	275.2	125	115	118	141	134	128	115	115	109	122	122	109	122	141	138
12	11.0 S	272.8	106	109	106	109	115	125	128	125	125	122	125	....	....	....	....
13	12.2 S	270.9	125	125	122	125	134	125	125	134	138	138	141	147	147	154	160
14	14.0 S	268.2	125	....	....	....	....	....	....	....	....	....	....	....	....	....	163
15	15.8 S	265.8	144	147	144	147	154	160	163	163	157	141	157	150	147	131	163
16	15.4 S	263.0	160	160	147	150	166	182	182	189	166	176	160	179	189	195	205
17	14.7 S	260.1	170	160	141	138	141	144	160	166	150	148	164	121	160	187	218
18	14.4 S	257.2	208	192	193	186	182	198	198	176	179	182	182	182	198	154	189
19	13.8 S	254.9	141	131	109	112	106	128	138	144	170	147	150	147	150	173	160
20	13.1 S	252.3	138	118	112	112	112	112	128	150	141	122	141	122	138	128	147
21	12.6 S	250.6	93	96	96	83	83	102	86	102	109	115	134	131	122	141	164
22	12.6 S	248.2	136	152	128	131	128	131	134	138	141	141	112	134	122	141	144
23	12.6 S	245.8	144	140	129	117	148	144	148	148	152	148	148	144	160	168	171
24	12.6 S	243.0	148	125	121	117	125	125	125	129	160	148	140	152	168	179	183
25	12.8 S	241.1	133	125	130	119	140	129	140	136	140	148	152	156	156	160	191
26	13.0 S	239.3	147	144	138	138	131	131	125	134	131	131	138	141	157	170	182
27	13.1 S	236.9	138	131	122	115	109	115	118	118	134	128	113	136	160	156	168
28	14.6 S	234.4	131	147	144	128	122	122	118	118	118	125	138	150	150	170	170
Mar 1	16.0 S	232.6	138	160	144	134	134	141	144	141	144	154	166	176	182	208	198
2	17.0 S	230.7	150	134	113	109	113	121	109	101	105	105	105	109	125	136	148
3	17.1 S	228.9	101	113	117	117	109	113	113	113	117	117	117	121	152	144	156
4	17.2 S	227.1	113	117	129	113	105	109	105	113	117	121	113	117	148	172	168
5	17.1 S	225.4	98	109	113	113	113	121	125	121	109	113	125	129	140	140	148
6	17.2 S	223.6	109	113	121	133	133	136	121	133	148	140	133	152	136	144	140
9	17.7 S	218.4	....	....	....	115	115	122	112	102	99	99	106	99	112	160	152
10	18.0 S	216.9	121	113	109	113	109	....	....	....	....	....	....	....	....	....	....
11	18.0 S	214.8	339	192	166	61	29	96	107	99	113	93	122	130	122	87	122
23	17.4 S	207.8	99	99	93	90	96	99	107	115	115	115	122	125	128	150	154
24	17.0 S	206.9	144	128	102	109	83	67	64	74	93	80	93	96	102	112	112
25	16.7 S	205.0	109	112	115	115	115	118	131	138	122	144	141	140	145	148	145
29	15.4 S	197.5	148	119	119	116	133	107	96	90	....	....	....	....	....	....	....
Apr 21	13.2 S	188.3	....	99	102	81	113	116	96	52	55	52	107	116	93	104	104
22	13.0 S	188.3	110	107	104	102	78	72	78	90	84	78	70	67	67	67	72
23	12.2 S	188.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
24	9.7 S	189.0	125	128	130	133	148	139	130	151	151	142	145	148	151	174	151

gradient in volts per meter on cruise VII of the Carnegie--Continued

15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	Elec. char.	Sail and boom	Mean	Remarks All times given are in GMT
163	173	185	189	208	198	195	189	166	0	S	150	
173	166	147	147	147	141	138	122	112	0	S	155	
134	134	138	125	134	125	118	109	102	0	S	126	
163	179	157	154	....	....	....	....	....	0	S	....	
176	166	189	186	186	170	170	163	154	1	S	....	q 10-12h; neg. P.G. 10-11h
144	141	154	160	141	138	131	122	112	0	S	131	z after 12h
138	90	102	166	166	173	150	157	74	1	S	....	r 3-4h; q 14-19h; neg. P.G. 17-18h
....	....	....	....	200	215	194	180	174	..	P	....	
182	150	205	195	186	179	179	160	147	0	S	160	
205	211	205	205	208	198	179	157	150	0	S	173	
147	170	195	221	218	214	186	[170	154]	1	S	....	d, neg. P.G. 2-5h, 6-8h
205	211	211	205	202	179	157	141	131	0	S	163	z
269	250	221	214	282	288	259	227	176	0	S	....	z
186	166	147	147	166	170	173	170	154	0	S	....	z; disturbed throughout
198	227	218	218	195	176	166	157	147	0	S	165	7-8h very low
253	307	342	358	320	275	221	195	182	0	S	210	
262	330	304	208	227	192	170	150	144	0	S	....	15.6-17.4h very high
227	[198	173]	147	166	163	134	141	138	0	S	....	occasional p 12-24h
90	168	168	168	188	191	183	171	154	1	D	....	p 0-16h; neg. P.G. 6-9, 12-16h
188	162	148	168	87	168	168	160	139	0	P	....	r 19-20h
....	....	....	....	....	144	157	90	....	..	D	....	
168	157	174	174	113	116	113	119	110	0	P	....	
165	168	150	163	208	176	122	109	102	0	D	138	high values 19-21h
131	125	122	122	122	125	109	102	80	0	S	108	
134	138	128	125	125	102	109	96	96	0	S	102	
180	188	197	200	197	215	197	197	174	0	P	....	r 5-6h
168	212	200	180	186	183	145	125	93	0	P	....	q and d throughout
150	96	154	160	162	159	145	119	122	0	P	123	low value 16-17h
191	200	197	197	206	203	212	200	168	0	P	160	
238	203	206	203	218	212	203	197	177	0	P	176	
215	215	226	218	226	200	186	180	180	0	P	174	
226	218	229	246	215	191	160	160	148	0	P	176	
....	....	....	....	....	....	....	....	....	..	P	....	
162	154	154	163	160	166	163	141	118	0	D	146	
163	157	163	166	157	147	144	134	[122]	0	S	133	
141	134	147	150	166	141	125	122	[112]	0	S	129	
....	....	....	....	....	....	....	....	....	..	S	....	
160	163	163	170	179	170	163	141	134	0	S	145	
150	170	188	195	195	182	176	170	154	0	S	....	
173	192	163	144	147	147	150	176	170	0	S	....	q 12-20h; d at 13h
198	147	170	202	176	170	176	170	173	0	S	....	r 16-18h
275	285	278	253	256	240	253	234	221	0	D	....	r 11-12h
179	166	186	195	198	192	166	166	144	0	S	....	
179	179	173	195	122	131	122	118	122	0	S	144	disturbed 18-21h
147	138	128	125	118	122	115	83	96	0	S	125	
160	156	160	152	160	160	140	148	164	0	D	127	
122	144	131	144	160	136	136	160	129	0	D	136	
176	176	125	160	148	133	136	140	129	0	C	147	
187	131	154	179	179	172	156	144	136	0	D	149	
179	172	168	168	187	191	183	179	166	0	D	156	
202	192	173	160	150	163	166	163	150	0	S	152	
176	191	192	205	182	182	176	160	131	0	D	....	d and q 9-12h
166	122	125	125	125	115	147	150	150	0	S	....	
198	195	198	186	208	189	173	160	138	0	S	167	
156	148	168	174	165	151	129	129	105	0	D	130	
148	148	176	207	211	179	144	136	129	0	C	137	
156	168	144	150	160	125	129	113	105	0	D	130	
148	148	133	140	164	168	168	164	152	0	C	133	
144	....	....	....	....	....	....	....	....	0	C	....	q 10-11h
156	160	195	261	242	176	160	133	121	0	D	....	
....	....	250	269	261	238	238	211	265	..	C	....	q 23-24h
157	226	281	238	207	176	211	218	....	1	D	....	occasional q; r, neg. P.G. 4-6h, 13-15h
154	150	150	122	96	99	99	118	131	0	D	....	Engine 7-19h, 22-24h
125	128	128	[130	131	132]	134	118	118	0	S	....	Engine 0-2h
153	160	177	168	206	180	156	171	157	0	D	....	l and q after 6h
....	....	....	....	163	157	....	....	....	0	D	....	
113	113	116	122	157	142	136	125	122	0	D	....	low values 7-10h; engine 19-24h
93	75	78	116	142	....	....	....	....	1	P	....	q after 20h; neg. P.G. 20-22h
....	....	....	....	....	128	136	133	142	1	P	....	q after 0h; neg. P.G. 2-3h
162	171	180	174	171	145	148	....	....	1	P	....	r, neg. P.G. 22-24h

Table 3. Hourly mean values on Greenwich Mean Time of potential-

Date	GM noon position Lat.	GM noon position Long. E	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15
1929	°	°															
Apr 26	7.1 S	187.8	....	131	130	154	136	128	139	142	157	133	133	136	165	148	122
27	5.8 S	187.6	....	....	....	....	67	83	61	14	99	157	151	168	171	183	197
28	4.3 S	187.4	136	116	16	93	96	109	102	106	102	61	58	64	67	74	96
29	2.8 S	186.8	116	110	104	99	96	96	102	104	104	107	107	107	125	136	145
30	0.6 S	186.2	125	128	125	122	116	128	116	125	142	136	128	130	145	165	174
May 1	1.6 N	185.4	136	128	119	116	122	130	133	154	157	160	157	151	154	154	157
2	3.6 N	184.1	151	148	148	142	139	133	145	142	145	99	157	136	145	154	168
3	5.2 N	183.1	133	148	136	165	....	....	78	136	116	116	125	110	104	183	183
4	7.5 N	181.6	151	136	136	139	133	122	122	116	93	93	139	139	145	145	171
5	9.4 N	180.3	122	110	99	96	107	107	49	119	122	154	151	165	165	168	174
6	12.4 N	178.3	145	148	145	148	133	130	154	154	157	168	174	171	174	177	174
7	14.6 N	176.0	171	162	165	168	133	139	136	136	116	116	119	130	142	148	160
8	16.0 N	173.2	113	110	110	99	87	93	96	113	116	119	125	139	142	154	171
9	17.5 N	170.5	125	130	139	151	142	139	128	128	128	128	125	133	139	148	151
10	18.9 N	167.7	125	107	102	107	113	107	104	113	119	110	104	99	99	99	107
11	19.8 N	165.3	133	125	116	122	113	119	128	139	119	116	119	113	113	116	119
12	20.3 N	162.4	99	99	81	99	107	116	119	116	104	107	96	81	90	87	93
13	19.9 N	159.8	119	99	104	99	96	99	102	107	110	119	125	129	136	156	164
14	19.0 N	157.3	144	147	150	150	141	138	147	147	147	138	122	131	128	134	150
15	18.1 N	154.8	106	102	99	96	96	102	102	102	106	109	106	109	109	109	112
16	16.9 N	152.3	115	99	93	90	90	86	86	93	102	96	96	86	90	83	102
17	15.6 N	149.7	106	102	99	99	102	96	96	93	86	83	74	67	70	74	86
18	14.4 N	147.2	106	99	99	102	106	90	115	102	106	96	93	93	106	131	147
19	13.8 N	145.1	118	102	99	102	96	109	109	112	112	112	109	106	112	131	134
25	14.4 N	144.4	....	....	....	....	....	174	154	168	165	177	180	160	160	165	165
26	17.3 N	144.1	212	188	171	177	180	194	194	203	203	209	200	203	194	188	194
27	19.8 N	144.0	168	168	154	160	139	148	151	154	154	151	142	148	151	154	157
28	22.3 N	144.2	183	168	154	148	122	122	139	154	157	160	150	136	142	154	130
29	24.1 N	144.0	174	174	165	171	171	157	174	200	203	215	....	....	....	....	....
30	25.8 N	144.3	[162]	160	122	110	96	93	96	102	107	104	102	110	130	154	150
31	27.1 N	144.3	171	157	148	125	122	116	128	157	....	....	....	....	....	....	....
June 1	29.6 N	143.8	165	171	148	148	144	147	150	160	163	173	182	195	195	202	....
2	30.6 N	144.1	147	163	160	163	198	202	205	195	163	154	157	157	154	163	166
3	31.7 N	143.6	186	208	237	275	291	291	275	256	275	288	234	237	237	240	243
4	33.2 N	141.7	230	227	253	278	320	333	326	304	294	269	208	211	211	253	269
5	34.5 N	140.9	138	138	160	154	147	141	138	95	84	90	90	90	139	84	84
6	34.8 N	141.0	38	55	107	113	116	128	113	116	116	139	142	168	128	139	154
26	36.3 N	142.9	276	270	244	249	258	276	296	290	299	331	313	302	290	287	281
27	36.7 N	144.3	313	258	226	197	157	200	206	....	232	218	249	255	226	212	218
28	36.9 N	145.4	244	287	220	232	235	235	218	232	244	273	264	276	290	287	322
29	38.1 N	145.8	226	258	287	281	276	264	264	244	244	281	249	220	241	258	270
30	38.4 N	147.4	362	429	365	232	249	255	267	226	226	197	218	218	191	241	235
July 1	39.3 N	148.3	354	377	354	304	273	238	235	215	229	197	223	197	186	203	215
2	40.1 N	150.3	357	383	360	336	313	267	258	342	412	377	304	296	273	238	261
3	40.6 N	151.8	191	209	203	203	203	197	223	223	203	215	186	174	165	160	160
4	41.9 N	154.4	215	171	165	223	223	235	235	235	223	218	174	203	229	273	313
5	43.1 N	156.9	418	389	360	371	325	348	383	580	595	452	316	313	287	345	452
6	44.7 N	159.0	331	235	261	235	154	197	174	174	276	287	197	171	304	348	296
7	46.3 N	161.0	203	99	180	116	160	342	481	394	371	342	331	287	244	368	249
8	47.0 N	164.7	583	470	545	450	378	275	115	189	218	230	205	77	144	144	144
9	46.9 N	167.8	209	154	136	122	142	136	93	142	84	148	110	197	380	148	130
10	46.4 N	170.6	200	212	113	165	206	183	165	165	165	194	177	160	165	165	160
11	45.7 N	172.3	145	160	151	194	160	151	145	113	119	151	133	206	212	194	380
12	45.8 N	173.6	751	505	368	304	322	394	351	345	464	310	345	548	519	528	740
13	47.2 N	176.1	....	99	206	313	638	768	710	673	676	603	545	496	519	313	368
14	48.6 N	180.6	299	368	435	342	310	249	113	145	220	394	261	....	....	....	....
15	49.9 N	185.3	455	606	618	687	713	676	684	728	679	673	458	206	232	238	290
16	50.9 N	190.2	328	290	281	281	536	220	215	244	232	226	215	232	220	220	232
17	52.0 N	196.0	244	244	232	215	194	188	183	177	160	188	249	452	244	244	220
18	52.6 N	201.8	232	226	238	276	409	673	531	438	505	528	528	545	644	644	647
19	52.2 N	207.7	226	215	220	237	212	171	177	206	194	215	183	188	183	194	188
20	51.0 N	212.2	206	244	255	261	200	206	223	307	380	302	302	160	177	200	206
21	48.7 N	216.2	188	177	171	139	133	110	125	125	188	188	125	183	171	125	125
22	46.7 N	219.2	229	200	177	160	125	116	93	133	102	139	145	139	160	154	139
23	44.7 N	221.6	168	148	125	148	136	136	125	125	136	125	125	136	136	136	136
24	43.2 N	223.9	254	214	207	214	214	196	207	207	179	168	168	136	94	105	156
25	41.1 N	226.6	171	110	160	110	139	177	194	200	194	194	177	200	212	223	241
26	40.0 N	229.3	125	148	156	113	168	148	156	179	214	125	145	122	58	77	67
27	39.0 N	233.1	176	182	202	189	189	227	221	214	214	227	214	227	214	214	214

gradient in volts per meter on cruise VII of the Carnegie--Continued

15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	Elec. char.	Sail and boom	Mean	Remarks All times given are in GMT
142	145	165	177	162	157	145	....	....	0	P	....	r 11-12h; engine 0-11h, 22-24h
197	157	113	128	133	151	157	154	157	1	D	....	q 0-9h; neg. P.G. 1-3h, 6-8h; engine 0-20h
86	80	107	162	136	122	116	119	116	1	D	....	q, neg. P.G. 2-3h; engine 0-20h
148	148	145	148	145	145	139	139	136	0	P	123	
177	171	160	157	157	165	148	139	142	1	P	....	r 10-12h; neg. P.G. 11-12h
....	157	128	99	162	162	130	154	139	1	P	....	q 15-24h; neg. P.G. 15-16h, 18-19h
157	162	160	142	128	44	75	157	157	1	P	....	q 9-10h, 20-22h; neg. P.G. 20-22h
188	223	223	212	209	191	188	183	171	1	P	....	heavy r 3-7h; neg. P.G. 4-6h
168	171	160	157	145	130	119	116	122	1	P	....	q 1-10h; neg. P.G. 8-10h
180	188	186	171	174	168	168	154	154	1	P	....	q 2-7h; neg. P.G. 6-7h
177	177	165	200	212	186	177	165	180	0	P	....	q 4.8-5.3h; r 16-18h
160	162	165	165	160	142	133	122	119	0	P	....	q 3-6h
168	180	171	171	168	168	133	154	136	0	P	....	q 10-11h
171	174	174	171	177	177	154	145	139	0	P	....	d 10-11h
116	119	130	122	142	139	102	128	122	0	P	114	
122	133	133	136	113	116	96	81	110	0	P	....	r 16-17h; q 21-24h
99	102	102	104	119	116	119	116	104	0	P	103	
146	160	147	144	144	138	134	150	150	0	D	128	
144	144	160	243	....	....	....	106	99	1	S	....	l 13-15h; q 17-24h; neg. P.G. 21-22h
112	109	125	131	125	125	118	118	109	0	S	110	
106	112	118	122	122	122	112	112	118	0	S	....	heavy r 13-14h; q 18-20h
93	99	99	96	93	109	106	109	115	0	S	94	
138	147	153	141	144	166	147	138	131	0	S	121	
109	77	70	64	70	....	....	....	....	0	S	....	
177	183	200	212	229	215	218	223	212	0	P	....	r 15.5-16.5h
212	215	232	225	237	244	223	194	177	0	P	....	d about 19h
128	110	171	188	194	200	186	200	194	1	P	....	neg. P.G. 9-11h; low values 15-17h
174	171	188	188	188	215	188	188	188	0	P	....	r 14-15h; q thereafter
....	....	....	....	....	....	....	177	165	0	P	....	q after 20h
160	180	206	200	197	220	203	177	203	0	P	148	disturbed 16-18h
....	....	....	....	....	....	....	139	128	0	P	....	
....	....	....	....	....	....	....	....	211	..	D	....	heavy storm after 13h
208	214	192	195	195	198	211	211	195	0	S	....	z throughout; engine 14-22h
250	243	250	256	266	230	214	202	192	0	S	....	z throughout; engine 2-20h
336	253	246	230	....	....	....	195	170	0	S	....	z throughout; engine 5-22h
113	194	145	....	....	35	32	38	35	1	D	....	d after 13h; neg. P.G. 13-15h, 18-21h
119	46	64	55	75	102	107	113	107	0	P	....	typhoon and gale; low values 15-20h
310	302	307	362	342	328	334	328	264	0	P	....	z throughout; engine 0-4h
235	296	296	296	415	281	281	290	264	0	P	....	z throughout; engine 7-24h
328	322	281	264	281	241	186	197	249	0	P	....	z throughout; engine 0-7h
290	339	339	371	354	371	438	455	461	0	P	....	z throughout; engine 9-24h
241	264	276	342	360	360	389	394	389	0	P	....	z throughout; engine 0-3h
180	223	273	287	273	322	357	348	360	0	P	....	disturbed 8-11h and after 16h
223	203	209	218	223	273	261	249	218	0	P	....	disturbed 7-12h
180	197	191	209	191	180	148	99	136	1	P	....	disturbed after 18h; neg. P.G. 22-23h
273	310	441	487	542	545	....	....	423	0	P	....	d 10-24h
484	389	377	760	745	728	377	249	249	0	P	....	m, f, or d throughout
316	368	389	534	577	525	476	78	165	1	P	....	m, f, or d throughout; neg. P.G. 22-24h
244	180	197	261	496	487	380	342	334	1	P	....	m, f, or d throughout; neg. P.G. 0-4h
150	189	237	259	224	252	336	281	191	0	D	....	m, f, or d throughout
148	122	154	197	203	203	192	169	218	0	D	....	m or f throughout; high value 12-13h
151	165	171	113	165	119	226	194	171	0	P	....	m or z throughout
632	710	786	931	1096	1137	931	806	676	0	P	....	m or f throughout
476	299	467	255	194	....	....	188	310	1	P	....	m or thick f; r, neg. P.G. 20-24h
232	220	188	226	....	....	....	368	232	1	P	....	m or thick f; r 0-4h; neg. P.G. 1-3h, 16-21h
....	....	....	....	....	....	394	389	328	1	P	....	m, f, or rain; neg. P.G. 6-8h
313	290	296	467	716	798	476	389	397	0	P	....	m, thick f, or r
232	232	226	284	342	276	371	313	261	0	P	....	thick f or m; high value 4-5h
215	188	249	188	177	165	188	244	264	0	P	....	thick f or m; high value 11-12h
655	571	418	452	351	409	409	270	319	0	P	....	thick f or m
183	238	232	232	226	232	290	319	290	0	P	....	r or m
261	244	200	200	235	212	244	235	241	0	P	....	m throughout
133	145	154	154	183	244	212	223	249	0	P	....	r, m, z
139	133	125	187	254	148	207	179	214	0	D	....	r after 13h
187	207	207	222	246	230	261	254	246	0	C	....	d to 18h, then z
132	139	78	200	206	229	212	188	139	0	D	....	r at intervals after 10h
244	267	....	....	....	....	....	139	116	0	D	....	z; r at intervals to 5h
112	122	128	154	138	195	195	202	202	0	D	....	d or m to 18h
214	240	246	253	275	275	246	269	269	0	S	....	

Table 3. Hourly mean values on Greenwich Mean Time of potential-

Date	GM noon position		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15
	Lat.	Long. E															
1929	°	°															
Sep 5	36.3 N	235.8	....	....	264	310	322	316	328	316	328	339	334	328	334	328	339
8	31.8 N	231.4	160	174	154	142	136	142	154	154	168	142	119	119	160	154	180
9	30.4 N	229.8	....	125	70	81	87	125	110	119	130	128	128	188	180	188	273
10	29.6 N	227.9	264	273	267	273	264	252	264	287	302	310	287	203	235	284	325
11	28.6 N	226.3	258	223	220	194	174	212	215	209	206	203	223	229	235	270	258
12	27.8 N	224.8	212	188	180	183	174	194	191	179	173	179	186	208	243	246	256
13	27.3 N	223.2	108	96	90	112	102	90	112	109	102	109	96	102	131	118	150
15	26.6 N	220.0	141	112	96	118	118	122	141	141	154	157	157	179	166	192	186
18	24.4 N	215.2	186	183	160	157	182	171	180	186	194	129	160	156	164	187	214
19	23.5 N	212.6	164	160	160	164	156	172	171	180	186	168	168	168	183	188	171
20	23.0 N	209.6	176	156	133	140	133	160	160	164	156	82	125	133	144	164	172
21	22.5 N	207.2	144	148	164	160	136	152	156	152	148	152	156	164	182	157	154
22	22.0 N	205.1	179	113	109	117	113	82	109	117	125	129	117	113	117	117	143
23	21.5 N	203.1	118	112	115	112	112	93	102	102	112	134	138	134	138	147	144
Oct 4	25.1 N	199.9	154	165	....	154	145	168	157	154	151	148	145	154	157	154	171
5	28.2 N	199.0	136	142	145	148	142	142	148	154	154	154	165	171	191	194	188
6	30.8 N	198.8	145	142	128	142	133	125	130	151	154	151	157	168	174	188	191
7	32.2 N	199.3	171	154	165	154	162	162	168	174	174	171	165	165	165	174	186
8	33.7 N	199.6	119	122	99	116	102	107	107	122	119	122	128	142	136	133	154
9	34.2 N	201.6	125	119	113	104	102	107	148	151	148	142	148	165	174	151	171
10	33.8 N	204.5	151	154	87	87	96	64	93	116	113	102	96	110	125	130	148
11	33.6 N	207.3	90	86	102	106	102	131	99	67	93	104	110	128	119	122	142
13	33.4 N	213.8	[117	117]	117	113	133	129	129	125	125	106	128	131	141	154	154
14	33.5 N	215.7	131	96	93	96	86	83	78	86	82	82	86	90	105	130	136
15	32.7 N	218.7	130	116	125	122	128	122	139	148	157	145	154	154	154	165	186
16	30.2 N	220.1	80	125	77	86	86	86	90	125	150	147	128	125	128	166	170
17	27.9 N	221.4	112	....	....	....	....	....	....	....	119	119	122	130	139	145	148
18	26.4 N	222.9	75	61	52	44	38	....	....	....	....	....	....	....	....	90	74
19	25.1 N	222.4	93	90	93	83	67	77	96	86	83	64	74	64	64	96	86
20	24.0 N	222.0	86	64	86	83	80	70	77	80	93	96	86	99	109	125	141
21	21.8 N	221.3	93	90	90	93	112	115	122	125	125	122	118	122	147	154	141
22	19.5 N	221.6	....	....	....	....	....	....	115	122	118	118	118	102	115	125	131
23	16.8 N	222.6	90	106	93	99	96	93	96	106	115	109	102	93	125	138	138
24	14.5 N	223.2	102	99	96	99	102	99	93	99	90	64	64	102	122	118	102
25	13.0 N	222.8	....	....	....	....	....	94	113	70	74	152	850	90	90	93	104
26	11.8 N	221.8	35	....	0	44	20	58	9	26	29	26	49	78	116	116	110
27	10.4 N	220.5	43	70	78	70	78	82	74	62	78	78	113	117	113	144	148
28	9.1 N	219.6	96	102	....	....	....	....	....	....	....	....	....	....	....	....	....
29	8.0 N	218.8	32	207	....	....	136	134	131	128	134	138	157	99	106	134	150
30	7.4 N	218.0	106	99	99	96	80	90	99	70	58	122	106	....	....	....	....
31	6.7 N	216.7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Nov 1	6.0 N	215.9	[109]	109	134	128	125	122	134	131	138	131	157	160	170	176	99
2	5.0 N	214.0	....	....	109	118	128	125	122	112	115	115	122	134	157	163	173
3	4.5 N	212.0	134	144	147	138	138	144	141	138	131	131	122	138	160	163	182
4	3.5 N	210.4	138	118	129	....	....	....	....	94	98	94	101	99	112	134	138
5	1.8 N	209.1	144	134	141	144	118	170	182	166	166	182	176	182	182	189	186
6	1.1 S	207.8	109	106	102	99	138	144	154	141	134	134	134	141	138	157	179
7	3.8 S	207.0	166	163	160	182	176	173	170	157	163	150	154	166	173	166	170
8	6.0 S	205.5	115	99	96	112	122	125	138	141	154	150	147	125	128	147	166
9	7.5 S	203.8	133	147	147	147	147	163	166	173	170	176	179	173	198	218	211
10	8.7 S	202.3	157	165	191	195	187	195	203	222	199	230	234	230	234	230	222
11	9.2 S	201.4	90	121	117	129	113	117	160	156	152	152	156	168	172	191	199
12	9.7 S	200.0	107	110	119	116	131	136	139	160	157	163	160	176	189	198	214
13	10.7 S	198.5	122	96	142	168	151	145	179	164	168	152	156	156	168	168	176
14	11.4 S	197.1	75	72	90	81	119	113	130	107	116	113	136	144	160	164	191
15	11.9 S	195.6	101	90	86	121	129	207	140	117	152	156	179	179	187	214	195
16	12.4 S	193.9	136	109	144	113	98	152	152	156	179	101	144	154	157	182	179
17	13.4 S	192.0	116	133	119	122	176	187	179	187	179	179	183	187	179	222	211
18	13.9 S	190.6	....	....	....	82	90	121	140	136	105	105	98	156	195	199	218

gradient in volts per meter on cruise VII of the Carnegie--Concluded

15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	Elec. char.	Sail and boom	Mean	Remarks All times given are in GMT
....	....	....	249	226	299	345	310	293	0	P	....	
215	180	119	....	....	....	....	....	....	0	P	....	
307	319	322	....	362	374	357	299	284	0	P	....	engine 0-4h
284	310	334	310	264	302	313	310	278	0	P	....	disturbed 11-20h
177	151	249	287	339	287	244	212	206	0	P	....	disturbed 14-20h
269	269	170	173	186	179	150	138	131	0	D	....	disturbed 12-17h; engine 20-24h
157	163	170	179	173	179	173	173	157	0	S	....	engine throughout
154	141	154	154	131	128	109	102	112	0	S	....	engine 4-9h, 15-20h
226	197	177	197	191	188	211	195	187	0	D	....	r 9-11h
191	220	235	238	235	238	223	200	168	0	D	188	
195	187	195	218	214	199	187	179	152	0	C	....	q 9-11h
150	141	179	179	191	121	156	160	156	0	D	....	disturbed 12-13h, 20-22h
148	148	155	159	163	148	211	166	154	0	D	....	q 12-15h; disturbed 5-6h
147	170	189	....	....	....	....	....	....	0	S	....	
177	174	165	157	162	154	151	148	151	1	P	....	r and neg. P.G. 2-3h
186	191	197	174	174	186	168	165	148	0	P	165	few drops r 2.1h
206	215	226	241	247	241	215	191	174	0	P	176	few drops r 0.2h and 3h
215	218	218	220	220	197	188	151	122	0	P	177	engine 22-24h
151	148	154	165	168	154	151	145	128	0	P	....	q about 11h; engine 0-22h
191	188	212	244	215	174	186	154	154	1	P	....	d 5.3h; q 13-21h; neg. P.G. 13-15h
145	142	145	148	....	....	....	....	....	0	P	....	q 2-7h; engine 19-24h
154	145	136	116	148	....	....	....	165	0	D	....	disturbed 6-9h, 12-14h, engine 0-6h
157	154	150	125	138	138	163	157	138	0	D	135	occasional q; low values 18-21h
125	139	165	165	113	139	142	113	139	0	D	112	quite disturbed 17-24h; low 19-20h
186	194	194	186	203	139	125	118	131	0	D	....	r 9h, 22-23h; disturbed 18-23h
150	192	170	192	189	182	157	144	131	0	S	....	disturbed 0-3h, 13-18h; r 1-2h, 13h
154	160	183	183	171	154	142	119	104	1	D	....	r 1-8h; neg. P.G. 1-5h; engine 4-24h
74	93	115	118	102	106	106	99	96	..	D	....	engine 0-16h
80	77	96	125	112	106	96	93	83	0	S	....	occasional r 9-17h
122	131	134	134	144	131	128	115	102	0	S	....	r 0-2h and 8-17h
157	118	147	160	154	147	141	125	122	0	S	127	
99	131	141	134	125	125	122	118	99	0	S	....	low value 15-16h
141	134	....	....	....	....	....	....	102	0	S	....	
113	125	131	134	124	101	109	117	281	0	D	....	d 9-11h; disturbed 13-24h
93	113	23	61	....	70	....	....	61	2	D	....	frequent r; neg. P.G. 8-9h, 17-23h
107	113	160	165	187	168	125	82	78	1	D	....	r to 8h; neg. P.G. 1-3h, 4-7h
156	140	191	214	168	199	125	102	118	1	D	....	disturbed; neg. P.G. 0-2h, 7-9h, 12-13h
....	....	122	128	150	141	128	70	93	..	S	....	r 1.4h, 3.4h, 9.4h
102	128	186	205	189	176	131	157	131	1	D	....	r at intervals; neg. P.G. 0-2h, 11-12h, 15-16h
....	....	....	....	....	....	....	....	....	1-2	S	....	disturbed; neg. P.G. 7-9h, 10-11h
134	208	170	186	182	170	96	122	106	..	S	....	r at intervals
32	70	131	125	144	128	182	173	....	2	S	....	r at intervals; neg. P.G. 15-17h, 23-24h
150	144	141	131	125	112	131	106	138	1	S	....	r, neg. P.G. 0-2h
182	179	163	166	170	157	150	147	138	0	S	150	
157	163	153	157	144	141	141	150	160	1	D	....	engine 2-18h; disturbed, neg. P.G. 1-3h
173	163	173	182	182	163	160	141	144	0	S	164	
131	96	109	170	189	195	157	179	163	0	S	....	disturbed 15-18h
170	173	170	176	176	170	163	160	125	0	S	166	
170	176	186	198	189	154	137	140	140	0	D	144	
221	208	224	230	202	202	200	177	160	0	D	182	
211	222	257	285	199	156	113	121	117	0	D	....	engine at intervals 18-24h
195	197	206	212	191	180	168	154	133	0	D	....	engine at intervals 0-6h
221	205	215	226	230	224	220	180	168	0	D	....	engine 23-24h
199	214	39	94	90	144	152	116	99	1	D	....	r 17-20h; neg. P.G. 17-19h
199	214	203	179	207	195	148	117	101	0	D	....	engine 19-24h
191	277	265	192	176	150	128	118	109	..	D	....	engine 0-19h; very disturbed
128	179	182	138	125	154	128	102	122	..	D	....	engine throughout; very disturbed
199	144	152	176	226	187	160	168	86	0	D	....	engine 0-19h, 23-24h
250	186	191	180	203	197	180	160	148	..	D	....	engine throughout

VIII. ATMOSPHERIC CONDUCTIVITY RESULTS

EXPLANATORY NOTES AND COMMENTS

Section VIII is the fourth and last of the major tables of data and contains hourly mean values, on Greenwich Mean Time, of the electrical conductivity of the atmosphere in 10^{-4} esu. These values were obtained from photographic records made with the recording apparatus installed at San Francisco in August 1929. The recording apparatus replaced the eye-reading electrometer with which conductivity values given in the tables in sections V and VI were obtained; other parts of the conductivity equipment, including the air-flow system, air-flow fan, and the central collecting cylinder, were retained without change as they had been installed at the beginning of the cruise.

Between September 3 and November 18, 1929, the ship was at sea sixty-eight days. During this time fifty-eight complete days of record of conductivity were obtained and seven days of partial record. Positive conductivity was measured on thirty of the fifty-eight complete days, and negative on the remaining twenty-eight. The high percentage of complete days obtained during the period of recording was very gratifying, indicating that apparatus suitably designed and built for conditions at sea can be maintained almost continuously in satisfactory operation.

Interpolated Values.--Interpolated hourly values have been placed in brackets in the present table. These are almost all found in September, the first month of recorder operation, when time devoted to calibration of the apparatus was more lengthy than later, and when it was customary to shut down the apparatus because the air-flow fan was turned off during magnetic observations. In subsequent months calibration periods were so brief as to obviate interpolation, and the shutting down for magnetic work was discontinued as the running motor was found to have no effect on the magnetic instruments. In this table, as for the potential-gradient tabulation, interpolation has been performed only for hours which were quiet and undisturbed.

Mean Daily Values.--All the complete days have been provided with daily mean values. Not all these days were regarded as undisturbed, there being twenty-one on which disturbed periods of a few hours were noted. Under the column headed "disturbed hours" record has been made of these disturbed periods. For a study of days representing least disturbed, fair-weather conditions, the twenty-one days having disturbed periods should be excluded.

Disturbed Hours.--Comparison of the periods of disturbance tabulated under "disturbed hours" with the disturbed periods noted in the table in section VII under "remarks," indicates that bad weather conspicuously affected both the potential-gradient and conductivity during two periods of several days each. Bad weather was encountered from October 7 to 13 and from October 24 to November 2, and during these two intervals many low values of conductivity are found, with simultaneous disturbed values of potential-gradient.

Table 4. Hourly mean values on Greenwich Mean Time of

Date	GM noon position Lat.	Long. E	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
							Positive conductivity							
Sep 6	34.2 N	233.9	0.56	0.71	[0.78	0.84]	0.91	1.04	1.16	1.20	1.20	1.20	1.14	1.18
7	32.8 N	232.5	1.16	1.39	1.24	[1.24]	1.24	1.29	1.24	1.24	1.29	1.24	1.44	1.54
10	29.6 N	227.9	0.12	0.12	0.14	0.12	0.12	.....	0.22	0.19	0.22	0.22	0.22	0.22
11	28.6 N	226.3	.....	.....	.....	.....	.....	0.22	0.29	0.32	0.35	0.38	0.38	0.38
15	26.6 N	220.0	0.57	0.57	0.54	0.52	0.50	0.50	0.50	0.50	0.52	0.52	0.52	0.54
18	24.4 N	215.2	0.76	0.63	[0.66]	0.69	0.66	0.66	0.71	0.71	0.71	0.74	0.76	0.76
19	23.5 N	212.6	0.69	0.71	0.84	0.69	0.76	0.86	0.89	0.91	0.91	0.94	0.94	0.89
22	22.0 N	205.1	1.03	0.96	0.89	0.96	1.03	1.01	1.06	1.06	1.06	1.08	1.11	1.13
23	21.5 N	203.1	1.16	1.16	1.18	1.23	1.21	1.22	1.23	1.21	1.26	1.28	1.23	1.26
Oct 3	22.7 N	201.0	1.14	1.22	1.30	1.25	1.25	1.25	1.19	1.25	1.25	1.25	1.28	1.36
5	28.2 N	199.0	1.16	1.14	1.08	1.02	1.08	1.11	1.08	1.08	1.11	1.08	1.11	1.11
7	32.2 N	199.3	1.16	1.14	1.14	1.19	1.19	1.16	1.22	1.22	1.22	1.22	1.22	1.22
9	34.2 N	201.6	1.44	1.44	1.39	1.44	1.44	1.33	1.22	1.22	1.25	1.22	1.22	1.25
11	33.6 N	207.3	0.66	0.63	0.63	0.84	0.99	1.05	1.14	1.25	1.25	1.22	1.25	1.22
13	33.4 N	213.8	0.99	0.90	1.14	1.22	1.22	1.22	1.25	1.44	1.47	1.50	1.47	1.42
14	33.5 N	215.7	1.42	1.33	1.25	1.25	1.36	1.28	1.28	1.25	1.28	1.30	1.25	1.25
16	30.2 N	220.1	1.28	1.33	1.42	1.36	1.30	1.30	1.28	1.25	1.28	1.30	1.28	1.28
18	26.4 N	222.9	1.40	1.37	1.31	1.34	1.31	1.31	1.40	1.43	1.46	1.43	1.46	1.43
20	24.0 N	222.0	1.55	1.55	1.55	1.58	1.61	1.58	1.58	1.55	1.58	1.58	1.52	1.61
23	16.8 N	222.6	1.37	1.34	1.37	1.40	1.37	1.40	1.40	1.40	1.40	1.37	1.34	1.29
25	13.0 N	222.8	0.41	1.14	1.20	1.29	1.29	1.31	1.34	1.34	1.29	1.29	1.20	1.14
26	11.8 N	221.8	1.10	0.80	1.31	1.34	1.31	1.34	1.14	1.14	1.29	1.26	1.31	1.34
28	9.1 N	219.6	1.04	1.01	0.76	0.80	0.95	1.01	1.07	1.14	1.10	1.10	1.07	1.14
30	7.4 N	218.0	1.34	1.31	1.31	1.31	1.31	1.31	1.34	1.31	1.10	1.34	1.31	0.73
Nov 1	6.0 N	215.9	1.23	1.23	1.17	1.20	1.20	1.17	1.14	1.14	1.17	1.05	1.14	1.20
3	4.5 N	212.0	0.92	0.92	0.96	0.92	0.88	0.88	0.88	0.85	0.88	0.85	0.85	0.88
5	1.8 N	209.1	0.76	0.76	0.79	0.79	0.82	0.79	0.79	0.76	0.76	0.76	0.79	0.82
7	3.8 S	207.0	0.92	0.96	0.85	0.88	0.92	0.96	0.96	0.92	0.92	0.96	0.98	0.98
9	7.5 S	203.8	0.82	0.85	0.96	0.92	0.96	0.96	0.96	0.92	0.92	0.92	0.88	0.92
12	9.7 S	200.0	0.69	0.66	0.66	0.69	0.76	0.79	0.82	0.88	0.88	0.92	0.96	0.96
14	11.4 S	197.1	1.01	1.01	0.98	0.98	0.98	0.96	0.92	0.92	0.92	0.88	0.92	0.96
16	12.4 S	193.9	0.46	0.53	0.59	0.69	0.72	0.76	0.79	0.79	0.85	0.96	0.96	0.98
18	13.9 S	190.6	0.98	0.98	0.98	0.96	0.92	0.92	0.96	0.96	0.98	0.96	0.98	0.98
							Negative conductivity							
Sep 5	36.3 N	235.8	0.31	0.28	0.24	0.25	[0.26]	0.27	0.25	0.25	0.22	0.22	0.22	0.24
8	31.8 N	231.4	0.94	1.05	[1.05	1.05	1.05]	1.05	1.05	1.04	1.02	1.04	1.04	1.05
9	30.8 N	229.8	0.98	1.01	1.01	[1.01	1.13]	1.20	1.25	1.25	1.20	1.20	1.20	0.77
12	27.8 N	224.8	[0.39	0.37]	0.35	0.37	0.33	0.28	0.28	0.30	0.22	0.22	0.26	0.28
13	27.3 N	223.2	0.44	0.44	0.48	0.43	0.43	0.43	0.46	0.48	0.49	0.48	0.46	0.46
16	26.4 N	218.4	0.44	0.48	0.52	0.48	0.50	0.52	0.54	0.54	0.50	0.52	0.54	0.50
17	25.6 N	217.1	0.63	0.68	0.70	0.76	0.72	0.65	0.65	0.65	0.63	0.63	0.65	0.65
20	23.0 N	209.6	0.72	0.74	0.72	0.70	0.78	0.74	0.74	0.76	0.78	0.87	0.83	0.85
21	22.5 N	207.2	0.91	0.87	0.87	0.89	0.92	0.92	0.92	0.92	1.05	1.05	1.04	1.07
Oct 4	25.1 N	199.9	1.06	1.01	1.06	1.04	1.10	1.08	1.10	1.13	1.10	1.13	1.13	1.13
6	30.8 N	198.8	1.10	1.10	1.10	1.06	1.08	1.08	1.08	1.06	1.04	1.01	0.99	0.93
8	33.7 N	199.6	0.95	0.93	0.89	1.01	1.10	1.15	1.15	1.17	1.22	1.15	1.13	1.15
10	33.8 N	204.5	0.99	1.01	1.19	1.04	0.99	1.04	0.99	0.97	0.95	0.93	0.93	0.89
12	33.4 N	210.7	0.99	0.97	0.95	0.91	1.01	0.91	1.06	1.04	1.01	0.99	0.99	0.95
15	32.7 N	218.7	1.10	1.08	1.08	1.06	1.04	1.04	1.04	1.01	1.01	1.04	1.04	1.06
17	27.9 N	221.4	1.26	1.26	1.26	1.11	1.14	1.11	1.09	1.09	1.05	1.02	1.02	1.00
19	25.1 N	222.4	1.21	1.18	1.16	1.18	1.26	1.24	1.18	1.21	1.24	1.28	1.24	1.26
21	21.8 N	221.3	1.18	1.21	1.18	1.16	1.14	1.11	1.11	1.14	1.11	1.11	1.11	1.09
22	19.5 N	221.6	1.26	1.21	1.16	1.16	1.11	1.07	1.07	1.07	1.05	1.05	1.02	1.05
24	14.5 N	223.2	1.11	1.09	1.07	1.05	1.02	1.02	1.02	1.00	0.98	1.00	1.02	0.98
27	10.4 N	220.5	1.07	1.14	0.68	0.38	0.58	1.07	1.16	1.02	1.05	1.05	1.09	1.11
29	8.0 N	218.8	1.00	1.05	0.75	0.64	1.02	1.11	1.16	1.14	1.16	1.16	1.14	1.16
31	6.7 N	216.7	0.45	0.93	0.93	0.86	0.84	0.47	1.00	0.78	0.49	[0.86]	0.98	0.80
Nov 2	5.0 N	214.0	0.51	0.93	0.82	0.78	0.78	0.78	0.80	0.82	0.80	0.80	0.76	0.73
4	3.5 N	210.4	0.67	0.56	0.62	0.65	0.65	0.65	0.62	0.65	0.65	0.65	0.64	0.62
6	1.1 S	207.8	0.60	0.60	0.62	0.58	0.58	0.62	0.60	0.56	0.60	0.62	0.64	0.58
8	6.0 S	205.5	0.93	1.00	0.98	0.95	0.95	0.95	0.95	0.95	0.93	0.91	0.93	0.95
10	8.7 S	202.3	0.71	0.71	0.71	0.73	0.71	0.69	0.65	0.69	0.71	0.65	0.65	0.67
11	9.2 S	201.4	0.73	0.71	0.71	0.73	0.62	0.43	0.76	0.76	0.76	0.76	0.73	0.73
13	10.7 S	198.5	0.78	0.80	0.73	0.67	0.80	0.78	0.73	0.76	0.78	0.78	0.78	0.78
15	11.9 S	195.6	0.80	0.82	0.86	0.82	0.80	0.73	0.76	0.78	0.76	0.80	0.76	0.80
17	13.4 S	192.0	0.93	1.06	1.00	0.95	1.04	0.98	0.98	1.00	0.98	1.02	0.98	0.98

conductivity in 10^{-4} esu, September through November 1929

12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	Mean	Disturbed hours
					Positive conductivity								
1.18	1.18	1.16	1.22	1.20	1.20	1.18	1.14	1.12	1.10	1.12	1.18	1.08	
1.39	1.49	1.49	1.39	1.34	[1.29	1.24	1.19]	1.14	1.14	1.14	1.14	1.29	
0.22	0.22	0.22	0.19	0.19	.....	.....	.....	0.22	0.22	0.22	0.22	.....	Very low
0.35	0.32	0.38	0.38	0.35	.....	.....	.....	.....	0.32	0.38	.....	.....	Low
0.54	0.54	0.52	0.52	0.52	[0.54	0.57	0.60]	0.62	0.59	0.57	0.59	0.54	
0.74	0.79	0.76	0.81	0.81	0.84	0.89	0.91	0.94	0.86	0.76	0.74	0.76	
0.91	0.91	0.89	0.86	0.84	0.76	[0.76	0.76]	0.76	0.74	0.71	0.74	0.82	
1.28	1.31	1.33	1.33	1.33	1.36	1.28	1.21	1.16	1.21	1.18	1.18	1.15	
1.26	1.23	1.21	1.21	1.23	1.33	.....	.....	.....	.....	.....	.....	.....	
1.33	1.36	1.39	1.36	1.36	1.30	1.28	1.25	1.25	1.22	1.19	1.16	1.27	
1.11	1.16	1.22	1.28	1.30	1.30	1.28	1.25	1.25	1.25	1.22	1.25	1.17	
1.22	1.22	1.19	1.16	1.11	0.99	1.05	1.14	1.16	1.05	1.02	0.99	1.15	16-19h
1.25	1.14	1.05	1.22	1.22	1.25	1.22	1.19	1.14	1.25	1.22	1.16	1.26	13-15h
1.22	1.28	1.25	1.28	1.28	1.28	1.28	1.25	1.22	1.25	1.22	1.16	1.13	0-4h
1.47	1.50	1.52	1.58	1.60	1.60	1.52	1.50	1.42	1.44	1.44	1.44	1.39	0-3h
1.25	1.39	1.42	1.42	1.36	1.28	1.25	1.25	1.22	1.22	1.28	1.33	1.30	
1.36	1.39	1.22	1.39	1.42	1.44	1.42	1.42	1.39	1.42	1.42	1.44	1.35	
1.43	1.40	1.34	1.34	1.43	1.46	1.43	1.49	1.49	1.49	1.43	1.43	1.41	
1.58	1.55	1.52	1.55	1.55	1.55	1.55	1.52	1.46	1.43	1.46	1.46	1.54	
1.31	1.37	1.37	1.40	1.34	1.31	1.31	1.31	1.37	1.40	1.43	1.40	1.37	
1.26	1.29	1.23	1.29	1.31	1.29	1.26	1.31	1.34	1.10	0.80	1.01	1.20	0-2h, 16-24h
1.31	1.04	0.54	0.48	0.51	1.20	1.07	1.04	0.95	0.83	0.76	1.04	1.06	0-2h, 13-24h
1.29	1.29	1.29	1.17	1.14	1.10	1.07	1.07	1.04	1.04	1.07	1.04	1.08	0-4h
1.37	1.37	1.34	1.31	1.31	1.29	1.26	1.29	1.20	0.67	0.73	0.10	1.18	11-12h, 21-24h
1.17	1.14	1.23	0.37	0.98	1.20	1.17	1.05	0.96	0.98	0.92	0.56	1.07	15-17h, 23-24h
0.88	0.92	0.92	0.92	0.92	0.92	0.88	0.85	0.85	0.82	0.79	0.72	0.88	
0.79	0.82	0.85	0.76	0.82	0.76	0.76	0.72	0.72	0.76	0.76	0.72	0.78	
0.98	0.98	1.01	1.01	1.01	0.98	0.96	0.92	0.88	0.92	0.92	0.92	0.95	
0.96	0.96	0.92	0.96	0.92	0.88	0.82	0.79	0.76	0.72	0.69	0.69	0.88	
0.92	0.92	0.88	0.85	0.82	0.79	0.76	0.82	0.82	0.79	0.76	[0.73]	0.81	
0.96	0.92	0.88	0.96	0.92	0.88	0.72	0.66	0.66	0.63	0.69	0.69	0.88	
0.98	0.98	1.01	1.11	1.11	1.23	1.33	1.23	1.23	0.96	0.98	0.92	0.92	0-3h, 21-23h
0.98	0.98	0.98	0.98	0.96	0.96	0.92	0.88	0.88	0.88	0.85	0.85	0.94	
					Negative conductivity								
0.25	0.22	0.22	0.25	0.25	[0.25	0.25	0.25]	0.25	0.22	0.33	0.40	0.26	Low
1.08	1.15	1.07	1.01	1.07	1.12	1.17	1.08	1.01	0.90	0.92	0.96	1.04	
0.79	0.77	0.38	0.29	0.22	.....	.....	0.14	0.14	0.14	0.12	0.14	.....	Low after 14h
0.28	0.28	0.26	0.22	0.18	0.18	[0.24	0.29]	0.35	0.35	0.36	0.41	0.29	Low
0.46	0.46	0.39	0.41	0.39	0.39	.....	.....	.....	.....	.....	.....	.....	
0.54	.....	.....	.....	.....	.....	.....	0.52	0.55	0.61	0.59	0.67	.....	
0.63	0.63	0.61	0.59	0.61	0.59	[0.58	0.56]	0.55	0.61	0.61	0.68	0.64	
0.83	0.83	0.85	0.81	0.85	0.83	0.81	0.85	0.83	0.87	0.83	0.83	0.80	
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
1.10	1.08	1.06	1.04	1.08	1.08	1.08	1.10	1.10	1.08	1.06	1.08	1.08	
0.89	0.87	0.87	0.85	0.87	0.87	0.85	0.85	0.83	0.89	0.89	0.91	0.96	
1.10	1.15	1.10	1.08	1.17	1.08	1.06	1.06	1.13	1.22	1.24	1.24	1.11	1-5h
0.89	0.87	0.83	0.83	0.75	0.68	0.66	0.64	0.59	0.57	0.62	0.68	0.86	2-5h, 16-24h
0.97	0.97	0.97	0.89	0.99	1.01	1.06	1.01	1.04	1.08	1.19	1.15	1.00	
1.08	1.06	1.01	0.97	0.97	0.95	0.89	0.93	1.08	1.22	1.24	1.26	1.05	
1.00	0.98	0.98	0.96	0.96	0.96	1.05	1.02	1.05	1.05	1.09	1.28	1.07	2-5h
1.26	1.18	1.21	1.16	1.26	1.21	1.18	1.26	1.16	1.26	1.28	1.28	1.22	
1.09	1.07	1.11	1.16	1.21	1.11	1.09	1.21	1.24	1.26	1.24	1.26	1.15	
1.02	1.05	1.05	1.11	1.11	1.09	1.07	1.09	1.05	1.05	1.07	1.05	1.09	
1.02	1.02	1.07	1.07	0.98	1.09	1.14	1.14	1.00	1.00	1.05	0.66	1.03	15-18h, 20-24h
0.94	1.02	0.96	1.00	1.00	1.00	0.98	1.02	1.02	1.00	1.00	0.98	0.97	0-5h
1.18	1.14	1.14	1.18	1.18	1.00	0.98	1.02	1.05	1.16	1.14	1.21	1.08	2-4h
1.09	1.04	1.06	1.02	0.89	0.91	1.00	0.95	1.00	1.18	1.13	1.13	0.91	0-10h, 16-21h
0.69	0.67	0.65	0.65	0.65	0.67	0.69	0.65	0.65	0.62	0.62	0.64	0.72	0-2h
0.62	0.62	0.60	0.58	0.56	0.54	0.51	0.51	0.53	0.54	0.56	0.58	0.60	
0.62	0.62	0.58	0.58	0.64	0.62	0.51	0.56	0.58	0.65	0.65	0.64	0.60	
0.93	0.95	0.91	0.89	0.91	0.86	0.73	0.73	0.76	0.78	0.78	0.76	0.89	
0.65	0.69	0.76	0.76	0.67	0.73	0.65	0.65	0.67	0.67	0.73	0.73	0.69	
0.73	0.69	0.67	0.71	0.69	0.73	0.64	0.64	0.71	0.71	0.69	0.73	0.70	4-6h
0.76	0.78	0.76	0.78	0.73	0.84	0.89	0.98	0.82	0.86	0.93	0.91	0.80	
0.82	0.80	0.80	0.76	0.73	0.73	0.73	0.73	0.71	0.73	0.73	0.54	0.76	23-24h
1.02	0.98	0.95	0.91	0.93	1.00	0.95	0.91	0.76	0.84	0.95	1.00	0.97	20-22h

IX. STUDIES IN ATMOSPHERIC ELECTRICITY

CONTENTS

DETERMINATION OF REDUCTION FACTORS FOR THE CONVERSION OF MEASURED VOLTS TO POTENTIAL-GRADIENT IN VOLTS PER METER FOR CRUISE VII, CARNEGIE, 1928-1929

In preceding sections of this volume values of potential-gradient have been tabulated in volts per meter, representative of conditions over an open, level expanse of the ocean. To convert measured volts, obtained with eye-reading and recording apparatus at the ship's stern, to volts per meter, conversion or reduction factors were determined on five separate occasions while the ship was in port. On these occasions, measurements were made of potential-gradient directly in volts per meter at suitable shore stations while simultaneous measurements in terms of volts were made on the ship anchored as near the shore stations as possible. The procedure has been described on page 5. The five series of reduction factor determinations were made at the following times and places.

Series	Date	Location
	1928	
1	May 5	Kitts Point, Maryland, U.S.A.
2	July 25	Engey Island, Reykjavik, Iceland
3	Sep. 28-29	Bridgetown, Barbados, B.W.I.
4	Dec. 9-10	Easter Island
	1929	
5	April 10-13	Apia, Western Samoa

Series 1 and 2 gave reduction factors for the stern eye-reading apparatus no. 2; series 2 to 5 gave factors for a recorder apparatus. For series 1, at Kitts Point, only the eye-reading apparatus was on the stern rail. On July 7, 1928, while at Hamburg, Germany, the recorder was installed on the stern rail, adjacent to the eye-reading apparatus, and was equipped with a long, bent collector rod. Series 2 and 3 were made with this arrangement of apparatus. On November 5, 1928, after an especially stormy period at sea, the bent rod was discarded and a short, straight collector rod installed on the recorder, and series 4 and 5 were made with this final arrangement.

Although it was recognized that the changes in apparatus would alter the reduction factors, examination of the five series showed discrepancies too great to be attributed to instrumental changes alone. Detailed examination therefore was undertaken of the whole body of potential-gradient data, and the present paper deals with that examination. Table 1 is a summary of the reduction factors obtained at the different stations. In this table the letters MUBP, etc., have the meanings given in earlier sections of this volume.

For the first series, made at Kitts Point, the eye-reading apparatus was mounted alone on the stern rail and was the same equipment as that used on previous cruises. The disposition of ship's gear in the vicinity of the stern rail was the same as for previous cruises except for one item. The one change was the installation of a small lifeboat at the stern port corner of the quarter-deck, hung in davits which stood approximately three meters above the deck and which projected out over the water somewhat less than one meter. One davit stood very near the stern rail, and a slight increase in the reduction factors might have been expected from its presence as well as from the presence of the lifeboat.

Seventeen 20-minute sets of measurements were made with eye-reading apparatus on the ship and on shore at the Kitts Point station on May 5, between 10h 30m and 19h 00m LMT. Recorder apparatus also was used at the shore station, connected in parallel with the eye-reading electrometer, and a satisfactory photographic record obtained over the period 11h 00m to 19h 00m. Comparison of the latter with the shore eye-reading measurements gave identical values of volts per meter, indicating that both measuring instruments were in good order. The first five of the seventeen sets of data were discarded because they differed so markedly from the remaining twelve. The large difference was attributed to the effect of wind conditions. There was only light wind during the earlier observations, and possibly the potential-gradient at the land station was different from that at the ship on that account. As the wind came up

Table 1. Summary of reduction factor results, Carnegie cruise VII

No.	Location	Electrometer no.		Reduction factor values							
				Stern no. 2				Recorder			
		Ship	Shore	MUBP	MDBP	MUBS	MDBPC	MUBP	MUBS	MDBS	MDBPC
1	U.S.A	28	25	3.34[a]	3.21[a]	.....	3.96[b]	.....	.....	.....	.....
		28	4946	3.42	3.28	.....	4.03	.....	.....	.....	.....
2	Iceland	28	26	2.17	.....	2.15	2.64	.....	.....	.....	.....
		4946	26	.....	.....	.....	.....	0.59	0.59	.....	0.62
3	Barbados	4946	4947	(2.91)	.....	(3.05)	.....	0.67	0.66	0.68	.....
4	Easter Is.	4946	4947	.....	.....	.....	.....	.....	(3.01)	.....	.....
5	Samoa	4946	26	.....	.....	.....	.....	.....	.....	3.14	.....
		4946	AMO	.....	.....	.....	.....	2.87	3.28	.....	3.86

[a]Mean value for MUBP and MDBP is 3.28. The comparable factor for MUBP (and MUBS) for previous cruises is 2.85. [b]The factor for MDBPC for previous cruises is 3.77.

Table 2. Reduction factor observations for potential-gradient, Atlantic Ocean, Carnegie cruise VII
Stern potential-gradient apparatus no. 2

Date	GMT		Potential-gradient eye reading		Reduction factor for ship's stern eye reading			Remarks
	Begin	End	Land	Ship's stern	MUBP	MDBPC	MDBP	
1928	h m	h m	V/m	Volts				
May 5	18 05	18 30	277.6	88.6	.....	.....	3.13	Eye electrometer no. 25 on shore
5	18 31	18 54	296.8	93.1	.....	.....	3.19	
5	19 11	19 33	280.1	92.7	.....	.....	3.02	Recorder 4946 on shore
5	19 34	19 55	307.5	87.5	.....	.....	3.51	Eye electrometer no 28 at stern in apparatus no. 2
5	20 10	20 30	285.0	87.3	3.26	.....	.....	
5	20 31	20 55	251.3	73.4	3.42	.....	.....	
5	21 07	21 30	201.3	60.3	3.34	.....	.....	
5	21 31	21 55	211.0	63.2	3.34	.....	.....	
5	22 06	22 30	213.0	52.5	.....	4.06	.....	
5	22 31	22 54	202.4	49.8	.....	4.06	.....	
5	23 06	23 30	187.5	50.4	.....	3.72	.....	
5	23 31	23 54	199.0	49.5	.....	4.02	.....	
Means					3.34	3.96	3.21	Mean MUBP-MDBP = 3.28

Table 3. Reduction-factor observations for potential-gradient, Atlantic Ocean, Carnegie cruise VII
Potential-gradient apparatus no. 2 and recorder 4946 at stern

Date	GMT		Potential-gradient			Reduction factor for ship's stern eye reading			Reduction factor for ship's stern recorder		
	Begin	End	Land eye reading	Ship's stern eye reading	Ship's stern recorder	MUBP	MUBS	MDBPC	MUBP	MUBS	MDBPC
1928	h m	h m	V/m	Volts	Volts						
July 25	12 27	12 55	139.2	60.7	....	.....	2.29	.....	.....	.....	.....
25	13 09	13 55	155.6	77.4	266	.....	2.01	.....	.....	0.59	.....
25	14 25	14 55	158.9	60.2	256	.....	.....	2.64	.....	.....	0.62
25	15 05	15 55	171.5	79.1	292	2.17	.....	.....	0.59	.....	.....
Means						2.17	2.15	2.64	0.59	0.59	0.62

Eye electrometer no. 26 on shore. Eye electrometer no. 28 at stern. Ship's draft 11.5 ft. for'd, 13.85 ft. aft. Installed ship's recorder at stern at Hamburg, July 7, 1928, with bent-arm collector rod. Ship anchored one-half mile from shore station.

and increased through later observations, the conditions at the two stations evidently became more alike. The twelve acceptable sets are shown in table 2, where the values of volts per meter for the shore station are those obtained with the eye-reading electrometer rather than the recorder. The recorder results will not be shown in tabular form as they merely repeat the results in table 2.

For previous cruises of the Carnegie the reduction factor for MUBP or MUBS was 2.85 and for MDBPC, 3.77. In table 2 the comparable figures are 3.28 and 3.96, respectively, which are some 5 to 15 per cent larger. These increased values are accepted as reasonable.

Series 2, made at Iceland with the recorder installed on the stern rail near the eye-reading apparatus, gave results for the eye-reading apparatus which are low in comparison with those of series 1. They are almost exactly two-thirds of the Kitts Point values for comparable sail positions. For the recorder the factors are approximately 0.6 for all sail positions, which appears to be reasonable. The results for series 2 are shown in table 3.

It is unlikely that the installation of the recorder on the stern rail produced the decrease in the factors for the eye-reading apparatus. The bent collector rod, being at air potential, would not distort the field, and the recorder box was too small to introduce any considerable distortion in view of the dominant position of the boom crutch and lifeboat. That the weather was responsible also seems unlikely. The weather was not particularly favorable, and cloudiness increased throughout the five hours of observation until rain fell in the last hour, but if the weather had been responsible, the effect should have been the same on the stern recorder as on the eye-reading apparatus, and this was not the case. The possible existence of instrumental defects or difficulties was recognized; the eye-reading data were carefully examined with this in mind, but nothing was found that would explain the low factors. It was noted, however, that if the measured volts for both the recorder and the eye-reading apparatus were to be reduced in all cases by an amount of 20 to 25 volts, the factors for the eye-reading apparatus would be increased about 50 per cent to agree with those obtained at Kitts Point and for the recorder would be increased about 10 per cent to agree with those obtained later in series 3 at Barbados. Why both stern instruments would give values 20 to 25 volts too high is difficult to explain. In any case, the low factors were not adopted for use because examination of later parallel observations with the eye-reading apparatus and the recorder made while at sea between Reykjavik and Barbados, taken in conjunction with the Barbados reduction factor results (series 3), has indicated that the factors for the eye-reading apparatus for sail positions MUBP and MUBS are nearer the Kitts Point value of 3.3 than the Reykjavik value of 2.2.

The sets of parallel observations between the eye-reading and recording instruments on the stern rail, made after leaving Reykjavik, were obtained between August 10 and September 14, 1928. August 10 was the earliest available date because prior to that time frequent difficulties were encountered with the recorder. Recorder 4946 had been in constant use since leaving Hamburg on July 7 but on August 9 recorder 4947 was substituted for 4946, and it remained in operation until August 20. After that date, the two recorders were alternated at short intervals until August 30, and instrumental adjustments were made on both recorders to secure the best possible photographic records. After August 30, recorder 4946 was permanently installed as the stern recorder. Twenty-four sets of data were obtained for sail position MUBP between August 10 and September 14, and nine sets for MUBS, as shown in table 4, where the average value of the ratio of eye-reading to recorder measurements for MUBP is seen to be 0.23 and for MUBS to be 0.22. These ratios will be used later in connection with the results obtained in series 3 at Barbados.

For series 3 only recording apparatus was employed on shore and on the ship. The shore instrument was carefully housed for protection against the weather, and both ship and shore installations were allowed to operate continuously for thirty-eight hours on September 27, 28, and 29. From this extended period it has been possible to select the hours during which the most favorable conditions existed for the observations. Fogging of the shore record caused the loss of several hours of data, and bad weather caused the atmospheric potentials to vary greatly for a period of five hours. In addition, spider webs on the shore apparatus prevented successful operation of the instrument at various times. Altogether these difficulties accounted for twenty-two hours of unusable record. The factors for the remaining sixteen hours show very good agreement among themselves. These are shown in table 5.

Table 4. Simultaneous values of potential by stern no. 2 and recorder appartus, to determine ratio between them, Carnegie cruise VII

Date 1928	GMT Begin h m	GMT End h m	Potential in volts MUBP Eye reading	MUBP Recorder	MUBS Eye reading	MUBS Recorder	Ratio eye reading/recorder MUBP	Ratio MUBS
Aug 10	18 36	18 55	34	143	...	....	0.24	.....
11	18 07	18 26	34	182	...	....	0.19	.....
12	12 53	13 12	51	227	...	....	0.22	.....
14	17 39	17 58	36	172	...	....	0.21	.....
14	19 05	19 24	40	194	...	....	0.21	.....
14	20 16	20 35	48	227	...	....	0.21	.....
14	21 17	20 36	57	242	...	....	0.24	.....
14	22 23	22 42	54	224	...	....	0.24	.....
14	23 48	23 57	49	199	...	....	0.25	.....
17	16 59	17 18	...	....	28	122	.....	0.23
17	22 51	23 10	...	....	41	198	.....	0.21
18	5 46	6 05	...	....	31	158	.....	0.19
18	11 36	11 55	...	....	30	155	.....	0.19
19	19 37	19 56	...	....	28	148	.....	0.19
21	19 43	20 02	...	....	30	106	.....	0.28
22	17 35	17 54	...	....	22	106	.....	0.21
23	17 15	17 34	...	....	29	142	.....	0.20
27	16 06	16 25	33	143	...	....	0.23	.....
Sep 1	16 06	16 25	...	....	29	135	.....	0.22
5	17 42	18 01	37	168	...	....	0.22	.....
5	22 18	22 37	40	168	...	....	0.24	.....
6	0 35	0 44	33	164	...	....	0.20	.....
6	2 37	2 46	37	173	...	....	0.22	.....
6	4 34	4 43	31	146	...	....	0.21	.....
6	6 39	6 48	32	128	...	....	0.25	.....
6	8 38	8 47	36	164	...	....	0.22	.....
6	10 41	10 50	38	135	...	....	0.28	.....
6	12 40	12 49	38	155	...	....	0.25	.....
6	16 01	16 20	38	168	...	....	0.23	.....
7	16 36	16 55	41	165	...	....	0.25	.....
8	16 21	16 40	39	143	...	....	0.27	.....
9	17 14	17 33	42	162	...	....	0.26	.....
11	16 47	17 06	...	.....	41	146	.....	0.28
12	16 47	17 06	31	115	...	....	0.27	.....
14	17 45	18 04	...	....	50	188	.....	0.27
Mean ratios							0.23	0.22

Table 5. Reduction factor observations for potential-gradient, Atlantic Ocean, Carnegie cruise VII
Recorder 4946 at stern

Date	GMT		Potential-gradient		Reduction factor for ship's stern recorder				Remarks
	Begin	End	Land recorder	Ship's stern recorder	MUBP	MUBS	MDBP	MDBS	
1928	h m	h m	V/m	Volts					
Sep 28	11 00	12 00	127	193	.....	.....	0.66	.....	Recorder 4947 on shore
28	13 00	14 00	97	137	.....	0.71	.....	.....	Ship's draft 12.3 ft. for'd,
28	14 00	15 00	102	205	0.50	.....	.....	.....	13.3 ft. aft
28	15 00	16 00	111	165	0.67	.....	.....	.....	Ship anchored approxi-
28	16 00	17 00	102	148	.....	0.69	.....	.....	mately one mile from
28	17 00	18 00	100	151	.....	0.66	.....	.....	shore station
28	18 00	19 00	111	160	.....	0.69	.....	.....	
28	19 00	20 00	108	163	.....	0.66	.....	.....	
28	20 00	21 00	114	195	.....	0.58	.....	.....	
28	21 00	22 00	119	200	.....	.....	.....	0.60	
28	22 00	23 00	85	144	.....	.....	.....	0.59	
29	2 00	3 00	69	88	.....	.....	.....	0.78	
29	3 00	4 00	64	102	.....	.....	.....	0.63	
29	4 00	5 00	72	99	.....	.....	.....	0.73	
29	9 00	10 00	77	104	.....	.....	.....	0.74	
29	12 00	13 00	152	184	0.83	.....	.....	.....	
Means					0.67	0.66	0.66	0.68	

Comparison of the Barbados results with those obtained at Iceland indicates that both sets of results are in general agreement, for individual values are found among the Barbados results which are identical with the Iceland values. The greater body of material for Barbados provides a better basis for establishing the magnitudes of the reduction factors than does the small amount of material obtained at Iceland.

In applying the reduction factors obtained at Iceland and Barbados to the measurements tabulated in preceding sections of this volume, it was considered desirable to use a value to only one decimal, and therefore the factor was taken as 0.7. This was employed for conversion of all values of recorded volts obtained with the long, bent collector rod which was in use until November 5, 1928, but with which the last satisfactory records were obtained on October 11, 1928. The ship was at Balboa from October 12 to 25, but at sea from October 25 to November 5 bad weather prevented successful recording with that type of rod.

Having the Barbados value of 0.67 for the mainsail boom to port or starboard with the mainsail either up or down, and having the data given in table 4 for the ratio of stern recorder to stern eye-reading measurements, namely, 0.23 for MUBP and 0.22 for MUBS, reduction factors for the eye-reading apparatus are readily obtained. Using the ratios 0.67/0.23 and 0.67/0.22, the factors become 2.91 and 3.05, or 3.0 as an average value taken to one decimal place. This agrees better with the Kitts Point factor of 3.3 than with the value of 2.2 obtained at Iceland, and on the basis of this result all potentials measured with the eye-reading apparatus (tabulated in tables 1 and 2), were converted to volts per meter with a reduction factor of 3.3 for either MUBP or MUBS, regardless of whether the measurements were made before or after installation of the recorder apparatus on the stern rail on July 7.

For series 4 and 5 of the reduction factor observations, made at Easter Island and Apia, Samoa, respectively, the instrumental conditions and arrangements on the ship were identical. Presumably, therefore, the factors obtained should have been the same. Both series extended over many hours. No entirely satisfactory data were obtained at Easter Island, however, because of instrumental difficulties and bad weather. At Apia the conditions were much better.

At Easter Island ship and shore recorders were operated for a period of fifty-four hours. Throughout the interval the sky was cloudy to overcast and for much of the time threatening, and drizzling rain or showers fell at several different times. On one occasion the supporting insulators for the stretched-wire system of the shore installation became wet with rain; on other occasions raincoats or pieces of canvas were placed over the insulators and recording was suspended. Altogether, twenty-seven hours of recording were made unusable by bad weather.

In addition to bad weather, spiders caused frequent trouble by spinning webs in the cap of the shore electrometer and in the caps of the supporting insulators of the stretched-wire system. The spiders were numerous. Several hours of record were affected by the presence of spider webs. Instrumental difficulties, aggravated by the bad weather, caused additional loss of record. Fogging of the shore record during the daylight hours was a difficulty that had been thought to be eliminated, but was not. Other difficulties included failure of hourly zero marks, and unsatisfactory focus of the electrometer telescope.

Of the fifty-four hours of recording, it was found that only three hours gave undisturbed, legible records at the ship and on shore, namely, 2 hours to 5 hours on December 10, GMT. Even during this interval, however, it is apparent that the shore recorder was only slowly recovering from poor insulation, and of the three hours only the last can be taken as indicative of the proper magnitude of the potential-gradient at the shore station. From this shore value and the simultaneous ship's value, the reduction factor obtained is 3.0 for MUBS, which is in good agreement with the value of 3.2 obtained four months later at Apia, Samoa (series 5).

Table 6. Reduction factor observations for potential-gradient, Pacific Ocean, Carnegie cruise VII
Potential-gradient apparatus no. 2 and recorder 4946 at stern

Date	GMT		Potential-gradient recorder		Reduction factor for ship's stern recorder			Remarks
	Begin	End	Land	Ship's stern	MUBP	MUBS	MDBPC	
1928	h m	h m	V/m	Volts				
Dec 10	2 00	3 00	67	41	.....	1.63	.....	Recorder 4947 on shore
10	3 00	4 00	78	34	.....	2.29	.....	Eye electrometer no. 28 at stern
10	4 00	5 00	79	26	.....	3.01	.....	Ship's draft 12.1 ft. for'd, 13.4 ft. aft.

Ship anchored one-half mile from shore station. On November 5, 1928 the bent-arm collector rod was replaced by a short vertical rod approximately 0.5 meter long.

Table 7. Reduction factor observations for potential-gradient, Pacific Ocean, Carnegie cruise VII
Recorder 4946 at stern

Date	GMT		Potential-gradient		Reduction factor for ship's stern recorder				Remarks
	Begin	End	Land eye reading	Ship's stern recorder	MUBP	MUBS	MDBPC	MDBS	
1929	h m	h m							
Apr 11	11 00	12 00	Observations		.....	.....	.....	3.11	Eye electrometer no. 26 on
11	12 00	13 00	lost at Apia,		.....	.....	.....	3.18	Watson's Reef
11	13 00	14 00	Nov. 1929		.....	.....	.....	3.03	Ship anchored one-half mile
11	14 00	15 00			.....	.....	.....	3.05	from Watson's Reef
11	15 00	16 00			.....	.....	.....	3.35	
Apr 10 to 13, 50 hours comparison with Apia Observatory gave					2.87	3.28	3.86	.....	
Means					2.87	3.28	3.86	3.14	

In addition to the measurements made with the recorders at Easter Island, nine twenty-minute sets of measurements were made with the eye-reading apparatus which was still located on the stern rail. This apparatus had not been in use since September 16, 1928, nearly three months earlier, but initially it appeared to be in good working condition. Examination of the nine sets of data, however, disclosed that the electrometer was very insensitive in its response to changes in air potentials. Furthermore, the calibration was found to differ greatly from calibrations made in September and earlier, indicating that the electrometer fibers may have become defective in the intervening months. This fact, coupled with the generally unfavorable behavior of the shore apparatus, made it necessary to regard the reduction factors obtained from these data as of no value.

Series 5, made at Samoa, utilized measurements obtained with the potential-gradient apparatus of the Apia Magnetic Observatory. First, however, reduction-factor apparatus belonging to the ship was set up on a reef known as Watson's Island, this reef being situated offshore from Apia Observatory about three or four hundred meters and within the confines of the harbor. The Watson's Island apparatus was operated simultaneously with the Apia Observatory apparatus and the ship's recorder for a period of five hours on April 11, and reduction factors for both ship's apparatus and observatory apparatus so were obtained. On the basis of the reduction factor thus obtained for Apia Observatory, more than fifty hours of observatory recording was reduced to volts per meter over a period from April 10 to 13. During this time the ship's recorder was also operating, and factors for the latter, under different sail positions, were determined from comparison of the ship and observatory records. Unfortunately, these data were retained on the ship until the time of her destruction and the papers were then lost, so that only a summary of the results can be presented in table 7, together with the preliminary work of April 11.

To augment the results obtained from the reduction factor observations in Apia harbor, the atmospheric potentials measured with the ship's recorder over a period of several hours after leaving the harbor on April 20, were compared with simultaneous Apia land values after reducing the latter to volts per meter. Table 8 contains thirteen hours of simultaneous measurements. Two positions of the mainsail boom were involved, and reduction factors for these two positions were obtained. It is noted in table 8 that the ship's values for the first two hours were somewhat disturbed; this was true also for the third hour when, in addition to the disturbance, the change in sail position made the value questionable. Since the ship already was several miles away from Apia when these disturbed hours were recorded, it is probable that the effect of the disturbance was not the same at both places. The factors 2.64 for MUBP and 3.80 for MUBS, however, are in fair agreement with the values shown in table 7 for these positions, 2.87 and 3.28, respectively.

Table 8. Comparison of Apia land values (reduced to V/M) with Carnegie values for period immediately following departure from Apia

Date	165th W MT	Apia land	R.-F. =1.09	Ship recorder	Sail position	Ship's R.-F.
1929	h h	Volts	V/m	Volts		
Apr. 20	14-15	109	119	31	MUBS	3.84[a]
20	15-16	109	119	32	MUBS	3.75[a]
20	16-17	98	107	(28)	MUBP	3.82[b]
20	17-18	98	107	39	MUBP	2.74
20	18-19	109	119	40	MUBP	2.97
20	23-24	87	95	37	MUBP	2.57
21	0- 1	98	107	40	MUBP	2.68
21	1- 2	76	83	32	MUBP	2.60
21	2- 3	87	95	36	MUBP	2.64
21	3- 4	87	95	36	MUBP	2.64
21	4- 5	76	83	39	MUBP	2.13
21	5- 6	87	95	39	MUBP	2.44
21	6- 7	109	119	40	MUBP	2.98
MUBP mean						2.64[c]
MUBS mean						3.80[d]

[a]Ship values somewhat disturbed. [b]Omitted from mean; sail changed during hour. [c]Standardization value of April 10 to 13, 1929 = 2.87 (MUBP). [d]Standardization value of April 10 to 13, 1929 = 3.28 (MUBS).

tained after July 28, 1929, were included because only one sign of conductivity was measured after that date. The results of the grouping are shown in table 10.

Had the Iceland reduction factor for eye-reading apparatus no. 2 been used to obtain the potential-gradient values from which seven of the ten air-earth current values in the first group were computed, the average of the ten observations in that group would have been 6.9 rather than 9.0. The average of 6.9 would have given much less satisfactory agreement than the average actually obtained.

In connection with potential-gradient measurements on previous cruises of the Carnegie, study of reduction factor determinations indicated that the factors should be adjusted for differences in the ship's draft at the different ports, although such corrections in general would be small. In tables 3, 5, and 6 in this discussion, remarks are made concerning the ship's draft. Similar remarks should have accompanied tables 1 and 7, but they apparently never were transcribed from the ship's log, and are not available now as the log was destroyed with the ship.. For lack of these data and because the series of reduction factor observations are few in number, it has not been possible to investigate the effect of changes in draft of the ship on the reduction factors for cruise VII.

In view of the comparatively limited number of reduction factor determinations and of the several changes in potential-gradient apparatus during cruise VII, it is believed that the factors given in table 9 are the most satisfactory that can be secured.

Table 9. Accepted reduction factors for potential-gradient measurements, Carnegie cruise VII

Apparatus on stern rail	Applicable period	Reduction factors		
		MUBP-MDBP	MUBS-MDBS	MDBPC
Eye-reading no. 2	May 11 - Sep. 16, 1928	3.3	3.3	4.0
Recorder (bent rod)	July 7 - Nov. 4, 1928	0.7	0.7	....
Recorder (straight rod)	Nov. 5, 1928 - Nov. 18, 1929	2.9	3.2	3.9

From the preceding considerations, the reduction factors finally adopted and their periods of applicability were as given in table 9.

That these factors may be accepted as substantially correct, may be seen from examination of the computed air-earth current values tabulated in Section V of the present volume. There is little reason for believing that the air-earth current density differs greatly from one part of the ocean to another in regions free from steamship routes and well away from large inhabited land masses. If, therefore, the air-earth current values in Section V are grouped in accordance with the three arrangements of apparatus shown in table 9, the average air-earth current values for the three groups might be expected to be similar. Such groupings were made, but the values for the period August 10 to 25, inclusive, were omitted as being obtained from a region not free from disturbing factors and, in addition, no values ob-

Table 10. Comparison of average values of air-earth current density derived from potential-gradient measurements made with three different instrumental arrangements

Apparatus on stern rail	Number of observations	Average computed air-earth current density in 10^{-7} esu
Eye-reading no. 2	10	9.0
Recorder (bent rod)	32	8.8
Recorder (straight rod)	159	10.4

THE DIURNAL VARIATION OF THE ELECTRIC POTENTIAL OF THE ATMOSPHERE OVER THE OCEAN

Successful continuous recording on the seventh cruise of the Carnegie (May 1, 1928 to November 18, 1929) of the electric potential of the atmosphere was begun August 7, 1928, after a three-month period of experimentation and adjustment at sea.

In the early part of the latter period the recording apparatus had been mounted at the top of the mainmast. After a three-week trial of the instrument in that position, it became apparent that the whipping of the masthead would be a constant source of loss of record because the motion was imparted to the fibers of the electrometer to such an extent that no photographic record of the fibers could be obtained even under the more favorable sea conditions. The instrument later was mounted on the roof of the atmospheric-electric laboratory for a short period, but this location was soon found to be so greatly shielded that diurnal variations did not appear.

While at Hamburg, Germany, the apparatus was mounted on the stern rail of the ship, slightly to starboard of the center line. It was retained in this position throughout the remainder of the cruise (until November 18, 1929) without modification except in the shape and length of the rod supporting the four ionium discs of the collecting system. Between August 10 and November 5, 1928, a long rod, bent in a rough arc so as to project astern approximately one meter, was used. Between November 5, 1928, and November 29, 1929, a short vertical rod was used to support the collecting discs.

Between July 8, 1928, the date of departure from Hamburg, and August 7, 1928, when the first of the successful records was obtained, the apparatus was under constant testing and adjustment.

Control of the records was very effectively maintained throughout the cruise. Tests of the adequacy of the insulation of the recorder were made regularly; usually twice each day, frequently several times a day when conditions demanded it, but always at least once each day. Calibration of the electrometer was done regularly once every week or ten days. Observations for the reduction of the observed potentials to volts per meter were made at five ports where conditions on shore were such as to provide a suitable location for the standard comparison station. The results from the five ports did not agree quite so satisfactorily as had been hoped for, but it is believed that the subsequent adjustment of the data has given reduction factors of reasonable accuracy.

Notes describing weather conditions were entered in the ship's log by the sailing officers and were abstracted into a general description of each day for the entire cruise. These notes included direction and velocity of the wind, condition of the sea, amount of cloud, the time of occurrence of distant lightning and thunder and their direction, and the beginning and ending time of rain squalls, showers, and thunderstorms in the vicinity of the ship.

In addition to the weather notes, record was kept of the various changes in the position of the mainsail and the beginning and ending times of the periods of operation of the auxiliary engine used in calm or nearly calm weather for propulsion. It was necessary to note the mainsail positions because the mainsail boom projected out into the region where the potentials were being measured and changes in the boom position affected the recorded values quite considerably. It was necessary to record the periods of operation of the engine because the exhaust was located directly below the potential recorder and the charge of the exhaust gas generally affected the records.

Notes of instrumental difficulties show that practically all the trouble with apparatus was owing either to breaking down of insulation by rain or sea spray, or to loosening or wearing of parts of the apparatus due to the motion of the ship.

Between August 7, 1928, and November 18, 1929, the ship was on the open sea 317 days. On 181 days complete twenty-four-hour records of potential-gradient were obtained, a few of these days being completed by interpolation over periods of one or two hours. On 86 additional days several hours of record were obtained each day. Of the 50 days at sea when no record was obtained, instrumental defects were responsible for the loss of 46, and running of the main engine for the remaining 4 days. Of the 267 days when record was obtained, 128 were affected by bad weather, and on 59 of these days some negative potential-gradient was recorded. Table 1 shows the distribution by months of the number of days at sea, the days of complete or partial recording, and the days when various disturbing factors existed which reduced to 82 the days acceptable as typical of fair-weather conditions over the oceans.

The 82 days in the last column of table 1 represent critical choosing of data for the study of diurnal variation of the electric potential under least disturbed conditions. These days were selected, however, without giving consideration to the type or amount of clouds or of the conditions of temperature, humidity, barometric pressure, or atmospheric pollution. Undoubtedly some of these factors did affect the values of the recorded potentials on some of the selected days.

The 82 selected days have been grouped into three-month periods and mean diurnal-variation curves prepared for each group as shown in figure 1. Comparable curves for 47 days of potential-gradient results from cruises IV, V, and VI are shown also. The curves for cruise VII are in very satisfactory agreement with those for previous cruises, and support the conclusion drawn from the earlier data that the atmospheric potential, when freed from local disturbing effects, varies in the same way and at the same time over the whole earth.

It will be noted that the 82 selected days of cruise VII exceed by 74 per cent the combined number of days from cruises IV, V, and VI. The data of cruise VII represent observations over the north and central Atlantic and the northcentral, southeastern, and southwestern Pacific oceans, whereas the data of the previous cruises were obtained from even more widely distributed areas; so the results may be accepted as representative of world-wide conditions.

Table 2 shows the results of harmonic analysis of the diurnal variation of the potential-gradient as previously reported for cruises IV, V, and VI, and as determined from the observations obtained on cruise VII. It will be noted from the last column of table 2 that the

Table 1. Summary of atmospheric-electric potential-gradient records obtained on cruise VII of the Carnegie and of factors affecting the potential-gradient

Month	Days at sea	Complete 24-hour record	Partial 24-hour record	Bad weather	Negative potential	Instrumental defects	Engine running	Accepted fair-weather days
1928								
Aug	25	9	11	11	4	10	5	6
Sep	17	9	7	7	6	4	0	9
Oct	17	1	7	6	6	9	2	1
Nov	30	19	6	10	6	9	0	12
Dec	24	17	4	6	4	7	0	9
1929								
Jan	14	10	2	2	0	3	0	8
Feb	23	18	2	4	0	4	0	12
Mar	24	8	5	4	1	12	11	5
Apr	11	3	6	7	6	5	6	1
May	26	19	7	17	7	1	2	7
June	12	7	4	3	1	3	9	0
July	27	22	5	24	6	2	0	0
Aug	0	0	0	0	0	0	0	0
Sep	20	10	4	3	0	8	8	1
Oct	29	15	12	20	8	12	11	6
Nov	18	14	4	4	4	0	10	5
Totals	317[a]	181[b]	86[c]	128	59	89	64	82

[a]On 46 days at sea no record was obtained because of instrumental defects and on 4 additional days no record was obtained because the main engine was running. [b]Negative potential occurred on 21 complete days. [c]Parts of 43 days at sea were lost because of instrumental defects, of 9 others because the engine was running, of 27 days more because of bad weather, and of 7 days because of the ship's arrival or departure from various ports.

Table 2. Summary of Fourier analyses of diurnal variation of the atmospheric potential-gradient (P) from Carnegie observations during 1915-21[a] (cruises IV, V, and VI) and during 1928-29 (cruise VII)

Cruises	Grouping	P_m	Phase-angles				Amplitudes								Ratio c_2/c_1	GMT Maxi-mum
			ϕ_1	ϕ_2	ϕ_3	ϕ_4	c_1		c_2		c_3		c_4			
	1915-21	V/m	°	°	°	°	V/m	per cent	V/m	per cent	V/m	per cent	V/m	per cent		h
IV, V, VI	Feb-Apr	132	205	313	235	8	20.6	16	5.8	4	1.2	1	2.3	2	0.28	16.3
	May-Jul	102	159	214	104	193	10.1	10	6.8	7	3.3	3	0.7	1	0.67	19.4
	Aug-Oct	113	173	209	302	28	19.6	17	6.7	6	0.8	1	1.7	2	0.34	18.5
	Nov-Jan	120	195	256	226	330	19.5	16	2.6	2	3.4	3	1.1	1	0.13	17.0
	Year	116	186	237	202	16	17.1	15	4.0	3	0.9	1	0.9	1	0.23	17.6
	1928-29															
VII	Feb-Apr	139	197	267	180	331	21.5	16	3.7	3	2.3	2	3.1	2	0.17	16.9
	May-Jul[b]	117	158	214	133	322	19.8	17	5.2	4	3.8	3	0.6	1	0.26	19.5
	Aug-Oct	119	180	205	205	325	13.5	11	7.0	6	2.8	2	0.5	1	0.52	18.0
	Nov-Jan	140	198	256	216	4	25.8	18	8.6	6	1.5	1	1.9	1	0.33	16.8
	Year	132	192	240	195	344	20.3	15	6.3	5	2.3	2	1.6	1	0.31	17.2

[a]These are finally revised values, correcting values published in Volume V of the Researches of the Department of Terrestrial Magnetism (p. 397). [b]There were no records obtained at sea during June or July 1928 and no quiet days in June and July 1929.

times of maximum of the twenty-four-hour wave compare excellently for the two sets of data. Very good agreement may be noted also for practically all the other items in the two groups.

By the utilization of recording apparatus, potential-gradient measurements on cruise VII of the Carnegie were increased several fold in comparison with previous cruises and the possibility of obtaining continuous series instead of isolated sets of observations greatly enhanced the value of the work. It is to be hoped that oceanographic or other scientific expeditions planned for the future may include recording potential-gradient apparatus similar to that employed on the Carnegie.

Information regarding the distribution and variation of conductivity at sea has been derived chiefly from observations made on board the Carnegie (1). The data thus obtained show no definite evidence of a simple dependence of conductivity on position, but near land the values are more variable than at sea both with position and time, and apparently tend to be somewhat smaller than well out over the open sea. The data seem to justify the conclusion that there is no dependence on latitude amounting to more than a few per cent. This result is consistent with the assumption (a) that the cosmic radiation is the sole ionizer at sea and (b) that the content of condensation nuclei in the atmosphere is independent of latitude. Calculations which involve these assumptions show that although the cosmic radiation is less at the magnetic equator than in higher magnetic latitudes--the difference amounting to about 13 per cent in the eastern Pacific and about 21 per cent in the Indian Ocean--yet when the difference in temperature is taken into account, the average conductivity in low latitudes should not differ from that in high latitudes by more than a few per cent. Such considerations lead one to expect that the conductivity of air over the open oceans should vary only when the concentration of nuclei varies. Observations of nuclei are not yet adequate to disclose a definite dependence on position or to test this surmise in other ways.

Variations in total conductivity from year to year apparently are indicated by the data in table 1.

Table 1. Variations from year to year in conductivity of air over open oceans

Value	Carnegie cruise number		
	IV	VI	VII
Mean epoch	1916.2	1920.8	1929.1
Mean of total conductivity (in 10^{-4} esu)	2.2	2.7	2.0

This feature merits further investigation. It implies that over a great part of the earth either the rate of ion-formation was less or the content of nuclei was greater during the first and last epochs than during the intermediate one. Either alternative presents a challenge to the investigator.

An annual variation in the conductivity over the oceans has escaped detection since scarcely any data are available for winter, the season of rough weather at sea.

Variations from day to day occur in an irregular sequence. In the course of a few days or weeks the highest mean value for a day will be found to be severalfold as great as the lowest mean value. This is shown in figure 2, where daily mean values of conductivity are shown for sixty-five days in the period September 3 to November 18, 1929. The daily mean values were obtained from continuous registrations of conductivity in the central Pacific Ocean during the last months of cruise VII. Registrations of positive and negative conductivity were made on alternate days, resulting in thirty complete days of record of positive conductivity, twenty-eight complete days of negative, and seven days of partial record. In figure 2 the two graphs have been drawn on the basis that the negative conductivity is approximately 15 to 25 per cent lower than the positive, and means for alternately missing values of each sign of conductivity have been interpolated accordingly. For the days of partial record, mean daily values have been placed in parentheses in figure 2.

Bad weather was responsible for large variations in the conductivity on a number of days between September 3 and November 18, 1929. The days most affected were October 10 and 11, October 24 to November 2, inclusive, and November 15 and 16, as may be seen from inspection of the tabulated conductivity data on pages 124 and 125. Most of the bad weather occurred in the late morning or in the afternoon, local time, and as the ship's position varied in longitude only between 235° east and 190° east during the three months, the effect when viewing the data on the basis of Greenwich rather than local time is to place abnormally low values of conductivity in the hours just preceding and following 24h GMT. Thirteen days affected by bad weather accordingly were omitted from studies of the diurnal variation in conductivity, as well as two additional days on which large changes were noted, leaving forty-three complete days.

A diurnal variation in both positive and negative conductivity of small amplitude--about 4 or 5 per cent of the mean--is indicated by the data for the forty-three days selected as least disturbed. The character of the diurnal variation of both positive and negative conductivity may be described with the aid of figures 3 and 4. The ordinates there represent conductivity for the three months of September, October, and November and, in the lowermost graph, for all three months. The abscissas represent the hours of the day counted from Greenwich midnight on the bottom scale and, since the registrations were obtained in the relatively narrow range of 45 degrees of longitude, on the top scale they are made approximately to represent the hours of the local day by shifting the scale ten hours to the right so that local midnight comes at 10h Greenwich time. For figure 3, twenty-three days of record of positive conductivity were available and for figure 4 twenty days of record of negative.

It will be noted that the diurnal variation of positive conductivity proceeds in a manner opposite to that of the negative, although the two are not exactly in opposite phase, the minimum in negative conductivity occurring later than the maximum in the positive. Viewed on the basis of local time, the positive conductivity may be described as varying gradually during the day from a minimum in the afternoon to a maximum in the morning. This variation appears not only in the average for all three months, but is prominently shown in each of the monthly graphs. Hence a diurnal variation of this type appears to be characteristic of positive conductivity over considerable areas of the ocean. For the negative conductivity, the graph for all three months shows a minimum in the morning hours, on the basis of local time, and a maximum just after local noon. The separate graphs for October and November show considerable similarity, but the September graph is irregular, and shows only a slight tendency to conform. One must recognize, however, that the five days making up the September group are widely scattered over a period when very large changes in conductivity occurred. The diurnal variation of negative conductivity may, perhaps, be better viewed on Greenwich time, since the character of variation is such as to suggest a relation with the variation in potential-gradient. For investigation of this point, data were assembled for the preparation of the graphs shown in figure 5.

For figure 5, the registrations of conductivity were examined in relation to registrations of potential gradient, the selection of days being based on the availability of undisturbed days on which both elements were satisfactorily recorded, and, equally important, on the availability of groups of successive days of data for which alternate registration of positive and negative conductivity indicated a homogeneity of conditions. Data for the period October 5 to November 12 were selected and included twenty-one days of potential-gradient, thirteen days of positive conductivity and twelve days of negative. Fewer days of potential-gradient than of conductivity data were available because no registrations of this element were obtained on October 12, 17, 18, 22, and November 4, whereas on one day, November 11, potential-gradient but no conductivity data were available. The homogeneity of the material, however, made it appear desirable to include these days and thus increase the amount of data. No September data were used because much loss of record occurred in that month and the available complete days were scattered and covered an unusually large range of values.

The graphs in figure 5, reading from top to bottom, represent (a) positive conductivity, (b) negative conductivity, (c) total conductivity, (d) the ratio of positive to negative conductivity, and (e) the potential-gradient. The diurnal variations in positive and negative conductivity show no important departures from the graphs already given in figures 3 and 4. The range from maximum to minimum in positive conductivity is 9 per cent and in negative conductivity 12 per cent. The difference in time between the maximum in positive conductivity and the minimum in negative causes the total conductivity to be low during the period from 18h to 22h GMT, but otherwise the total conductivity is essentially constant. The ratio of the two conductivities, on the other hand, undergoes a considerable variation and the character of that variation is very similar to the variation in potential-gradient, having its maximum at 18h to 19h GMT, with gradual rise to the maximum and abrupt falling off thereafter. Similar agreement will be found in cruise VI data which will be examined later. The negative conductivity varies in a manner opposite to that of the potential-gradient, suggesting that even a small diurnal change in field in fair weather may produce an appreciable "electrode effect," causing the negative small-ion content of the atmosphere near the earth's surface (and therefore the negative conductivity) to diminish as the potential-gradient increases. Since the variation in potential-gradient proceeds according to universal time (Greenwich time), as discussed in the preceding paper, rather than local time, this would imply that the variation in negative conductivity should do likewise.

Whether the diurnal variation in either or both conductivities proceeds according to local or to universal time cannot be decided from the three months of recorded data, because of the restricted distribution in longitude. Therefore, comparisons with data obtained by manual observations earlier on cruise VII and data obtained in 1921 on cruise VI are of some interest. Diurnal variation data were obtained by manual observations on cruise VII for complete twenty-four hour periods on twenty-three days between July 29, 1928 and July 28, 1929. Measurements of positive conductivity were made on seventeen of these days and of negative on six days, as shown in the table on pages 103 to 112. Of the seventeen days of positive conductivity, three were obtained in the north central Atlantic Ocean at approximately 320° east longitude, eight in the southeastern Pacific Ocean between 237° and 280° east, one in the north central Pacific near 220° east, and five in the northwestern Pacific between 144° and 185° east. Only the eight-day group (reduced to seven days by discarding one disturbed day) offers enough material for accomparison with the graph for positive conductivity in figure 3. The comparison is made in figure 6 where the agreement perhaps is somewhat better on a Greenwich time basis than on a local time basis. Thus, for cruise VII, two groups of data separated about 50 degrees in longitude, the measurements in one obtained manually and in the other by registration, give comparable results for the character of the diurnal variation in positive conductivity. The graphs in figure 6 are based on a very considerable part of the total days of data for positive conductivity obtained on cruise VII; forty-seven days of data were obtained of which seven were disturbed by bad weather. Of the remaining forty days, thirty --75 per cent--were used in figure 6. There is, therefore, a great preponderance of cruise VII data favoring a diurnal variation in positive conductivity of the character shown in figure 6.

Turning to examination of positive conductivity measurements made on cruise VI, the diurnal variation is found to be quite different. This feature is not, however, the only one in the earlier work which merits some discussion. Between April 9 and August 31, 1921, on cruise VI, manual measurements were made of both positive and negative conductivity (and simultaneously of potential-gradient) for complete twenty-four-hour periods on ten days in the central Pacific Ocean in the same longitude range, 188° to 235° east, as that in which the data in figure 5 were obtained. On each of the ten days the measurement of positive conductivity was alternated from hour to hour with measurement of negative conductivity, thus giving twelve measurements through each day of each sign of conductivity. One day, July 29 to 30, was disturbed by bad weather, leaving nine days of data from which to prepare the graphs in figure 7. In this figure, the sequence of graphs from top to bottom is the same as in figure 5.

The character of the diurnal variation of positive conductivity in figure 7 shows no similarity to that in figure 5. Instead, it is very much like the variation in negative conductivity for cruise VI, and the total conductivity for the cruise consequently shows a similar variation. The completely different character of diurnal variation in positive conductivity for cruises VI and VII would seem to indicate that purely local factors were operating on one or both of these two occasions eight years apart, to give the results obtained. Careful examination of the results from both cruises has revealed no reason for questioning the validity of either group of material, and the question as to what brought about the quite different diurnal variation characteristics must remain unanswered for the present. The negative conductivity exhibits some similarity on the two cruises, since it shows a gradual downward trend from Greenwich midnight until 16h for cruise VI, and to 18h for cruise VII. The "hump" seen in figure 7 between 16h and 20h GMT, not only on the graph for negative conductivity but also on the graphs for positive and total conductivity, is the result of "noncyclic change." For nearly all the nine series of observations, begun between 16h and 20h GMT and finished twenty-four hours later, the magnitude of the conductivity value differed appreciably at the beginning and end of the observing period, thus causing a discontinuity evidenced by the hump. Had the data been obtained on nine successive days instead of on nine days scattered over a period of several months, the discontinuity probably would not have appeared. With the discontinuity contributing to the form of the graph for negative conductivity in figure 7, the inverse relation between this conductivity and the potential-gradient is not so closely adhered to here as was the case in figure 5 and the suggestion of an electrode effect not as well supported. The field changes, however, and the average value of the gradient both are much smaller for cruise VI than for cruise VII and so for the former cruise the electrode effect would be expected to be less.

Turning to the graph for the ratio of positive to negative conductivity in figure 7, the general character of the variation consists of a gradual increase in the ratio through the Greenwich day up to 20h, with a rapid decrease thereafter, much like the variation in potential-gradient. In both figures 5 and 7, therefore, the graphs for the ratio of the two conductivities seem to be in general agreement as to trend through the Greenwich day, with the maximum values of the ratio at the times of highest potential-gradient. The results for both cruises thus agree in supporting the idea that the electrode effect is present, even though local or transitory factors are operating to obscure the effect as far as the separate diurnal variations of the positive and negative conductivities are concerned.

From figures 5 and 7 the mean values for positive and negative conductivity and for potential gradient may be taken and the value of earth-current density computed. The results are shown in table 2.

Table 2. Computed air-earth current density for the central Pacific Ocean from measurements on cruise VI and cruise VII, 1921 and 1929

Cruise	Potential-gradient V/m	Conductivity		Air-earth current density 10^{-7} esu
		Positive 10^{-4} esu	Negative 10^{-4} esu	
VI	94	1.65	1.44	9.7
VII	149	1.14	0.96	10.4

Although the method here used of computing the air-earth current density from mean values of large groups of data does not provide an accurate value of that quantity, it suffices nevertheless to show that the two groups of data support the view that in fair weather the air-earth current density has an essentially constant average value approximating 10×10^{-7} esu. The concordant results engender confidence in the reliability of the techniques of measurement and the instrumental constants, for two periods several years apart. In particular, the reduction factors used in converting volts measured with the potential-gradient apparatus to volts per meter appear to have been satisfactorily determined.

To account for the lower conductivity and higher potential-gradient values in the central Pacific Ocean for cruise VII as compared with the values for cruise VI, one may surmise that the condensation nuclei were more numerous in that region on cruise VII than they were on cruise VI. Evidence to support this conclusion is lacking, however, since nuclei measurements were not made until cruise VII. The nuclei results for cruise VII (see pages 65 to 112) showed large concentrations of nuclei in the western Pacific Ocean, probably produced by volcanic activity in the islands of that region. Possibly volcanic activity in the years between 1921 and 1929 may have caused a higher level of nuclei content over the ocean in 1929 than existed in 1921.

The nuclei content of the atmosphere over the oceans generally is much less than that over land or near land, because in the vicinity of land or over land smoke particles and other condensation nuclei are much more numerous. The "land effect," so called, is strikingly illustrated by conductivity records obtained when approaching land and while in harbor. Sample records are reproduced in figure 8. The upper record was obtained when the Carnegie was approaching the Hawaiian Islands and for the first eighteen hours is typical of an undisturbed day at sea. Baseline spots may be seen at hourly intervals on the record, and a set of calibration spots is shown between 5h and 6h. At 18h the ship had just reached the leeward side of Oahu Island, and the conductivity thereafter shows large fluctuations and a general trend to lower value. In the middle record, with the ship in Honolulu harbor, the value of conductivity is, on the average, only about one-third or one-fourth as great as it was at sea just before arriving, and very large fluctuations are constantly taking place. These two records, obtained on successive days, show the striking change from sea to land conditions.

The lower record in figure 8 shows the effect of bad weather. After 8h, 11h, and 21h, the positive conductivity is decreased almost to zero, remaining so for twenty to thirty minutes or more. Such decreases in the positive conductivity have been shown by other observations to be associated with very large negative values of potential-gradient, with the negative conductivity in the meantime remaining unaffected. With large positive values of potential-gradient, on the other hand, the negative conductivity is much decreased and the positive conductivity shows no effect. Records obtained at sea which were disturbed in the manner illustrated, were omitted from the investigation into the character of diurnal variation of conductivity.

LITERATURE CITED

1. Mauchly, S. J. 1926. Studies in atmospheric electricity based on observations made on the Carnegie, 1915-1921. Researches of the Dept. Terr. Mag., Carnegie Inst. Wash. Pub. No. 175, vol. 5, pp. 385-424.

THE RATIO OF POSITIVE TO NEGATIVE CONDUCTIVITY ON CRUISE VII AND ITS VARIATION WITH POTENTIAL-GRADIENT

In the preceding paper attention was called to the similarity in diurnal variation of the ratio of positive to negative conductivity and the potential-gradient, based on measurements made on cruise VII of the Carnegie. The preceding paper was chiefly concerned with the registrations of conductivity during the period September 3 to November 18, 1929, and simultaneous registrations of potential-gradient. In figure 5 of that paper, the graph showing the diurnal variation in ratio of the two conductivities was shown to proceed to a maximum at 18h to 19h GMT, this being also the maximum of the potential-gradient. The values of the ratio fell in the range 1.09 to 1.29, for changes in potential-gradient from 121 to 189 volts per meter. These data are presented again in figure 9 of the present paper, where the ordinates represent potential-gradient and the abscissas represent the values of the ratio. It will be noted that the line through the points, extrapolated back to a value of zero potential-gradient, gives a value of the ratio at that point of about 0.8 to 0.9. For values of the field approaching zero, such a value of the ratio would be expected because the positive and negative small ions then would approach numerical equality and only differences in their mobilities would cause the ratio to depart from unity. Since the mobility of the negative small ion is greater than that of the positive small ion, the ratio of the conductivities therefore would be less than unity. If the value of positive small-ion mobility is, for example, 1.30 cm/sec/volt/cm, the mobility of the negative ion would need to be only 1.53 to give a ratio of the conductivities of 0.85. In examining figure 9 it must be kept in mind that the plotted points are mean values for approximately twenty days of data, and that the range of values of both elements is smaller than would be obtained by other methods of handling the data.

To explore further the relation between the conductivity ratio and the potential-gradient, the day by day observations tabulated in section V of the present volume were examined. The measurements given in that table were obtained daily during a one- to two-hour observing period in the afternoon. For the present discussion, potential-gradient was taken as the independent variable and the data grouped under specified ranges of values of that element. The results of this treatment are shown in table 1.

The data presented in table 1 were grouped separately for the Atlantic and Pacific oceans because preliminary inspection showed that the conductivity ratios were consistently higher for given values of potential-gradient for the Atlantic than for the Pacific. A further reason for this grouping was the greater homogeneity achieved within each group; a change in the potential-gradient apparatus when entering the Pacific Ocean required the use of a different set of reduction-factor values for the Pacific from those for the Atlantic potential-gradient data.

The data of table 1 are plotted in figure 10 (except the last group of two observations for the Atlantic), where a linear relation is indicated between increasing values of the conductivity ratio and increasing values of potential-gradient. In figure 10, as in figure 9, extrapolation back to zero potential-gradient of the line drawn for the Pacific data, gives a value of the ratio between 0.8 and 0.9, which is very satisfactory agreement. For the Atlantic the data are too few to provide a sound basis for discussion; in fact, thirty-five out of forty-six observations, or 80 per cent, in the range of 90 to 150 volts per meter, could be viewed as supporting the idea that the conductivity ratio is effectively constant at a value of 1.16. On the basis of the more definite indication given by the Pacific data, however, of an increase in ratio with increase in potential-gradient, it has seemed preferable to draw through the points for the Atlantic data in the manner shown in figure 10. No satisfactory explanation for the lack of agreement shown in figure 10 of the data for the two oceans presents itself at this time.

Table 1. Values of recorded potential-gradient and corresponding computed values of $\lambda+/\lambda-$ from daily eye readings of $\lambda+$ and $\lambda-$

Potential-gradient range V/m	Atlantic Ocean July 28 to October 9, 1928			Pacific Ocean Nov. 5, 1928 to July 28, 1929		
	Potential-gradient	$\lambda+/\lambda-$	No. of obsns.	Potential-gradient	$\lambda+/\lambda-$	No. of obsns.
70- 89	84	1.12	6	....	.....	...
90-109	102	1.15	11	102	1.05	18
110-129	118	1.17	14	121	1.07	20
130-149	139	1.15	10	140	1.09	22
150-169	162	1.22	5	158	1.14	27
170-199	....	......	...	181	1.19	25
200-249	201	1.37	2	219	1.19	24
250-299	....	.....	...	269	1.28	10
300-415	....	.....	...	355	1.47	6
Mean or total	122	1.17	46	172	1.15	152

The present investigation indicates that all conductivity and potential-gradient measurements in the Pacific on cruise VII of the Carnegie, regardless of whether the conductivity results were derived from continuously recorded data or from daily eye-reading observations of an hour or two, are in agreement in showing that the ratio of positive to negative conductivity increases with increasing value of potential-gradient. There is, therefore, general agreement on the indication that small changes in field occurring in fair weather produce an appreciable "electrode effect." This effect appears to be most clearly demonstrated by the day to day eye-readings of conductivity over the Pacific Ocean. For those data both conductivities decrease with increase in potential-gradient, but the negative conductivity is decreased more than the positive, thus giving an increase in the ratio with increase in gradient. This may be seen from table 2, where mean values of positive and negative conductivity are tabulated with mean values of potential-gradient. The mean values of the ratio of the conductivities are repeated here, taken from table 1.

Taking, for example, the values of conductivity corresponding to 219 volts per meter, it is seen that the positive conductivity is 25 per cent lower than it was for 102 volts per meter, but the negative is 33 per cent lower. Other sets of data in the table give the same result; greater reduction of the negative conductivity than of the positive, with increase in potential-gradient.

Table 2. Mean values of potential-gradient and corresponding mean values of positive and negative conductivity and of the ratio of the two conductivities, from data obtained in the Pacific Ocean

Potential-gradient V/m	Positive conductivity in 10^{-4} esu	Negative conductivity in 10^{-4} esu	Ratio $\lambda+/\lambda-$	No. of obsns.
102	1.20	1.14	1.05	18
121	1.14	1.06	1.07	20
140	1.04	0.96	1.09	22
158	1.12	0.99	1.14	27
181	1.06	0.89	1.19	25
219	0.92	0.77	1.19	24
269	0.52	0.41	1.28	10
355	0.51	0.35	1.47	6

THE COMPUTED MOBILITY OF SMALL IONS IN THE ATMOSPHERE OVER THE OCEANS

A considerable number of laboratory determinations of the mobility of small ions have been carried out over a period of many years. The results indicate that at normal temperature and pressure the mobility of the negative ion generally is appreciably greater than that of the positive ion. In gaseous compounds the mobility of both the negative and the positive ion is reduced from that found in the elementary gases. The introduction of water vapor into dry air has a similar effect on the mobilities. In both cases the reduction in mobility of the negative ion is greater than that of the positive ion. The ratio of negative to positive mobility consequently is reduced under these circumstances. Zeleny (1), using x-rays as a source for ions, for example, found that the mobility of the negative ion in dry air was 1.87 cm/sec/v/cm, while that of the positive ion was 1.36 cm. In moist air, on the other hand, the mobilities were 1.51 and 1.36, respectively, for the negative and positive ion, a reduction in the ratio from 1.36 to 1.10, in going from dry to moist air. In any attempt to estimate the mobility of the small ion in the atmosphere from laboratory determinations, it is necessary to allow for the effect of various gaseous compounds that may appreciably alter the mobility and also for moisture which always is present in varying amounts. The picture is still further complicated by the fact that there may be other factors as well which appreciably influence the mobilities but by different amounts.

The answer to any question concerning the mobility of the small ions and the relation between the negative- and positive-ion mobility in the atmosphere probably can best be answered through observation on ordinary air, that is, air which has not been artificially ionized, dried, or purified in any way. Simultaneous observations on the ion content and conductivity during fair weather provide valuable material for such determinations. Observation as ordinarily carried out, however, must be used with considerable caution because of various effects which can appreciably alter the results. The presence of a considerable number of large ions, for example, may appreciably contribute to the current in the ion counter and thus lead to an error in the determination of the small-ion content of the atmosphere. This effect is such as to increase the value attributed to the small-ion content of the air and consequently to reduce the computed value of the mobility. The negative and positive large ions may not always be equally numerous and consequently the ratio of negative- to positive-ion mobility, as well as the absolute value of the mobility, then will be affected. Another effect may arise from the earth's electric field. The charge induced on the exposed part of the ion counter by the normal potential-gradient reduces the number of negative ions measured with this instrument. The reduced negative-ion count under these circumstances will result in a corresponding increase in the negative small-ion mobility. Since the positive-ion content remains unaffected by the potential-gradient, there will then be an increase in the ratio of negative- to positive-ion mobility.

Observations made over the ocean areas aboard the Carnegie were such as largely to avoid these effects. The large-ion content of the air over the ocean generally is small compared with that over land areas and there is no evidence that the intermediate-ion content is of any consequence. Any electric field at the observing station was practically eliminated owing to the presence of the sails overhead. The observations aboard the Carnegie were carried out in such a manner that the measurements of ion count and conductivity were simultaneous, and positive- and negative-ion and conductivity measurements were alternated in order that negative-ion mobility would center on the same average time as the value of positive-ion mobility. Considering all these circumstances it appeared of interest to examine the values of mobility computed from small-ion and conductivity measurements of the last cruise of the Carnegie and, for comparison purposes, values computed for previous cruises as well.

One might reasonably expect that the mobility of the small ions in the atmosphere, even over the ocean, might differ greatly from time to time owing to changes in the various factors which are generally supposed to affect it. On examining the values of the mobilities calculated from ion-content and conductivity data it is found that they do scatter over a considerable range in values. It would seem desirable to determine to what extent this scatter may be attributed to real changes in the mobility and to what extent it may be due to errors in measuring the ion content or the conductivity of the atmosphere. This matter has been investigated and will be discussed in what follows.

Frequency curves of the computed mobility of the positive and the negative ion have been constructed from data taken during cruises IV, VI, and VII, and are shown in figure 11. In each case the resulting curve corresponds closely to a probability curve, the latter being drawn also in the figure. The mean values of the computed mobilities differ considerably for the various cruises. For cruises IV and VI the mobility of the positive ion is practically the same as that of the negative ion, whereas for cruise VII it is appreciably less. The mean approximate values are as follows: 1.4 cm for cruise IV, 1.6 cm for cruise VI, and 1.3 and 1.4 cm for the positive and negative ion, respectively, for cruise VII. The changes in the mean value from cruise to cruise probably can be ascribed to changes in the instruments not compensated for by appropriate changes in constants. The difference in the mean computed mobilities of the two signs of ions in the case of cruise VII, however, cannot be accounted for in this manner. The difference in this case may be related in some way to a change in meteorological and other conditions of the atmosphere, but as yet it must remain unexplained.

The spread in computed mobilities, as illustrated by the frequency curves, appears rather large, and further consideration was given to this matter. As a step in this direction the values of conductivity and ion content were grouped and meaned for various values of mobility over the range of 0.7 to 2.5 cm/sec/v/cm, the values of mobility being taken in steps of 0.1 cm. The mean values of conductivity and ion content for the various mobility values have been plotted in figure 12A, for the combined data of cruises IV and VI. To use all possible available data, the results for both positive and negative ions have been included in a single plot. By this arrangement a total of 1470 simultaneous observations has been utilized. The corresponding frequency curve also is given in the figure. In the case of cruise VII data, for which the curves are given in figure 12B, there is a total of 957 simultaneous observations on ion content and conductivity, including both positive and negative elements. As will be seen for both sets of data, the ion content remains essentially constant as the computed mobility increases, until the mean value is reached. The ion content then diminishes as the computed mobility is still further increased. The conductivity, on the other hand, gradually increases at the low values of computed mobility and then assumes a more or less constant value at about the mean mobility and remains essentially constant as the computed mobility is further increased. The curves are identical in character for the early cruises and for the last cruise. Such a relation between the mobility and the ion content of the air is extremely interesting, if real.

A dimunition in the ion content of the air with an increase in mobility, due to the recombination of oppositely charged ions, is to be anticipated. The ion content, because of this effect, should vary inversely as the square root of the mobility, the variation beginning with the lowest mobility and continuing throughout the entire mobility range. The observed variation differs from this in two respects. In the first place no dimunition occurs at the lower mobilities. In the second place the variation which occurs at the higher mobilities is inversely proportional to the first power of the mobility. This lack of agreement, therefore, between the observed and the expected variation in ion content with mobility is sufficient to cast doubt on the reality of the computed mobilities. It seems necessary, therefore, to consider the possibility that the scatter in values of the computed mobilities is due to errors in making the ion content and the conductivity measurements. To explain the results on this basis, it is necessary to assume that, on the average, both elements when measured incorrectly, were measured too small. The computed mobilities which are less than the mean value are due to the use of conductivity values which are less than the true ones. Likewise, computed mobilities greater than the mean value are due to the use of values of the ion content less than the true values of this element. The error of measurement of each element accordingly is systematic in that it is not equally distributed plus and minus. The errors, however, fit extremely well a normal frequency curve and consequently suggest that they are of an accidental character. From the data a precision index has been computed and also the probable error of the arithmetical mean. A list of the probable errors as determined is given in the table below. The errors do not apply exclusively to either the ion content or the conductivity measurement but are a compromise of the two. From an examination of the frequency curves, however, it is seen that there is but little difference in the probable error for the two elements in question.

It is of considerable interest to compare the probable error in the case of the conductivity measurement after the recording of this element began, with the probable error indicated above for data obtained by eye readings. The number of observations secured after the recording began is not large and consequently too much reliance must not be placed on the results obtained. The frequency curve, combining the observations on both signs

Table 1. Values of mean mobility of small ions for cruises IV, VI, and VII, 1915 to 1929

Cruise	Sign	No. of obsn's.	Mean mobility	Probable error of the mean
IV	Positive	188	1.42	0.013
IV	Negative	175	1.41	0.014
VI	Positive	809	1.60	0.006
VI	Negative	291	1.62	0.012
VII	Positive	600	1.30	0.006
VII	Negative	357	1.39	0.009

of ions is given in figure 13. In this figure also are given plots of the conductivity against mobility and of the ion content against mobility. The data for these plots were obtained by grouping the computed mobilities in the manner explained earlier. The most noteworthy feature of this plot is the fact that there is no suggestion of a change in conductivity with computed mobility. This result, though based on few data, suggests that the systematic error has been largely eliminated from the measurements obtained with the conductivity recorder. The systematic error, in other words, appears to have been introduced through the eye readings. The particular manner in which the errors were introduced is not immediately apparent.

The elimination of the systematic errors in the case of the conductivity recorder data increases the value of the mean mobility, because the lower values of the computed mobilities are no longer obtained. Since the systematic errors are still retained in the case of the ion-content measurements, the higher mobilities also are retained. The mean mobility, in consequence, is somewhat enhanced as seen in table 2. The question arises, then, as to how much value can be ascribed to a mean where systematic errors have affected the data, although in the case of the Carnegie instruments the errors in the conductivity apparatus about counterbalance those of the ion counter. In view of the occurrence of systematic errors in the measurement of ion content and the conductivity during all cruises of the Carnegie, one should be prepared to accept the differences shown in table 1 in the mean mobilities from cruise to cruise. The small differences between the positive and negative mobilities for each cruise shown in table 1, as well as the magnitudes of the mobilities themselves, are in good agreement with those to be expected from laboratory measurements on moist air.

Table 2. Increase in mean mobility with change from eye-reading to recording conductivity apparatus

Apparatus	Period of use	No. of obsn's.	Mobility
Eye reading	May 10, 1928- July 28, 1929	600 357	k+ 1.30 k- 1.39
Recording	Sep. 5- Nov. 18, 1929	46[a] 49[b]	k+ 1.49 k- 1.56

(a) Nov. 4-5, (b) Oct. 21-22; 24 abnormal values omitted

INTERESTING ASPECTS OF THE AIR-EARTH CURRENT DENSITY OVER THE OCEANS AS DERIVED FROM ATMOSPHERIC-ELECTRIC DATA OF CRUISE VII OF THE CARNEGIE

In the tables in sections V and VI of the present volume there have been tabulated computed values of air-earth current density expressed in 10^{-7} esu. In section V there are 263 values of the current density, each representing a period of approximately one to two hours in the early afternoon, local time, for 263 days at sea. In section VI there are twenty-four complete, or essentially complete, diurnal-variation series and seven partial series of values of current density, containing 645 individual values. On the average, one diurnal-variation series was obtained every two weeks during the cruise. It is of interest to examine these air-earth current density data as an aid to interpretation of the changes constantly taking place in the electrical conditions in the lower atmosphere.

For the present discussion the earth and the high atmosphere may be regarded as two conductors, each of negligible resistance, which constitute a spherical condenser, the outer element having a potential E relative to the inner element. Then if R is the resistance of a vertical column of unit cross section of the atmosphere between the elements of this condenser, at a given geographical location, the air-earth current density, i, through that column, assuming Ohm's law to apply, is E/R. From measurements of conductivity in the region between the earth's surface and an altitude of 18 kilometers, Gish (1) has made an estimate of the columnar resistance up to the latter altitude, and gives the result as 10^{21} ohms or 1.11×10^{9} esu. In a preceding paper, the quite small variation of the conductivity through the day over the oceans, under least-disturbed conditions during fair weather, has been discussed and diurnal-variation curves for various periods of cruise VII have been presented (figs. 3, 4, and 5). Those results indicate that the variation is from 5 to 10 per cent of the mean. When the conductivity is so constant one may fairly conclude that disturbing factors such as smoke, fog, mist or haze, which act to reduce the conductivity, are largely absent, not only in the lowest part of the atmosphere where the conductivity is measured, but also throughout the regions above which are even less likely to come under the influence of any disturbing factor, so that the columnar resistance R, like the conductivity, may be regarded as essentially constant through the day. For the present paper, this constant value of R will be taken as 10^{21} ohms or 1.11×10^{9} esu, as given by Gish, and will represent the total columnar resistance rather than the resistance to a height of 18 kilometers. Such a procedure introduces no important error in the conclusions to be drawn here because, as Gish has pointed out, the upper 8 of the 18 kilometers contribute only 5 per cent of the total resistance, and from the region beyond the 18 kilometers on up to the highly conducting upper region one might expect an even smaller contribution to the total.

When disturbed conditions arise, and conductivity values are lower than usual, disturbing factors must be present in a region of unknown height near the earth's surface. The magnitude of the drop in conductivity (or increase in resistivity) and the height to which the disturbing factor penetrates are important in determining the degree to which the columnar resistance R may be affected. A very thick layer containing the disturbing element, with the conductivity greatly reduced throughout that layer, would produce a considerable increase in R. On cruise VII there were occasions when conductivity was notably reduced below the usually prevailing value, and on some of these occasions potential-gradient was much increased, whereas on others it was not greatly different from the normal value. Values of air-earth current density sometimes were much lower, therefore, than ordinarily encountered while at other times they were only slightly low. Some of the disturbed periods will be discussed in detail later, and the attempt will be made to determine the height to which the disturbing factor existed in the atmosphere during each period. First, however, an examination will be made of the values of air-earth current density generally found for "normal" or "least-disturbed" conditions, in order that a basis may be established for recognizing disturbed values.

Since the air-earth current density i equals E/R, and R is essentially constant under least-disturbed conditions over the oceans, variations in i under those conditions are the result chiefly of variations in E. Measurements of potential-gradient in those circumstances reveal the extent and character of the variations in E, and cruise VII data discussed earlier in this volume have supported previous conclusions that potential-gradient has a large diurnal variation which proceeds according to universal time. Necessarily, then, the air-earth current density varies through the day according to universal time. To examine this variation, all complete diurnal-variation series of current density in the table in section VI, except the series for November 13 to 14, 1928, which was disturbed, and the four series obtained in October and November, 1929, were assembled into three groups and an average diurnal-variation curve was drawn for each group. The four October and November series omitted were included in a fourth group based on continuous registration of conductivity as well as potential-gradient during those months, which made more than twenty days of data in each element available (see tables in sections VII and VIII and the curves in fig. 5) for computation of air-earth current density. Assembling the current-density data into four groups has divided the material seasonally and geographically as shown in table 1.

Diurnal-variation curves for the four groups are shown in figure 14, and their similarity to diurnal-variation curves for potential-gradient for the same periods (fig. 1) is obvious. The displacement of the time of maximum in the months April to September to a later hour than is found for the months of October to February, and the smaller amplitude of the diurnal variation in the former months than in the latter, are features of the diurnal variation in current density which have become recognized as important features of the potential-gradient also, as pointed out by Wait and Sverdrup (2) in their discussion of a mechanism for explaining the universal character of the diurnal variation of the potential-gradient.

It is seen, then, that the air-earth current density changes through the Greenwich day in a systematic and regular manner, with a daily range of 2 to 5 × 10^{-7} esu in mean curves representing several days. When individual days are examined, as found in the table in section VI, the daily minimum may be as low as 5 × 10^{-7} esu and the maximum as high as 15 × 10^{-7} esu, thus giving a range of 10 × 10^{-7} esu. This not unusual range through the day must be borne in mind when decision is made as to whether certain values of air-earth current density are unusually low or not.

Table 1. Daily means of air-earth current density and daily ranges for four groups of data containing forty diurnal-variation series of measurements from cruise VII: first group, Atlantic data; other groups, Pacific data

Month and year	Average longitude east °	No. of days	Range of current density in 10^{-7} esu	Average current density in 10^{-7} esu
Aug.-Sep. 1928	316	5	5.8- 7.6	6.4
Nov. 1928-Feb. 1929	256	9	7.4-11.7	9.1
Apr.-July 1929	160	5	8.2-10.6	9.1
Oct.-Nov. 1929	210	21	8.5-12.9	10.5

Similarly, daily average current-density values vary over a considerable range. This may be seen from table 2, where mean daily values of conductivity, potential-gradient, and air-earth current density are tabulated for the twenty-seven diurnal-variation series found in the table in section VI. Included in the table, in the last column, are maximum and minimum values of current density for each day, illustrating the large diurnal range mentioned in the preceding paragraph.

In table 2 there are two days with conspicuously low mean values of air-earth current density, namely, August 17-18 and 24-25, 1928, with values of 4.8 and 4.5 × 10^{-7} esu, respectively. These days are part of a period of sixteen days between August 10 and 25, for which the brief day-to-day observations also showed consistently low values of current density, the latter being computed from unusually low values of conductivity and more or less ordinary values of potential-gradient. This disturbed period is one of three which will be discussed in detail later.

Besides the two lowest daily mean values of current density just mentioned, there are two other low values of

Table 2. Daily mean values of conductivity, potential-gradient, and air-earth current density for diurnal-variation series of cruise VII from July 30, 1928 to November 5, 1929

Date	λ+ in 10^{-4} esu	λ- in 10^{-4} esu	P.-G. V/m	i[a] in 10^{-7} esu	Range in i in 10^{-7} esu
1928					
July 30 - 31	1.04	.....	....	.....	....
Aug. 7 - 8	.....	0.93	110	7.9	5.8- 8.6
Aug. 17 - 18	0.78	.....	97	4.8[b]	3.6- 6.7
Aug. 24 - 25	.....	0.85	75	4.5[b]	3.6- 5.7
Sep. 5 - 6	1.17	.....	103	7.7	6.3- 9.1
Sep. 13 - 14	.....	0.96	122	8.1	6.9- 9.4
Nov. 13 - 14	1.19	.....	126	9.6	6.9-14.0[c]
Nov. 21 - 22	.....	1.02	88	6.2	5.1- 8.2
Nov. 27 - 28	1.34	.....	109	9.3	5.6-13.1
Dec. 3 - 4	.....	1.08	121	9.1	6.6-11.5
Dec. 18 - 19	1.04	.....	169	11.2	8.7-14.3
Dec. 26 - 27	0.93	.....	204	11.1	9.4-15.9
1929					
Jan. 1 - 2	0.97	.....	134	8.3	5.0-11.9
Jan. 10 - 11	0.70	.....	175	7.6	6.0-11.1
Feb. 10 - 11	0.93	.....	....	.....	....
Feb. 18 - 19	.....	1.05	146	10.7	8.2-14.3
Feb. 26 - 27	0.87	.....	145	8.0	5.1-13.0
Apr. 30 - May 1	0.98	.....	137	8.2	6.6-12.8
May 9 - 10	1.12	.....	135	10.2	9.0-12.1
May 17 - 18	1.08	.....	90	6.2	4.6- 7.3
May 27 - 28	1.18	.....	159	11.9	8.5-15.7
July 3 - 4	0.73	.....	180	8.3	6.7-10.8
July 21 - 22	1.15	.....	157	11.1	7.6-16.5[d]
Oct. 5 - 6	.....	0.96	174	11.5	9.5-14.3
Oct. 13 - 14	1.32	.....	110	9.4	6.6-14.9[e]
Oct. 21 - 22	.....	1.12	(122)[f]	(9.5)	(5.7-12.7)
Nov. 4 - 5	0.78	.....	164	8.1	6.5- 9.2

[a]Air-earth current density computed assuming λ+ = 1.10 λ-. [b]Low values throughout day. [c]Except two low values 2.6 and 2.7. [d]Except two low values 4.1 and 5.0. [e]Except one low value of 3.7. [f]October 21-22 has only 18 hourly values.

interest. These are found on November 21 to 22, 1928, and May 17 to 18, 1929, and the value in each case is 6.2 $\times 10^{-7}$ esu. In these two cases the values of conductivity are typical of those obtained under least-disturbed conditions, but the potential-gradient values are lower than average. Now, storm clouds of proper polarity at appropriate distances might be thought of as causing the low potential-gradients on these occasions, but the abstract of the log in section IV does not indicate that such clouds were present. Another explanation for the low values of potential-gradient may be found in the change in this element with latitude. Gish (4) found a conspicuous change with latitude in his study of the potential-gradient data from the earlier cruises of the Carnegie. Although he did not find a comparable change in air-earth current density with latitude from the data for earlier cruises, the data of the present cruise, which show that under least-disturbed conditions the conductivity is essentially constant, require that the current density change with latitude in accordance with the change in potential-gradient for different latitudes.

When the current-density values in table 2 are plotted against latitude, an increase with latitude is indicated, but the two low values under discussion still appear low for the latitudes at which they were obtained (11° south and 16° north). There remain two ways of accounting for the low values of current density on these occasions. Either an unusually low value of the total potential E may have existed between the earth and the upper conducting region, or there may have been an unusually high value of columnar resistance R. Since, however, the conductivity appeared undisturbed, the value of R probably was not unusually high, and in that case the low potential-gradient and low current density on these occasions was caused by a low value of E. That the value of E might on one day be low and the next day high, say half again as great or even more, does not appear unreasonable.

From the preceding discussion it may be seen that the air-earth current density may have high or low values through the day or from day to day from various causes. As one cause, some disturbing element may enter the lower layer of the atmosphere as evidenced by smoke, dust, fog, mist, or haze, to lower the current density to a smaller value than would prevail if this element were absent. As a second cause, observing in middle or low latitudes would yield smaller values of current density than would measurements in high latitudes. As a third cause, the total potential E might vary from one occasion to another to produce higher or lower values from one time to the next. In the discussion to follow, account will be taken of these various causes in a study of disturbed periods encountered during cruise VII. The disturbed periods will be compared with so-called least-disturbed periods, and for the latter periods it will be assumed that the columnar resistance is constant and has the value given by Gish. Departures from this value in periods of disturbance will be evidenced by unusually low values of conductivity, the degree of "lowness" being indicated by comparison with a value derived from measurements of this element obtained under least-disturbed conditions and accepted as essentially constant. There will also prevail, in the disturbed periods, low values of current density, and the degree of "lowness" in this element will be indicated by comparison with a value representing least-disturbed conditions after giving proper weight to the effect of latitude and of variations in E.

The first of the three disturbed periods encountered on cruise VII to be considered will be that of June 2 to July 21, 1929. Throughout the thirty-three days at sea during this period the atmosphere was hazy, foggy, or misty, or a fine drizzling rain was falling, as recorded in the abstract of the log in section IV. The periods June 2 to June 7, before arriving at Yokohama, and June 26 to July 2, just after leaving that port, were characterized by haze. The period June 2 to 7 was also marked by two typhoons, the first reaching the vicinity of the Carnegie on June 2 and the second on June 6. That the haze encountered before arriving and after leaving Yokohama is typical of the typhoon season is probable. Captain Ault recorded these meteorological conditions in his progress reports of the cruise (3), and continued with very revealing descriptions of the conditions prevailing for the balance of July. Briefly, on July 3 or 4, the region of cold surface water was entered, with practically one hundred per cent of mist, fog, or drizzle thereafter until July 21. The fog or mist was "thick" on most days. On July 14 the winds changed from easterly and southerly to southwesterly, and freshened, driving the ship an average of two hundred miles per day for the next several days in contrast with an average of one hundred miles per day for the preceding interval. Thus, there are three periods having different meteorological conditions, these being June 2 to July 2, July 3 to 13, and July 14 to 21.

Daily values of the atmospheric-electric elements for the three periods are tabulated in table 3. The sum of the two conductivities, $\lambda+ + \lambda-$, is given for each day, together with the simultaneous value of potential-gradient, G, and the computed value of air-earth current density, i. For each of these sets of data the geographical position is given and the mean time of observations in Greenwich time. The subscript u is used with the designation for each atmospheric-electric element, to indicate what may be called "unusual" or disturbed conditions. Use will presently be made of this subscript. In the last column of the table are given values of i_n, the subscript n designating normal or undisturbed conditions, the significance of which will be brought out in later discussion.

Examination of table 3 reveals that the data for June 2 to July 2 were obtained in the 30° to 40° north latitude belt, those for July 3 to 13 in the 40° to 47° belt, and those for July 14 to 21 between 48° and 53° north. These groups are designated 3a, 3b, and 3c, respectively, for purposes of discussion. For group 3a the mean value of air-earth current density is only 7.4 $\times 10^{-7}$ esu, for group 3b, 9.1 and group 3c, 12.9 $\times 10^{-7}$ esu. When one compares these values with those obtained for April and May, 1929, taking account of the increasingly higher latitudes in going from April to July, as in figure 15, one finds that, had fog, mist, or haze not been present in June and July, the value for group 3a might have been expected to be about 11.8 $\times 10^{-7}$ esu, for group 3b, about 12.7 $\times 10^{-7}$ esu, and for group 3c about 13.3 $\times 10^{-7}$ esu. That the curve in figure 15, drawn through the points representing the April to July data, should have the slope shown, appears to be supported by the curve for the September to November data, which has been placed in figure 15 for comparison. The thirty-five sets of observations composing the September to November data were obtained at approximately Greenwich midnight, whereas the fifty-two sets of April to July data were obtained between 1.5h and 4.5h, Greenwich time. Evidently the universal diurnal-variation characteristic and the seasonal variation combined to make the September to November values of

Table 3. Values of atmospheric-electric elements during fog, mist, and haze, June 2-July 21, 1929; derived fair-weather current-density values based on assumed heights of regions containing the fog, mist, or haze

Gr. date	GMT h	Latitude north °	Longitude east °	G_u V/m	$\lambda_u^+ + \lambda_u^-$ in 10^{-4} esu	i_u in 10^{-7} esu	i_n in 10^{-7} esu
				Group (a)			(h_u = 1.0 km)
June 2	4.5	30.3	144	186	1.42	8.8	10.6
3	5.0	31.3	144	282	0.60	5.6	11.7
4	5.0	32.8	142	339	0.57	6.4	13.8
5	4.8	34.1	141	144	1.20	5.8	7.6
26	5.1	36.1	142	267	0.88	7.8	12.5
27	4.9	36.7	144	180	0.95	5.7	8.7
28	(10.3)	36.8	145	270	0.58	5.2	11.1
29	4.6	37.9	145	276	0.83	7.6	12.6
30	4.5	38.2	147	246	1.03	8.4	12.2
July 1	4.4	38.8	148	276	1.07	9.8	13.9
2	4.1	39.9	150	319	0.97	10.3	15.5
Mean	4.7	35.7	145	253	0.92	7.4	11.8
				Group (b)			(h_u = 1.3 km)
July 3	2.3	40.4	151	206	1.53	10.5	12.7
4	1.8	41.4	153	171	1.38	7.9	10.2
5	4.3	42.8	156	342	0.71	8.1	16.9
6	3.7	43.9	158	203	1.22	8.3	11.6
7	3.2	45.7	160	104	1.91	6.6	7.0
8	3.9	47.0	163	389	0.98	12.7	20.8
9	3.4	47.0	167	130	1.24	5.4	7.5
10	3.1	46.7	170	119	2.15	8.5	8.4
11	2.6	45.9	172	165	1.90	10.4	11.0
12	2.7	45.4	173	360	0.96	11.5	19.1
13	2.5	46.5	174	220	1.40	10.3	13.1
Mean	3.0	44.8	163	219	1.40	9.1	12.6
				Group (c)			(h_u = 0.1 km)
July 14	2.4	48.2	178	415	0.85	11.8	12.5
15	2.8	49.4	184	652	0.55	12.0	13.4
16	1.5	50.6	188	290	1.38	13.3	13.6
17	2.2	51.6	194	235	1.80	14.1	14.2
18	1.8	52.5	199	229	1.51	11.5	11.7
19	1.1	52.5	205	220	1.46	10.7	10.9
20	0.9	51.8	210	226	1.75	13.2	13.3
21	0.0	50.0	214	215	2.28	16.3	16.3
21	(21.9)	48.0	217	220	1.81	13.3	13.4
Mean	1.2	50.5	199	300	1.49	12.9	13.3

current density average about 1.4×10^{-7} esu lower than the April to July values, throughout the latitude range.

Accepting the curve for April to July data shown in figure 15, the air-earth current density for group 3a is too low by the amount of 4.4×10^{-7}, for group 3b it is too low by 3.6×10^{-7} esu, and for group 3c it is only 0.4×10^{-7} esu too low. If, now, one wishes to examine into the mechanism which is causing too low values of current density, the method employed by Wait (5) in his study of changes in the columnar resistance of the atmosphere over the Watheroo Magnetic Observatory in Western Australia, provides some interesting information. In this method the columnar resistance of the atmosphere is thought of as consisting of an upper and lower part, with the resistance of the upper part remaining unchanged even on those occasions when the resistance of the lower part is altered considerably by the introduction of mist, fog, or haze particles. Measurements of potential-gradient and conductivity in the lower part during the periods of fog, mist, or haze, used in conjunction with other measurements accepted as typical of conditions prevailing when the disturbing effects are absent, permit one to deduce a height for the lower disturbed region, assuming always a uniform vertical distribution of the medium in that height.

One must note at this point a difference between the present data and those utilized by Wait. In his paper, the data included observed ocean values of i_n and simultaneously observed values of i_u for the Watheroo Observatory, from which he obtained the height, h_u, of the disturbed lower region of the atmosphere at Watheroo. For the present paper, since only ocean data are being considered, only values of i_u, and not simultaneous values of i_n and i_u, are available for any disturbed period. Under these circumstances both i_n and h_u are unknown, and one may assume certain values for either one and compute the other. On the one hand, to determine h_u one must resort to the use of average values of i_n, such as are obtained from figure 15 for use with each group of data of table 3, together with average values of i_u from table 3, thereby deriving average values of h_u. On the other hand, if suitable average values of h_u are assumed for each of the three groups in table 3, one may compute individual values of i_n for each of the thirty-one days comprising the three groups, and the values of h_u chosen must be such that, when the values of i_n are averaged for each group, these average values will agree with those required by figure 15. Comparison of the two methods of treatment will be made later, after developing the formula from which either i_n or h_u may be derived.

It was stated earlier that the relation between the air-earth current density, i, the columnar resistance, R, and the total potential between the earth and the upper conducting region, E, would be taken as

$$E = iR \tag{1}$$

The current density, i, is obtained from the total conductivity, $\lambda + + \lambda -$, multiplied by the potential-gradient, G, or

$$i = G(\lambda + + \lambda -) = G/\rho \tag{2}$$

where ρ, the resistivity, is the reciprocal of the total conductivity.

Now if we assume that the columnar resistance, R, is divided into two parts, r' and r'', and assume further that the lower part, r', is given by ρh, where h is the height of the lower region, we have

$$R = r' + r'', \text{ and } r' = \rho h \qquad (3), (4)$$

whence

$$R = \rho h + r'' \tag{5}$$

Then from (1), (2), and (5), we have

$$E = \frac{G(\rho h + r'')}{\rho} \tag{6}$$

If, now, we use the subscript n to indicate normal, least-disturbed conditions and the subscript u to represent unusual conditions, we may write for unusual conditions

$$E_u = \frac{G_u(\rho_u h_u + r_u'')}{\rho_u} \tag{7}$$

and for normal conditions

$$E_n = i_n R_n \tag{8}$$

If, further, the unusual conditions are local, or limited in horizontal extent, they are not likely to affect E, so that $E_u = E_n$, and we may then write, from (7) and (8)

$$i_n = \frac{G_u(\rho_u h_u + r_u'')}{\rho_u R_n} \tag{9}$$

Finally, adopting the view that r'' does not change when the unusual conditions occur, so that $r_u'' = r_n''$ and $h_u = h_n$, and in (9) we replace r_u'' by $R_n - \rho_n h_u$, then we obtain

$$i_n = G_u \frac{h_u}{R_n} + \frac{1}{\rho_u} - \frac{\rho_n h_u}{\rho_u R_n} \tag{10}$$

Substituting i_u for G_u/ρ_u in (10)

$$i_n = G_u h_u/R_n + i_u(1 - \rho_n h_u/R_n) \tag{11}$$

Restating (11) as an expression for h_u, we have

$$h_u = (i_n - i_u)R_n/(\rho_u - \rho_n)i_u \tag{12}$$

In computing, now, values of h_u from equation (12), for each of the three groups of data in table 3, the value of R_n is taken as 1.11×10^9 esu, a figure discussed earlier, and the value of ρ_n as 0.476×10^4 esu, this value being the reciprocal of the average value of total conductivity, 2.10×10^{-4} esu, found for least disturbed conditions in the Pacific Ocean from the table in sectior V. For i_n the three values are 11.8, 12.7, and 13.3 $\times 10^{-7}$ esu as stated on page 147. The values of h_u found from this computation for the three groups 3a, 3b, and 3c, are 1.1 km, 1.8 km, and 0.2 km, respectively. When the attempt is made to compute individual values of h_u, however, particularly for the eleven days in 3b, impossibly large values of h_u are obtained for some of the days, indicating that this method cannot be used in this detailed manner.

Equation (11), on the other hand, lends itself to the computation of i_n in a detailed manner, for the data in table 3. The thirty-one individual values of i_n in the last column of table 3 were computed from this equation. For this computation, the same values of R_n and ρ_n were used as in the preceding computation. An average value of h_u was chosen for each of the three groups, of such magnitude that, when used in the computation of the individual values of i_n, an average value of i_n was obtained for each group which closely approximated that called for in figure 15 for the proper latitude. That is, the height of the fog, mist, or haze in the atmosphere was taken as 1.0 km, 1.3 km, and 0.1 km for groups 3a, 3b, and 3c, respectively, and individual values of i_n computed, from which average values of i_n of 11.8, 12.6, and 13.3 $\times 10^{-7}$ esu were obtained for the three groups to meet the requirement of 11.8, 12.7, and 13.3 $\times 10^{-7}$ esu of figure 15. The fact that the scatter of individual values of i_n around the required average values is essentially the same as that exhibited by the day to day values in table 2 would point to the use of equation (11) as a satisfactory procedure. The differences shown between the values of h_u obtained by the two methods, namely 0.1 km, 0.5 km, and 0.1 km for the three groups, are not significant except perhaps in the case of the 0.5 km for group 3b. The scatter of the observed data in this group no doubt is responsible for divergent results from the two computations, and in this connection it would appear that the method using equation (11) gives a more reliable value of the average height, h_u, than the other.

Accepting, therefore, the results obtained with equation (11), it appears that during the hazy period between June 2 and July 2, in which interval the conductivity was less than half of normal value, the height of the haze was about 1.0 km. After the region of cold surface water was reached, with its attendant thick fog or mist, the height of the fog or mist layer was somewhat greater than that of the preceding haze layer, namely 1.3 km, until the wind freshened and changed to southwest on the fourteenth, at which time the layer became very thin, about 0.1 km. For the latter period a thin layer would be expected, since the current density was so nearly normal; the fog or mist increased the resistivity in this thin layer by about 50 per cent, but the increased columnar resistance in the layer added only about 3 per cent to the total columnar resistance, if the assumption is valid that the total potential E was from day to day the same as it would have been had not fog or mist been present.

The second period of interest is that in the Atlantic Ocean between August 10 and 25, 1928. During this period the conductivity was about half normal value, and the potential-gradient slightly lower than the average for all undisturbed values in the Atlantic, so that computed values of air-earth current density for the period had an average value of approximately half of that obtained for the remainder of the Atlantic data. The ship remained between 311° and 322° east longitude during the thirteen-day period under discussion, but sailed southward 1700 miles from 40° north down to 15° north. The daily set of observations was generally made about 18h GMT. Table 4 shows the values of the atmospheric-electric elements for August 10 to 25, and again the last column in the table contains values of current density derived on the basis that the lower layer in the atmosphere, in which the conductivity was about half normal value, had a definite vertical extent.

Table 4. Period of low values of air-earth current density in the north central Atlantic, August 10 to 15, 1928, and derived equivalent fair-weather values based on assumed height of affected region of the atmosphere

Gr. date	GMT h	G_u V/m	$\lambda_u^+ + \lambda_u^-$ in 10^{-4} esu	i_u in 10^{-7} esu	i_n in 10^{-7} esu
Aug 10	18.7	98	1.56	5.1	7.2
11	18.4	122	0.91	3.7	9.0
12	13.1	151	0.53	2.7	11.2
13	18.7	201	0.79	5.3	14.9
14	18.6	120	1.18	4.7	8.9
16	18.5	121	1.10	4.4	9.0
17	15.6	97	1.49	4.8	7.2
18	14.7	76	1.51	3.8	5.6
19	19.7	97	1.39	4.5	7.2
22	17.5	82	1.75	4.8	6.1
23	17.9	90	1.23	3.7	6.7
24	15.3	55	1.82	3.3	4.1
25	14.3	85	1.81	5.1	6.3
Mean	17.0	107	1.31	4.3	8.0

Utilizing equation (11), as before, preliminary inspection of the data indicated that the layer having higher than normal resistivity was quite thick. This was apparent from the fact that, the potential-gradient being very little different from normal, the reduced air-earth current density would be indicative of a significant change in columnar resistance of the atmosphere. Accordingly, the value of h_u was chosen such that the second term of equation (11) became zero. This is

$$1 - (\rho_n h_u / R_n) = 0 \qquad (13)$$

With the columnar resistance R taken as 1.11×10^9 esu, as before, and the values of ρ_n in this case as 0.461×10^4 esu (the average value of total conductivity over the Atlantic was found to be 2.17×10^{-4} esu for least-disturbed days on cruise VII) the value of h_u is found to be 2.7 km. In effect, the present procedure means that all the columnar resistance is confined to a height of 2.7 km, which is not true, but it may be within a reasonably good approximation of being true. The values of i_n found on this basis average 8.0×10^{-7} esu, a value close to the average of 8.7×10^{-7} esu found for all least-disturbed days over the Atlantic.

In this case, whatever may be the nature of the particles or nuclei responsible for the low air-earth current density, the region containing the particles appears to have extended vertically to a considerable distance.

The third and last group of material containing unusual values of air-earth current density was obtained between September 9 and 20, 1929, after the ship left San Francisco on the voyage to Honolulu. It will be recalled from an earlier paper in this volume that a few days after leaving San Francisco the conductivity decreased in the course of one day to about one-tenth its normal high value, and subsequent recovery to the original value required a period of ten days. The day on which the drop occurred was September 9, 1929, and the present discussion will deal only with that day. The hourly mean values of conductivity for September 9 (negative conductivity recorded on this date) have been tabulated on pages 124 and 125 in the table in section VIII, and corresponding hourly mean values of potential-gradient on pages 120 and 121 in section VII. For convenient reference the data have been reproduced in table 5 below, where it will be noted that five groups have been arranged, the first (5h to 11h GMT) representing least-disturbed or normal conditions, and the remaining four showing progressive changes in the various elements tabulated.

When the conductivity and potential-gradient data are examined together, it is clear that as the conductivity decreased through the Greenwich day, the potential-gradient increased to much higher values than would be expected on the basis of the normal universal diurnal variation. In group (1) in table 5 the potential-gradient averaged 123 volts per meter, representing least-disturbed conditions in the early hours of the Greenwich day, and the normal increase to maximum at 18 to 20 hours GMT might have been expected to give a value for those hours of perhaps 180 volts per meter instead of the 360 volts actually recorded. Air-earth current density also would have increased through the Greenwich day, had the day been normal, from 10.4×10^{-7} esu as found for the period 5 to 11 hours GMT, to perhaps 13×10^{-7} esu or more at 18 to 20 hours GMT. In table 5, under the column i_n, assumed values of "normal" current density are given for groups (2) to (5) to represent the diurnal change in this element with universal time. These values were arrived at with the help of the lowermost curve in figure 14, which gives the diurnal variation, on Greenwich time, of the air-earth current density for October and November, 1929. On that curve the average current density for the six-hour period from 5 to 11 hours, is 9.8×10^{-7} esu, which is 0.6×10^{-7} esu lower than the value found for group (1) in table 5. For groups (2) to (5) comparable values from the curve are 11.0, 12.1, 11.7, and 10.0×10^{-7} esu, respectively, and when these are adjusted upward by the difference of 0.6×10^{-7} esu found between group (1) and the curve, the best available

Table 5. Study of conspicuous change in conductivity and air-earth current density on September 9, 1929 in the Pacific Ocean

Group	GMT h	λ_n^- 10^{-4} esu	λ_n^+ (a) 10^{-4} esu	$\lambda+ + \lambda-$ 10^{-4} esu	ρ_n 10^4 esu	G_n V/m	i_n 10^{-7} esu	i_u 10^{-7} esu	h_u (b) meters
(1)	5- 6	1.20	1.32	2.52	0.397	125	10.5	.....	
	6- 7	1.25	1.38	2.63	0.380	110	9.4	.....	
	7- 8	1.25	1.38	2.63	0.380	119	10.2	.....	
	8- 9	1.20	1.32	2.52	0.397	130	10.9	.....	
	9-10	1.20	1.32	2.52	0.397	128	10.8	.....	
	10-11	1.20	1.32	2.52	0.397	128	10.8	.....	
Mean		1.22	1.34	2.56	0.391	123	10.4	.....	......
		λ_u^- 10^{-4} esu	λ_u^+ 10^{-4} esu	$\lambda+ + \lambda-$ 10^{-4} esu	ρ_u 10^4 esu	G_u V/M			
(2)	11-12	0.77	0.85	1.62	0.617	188	.....	10.2	
	12-13	0.79	0.87	1.66	0.602	180	.....	10.0	
	13-14	0.77	0.85	1.62	0.617	188	.....	10.2	
Mean		0.78	0.86	1.63	0.612	185	11.6(c)	10.1	750
(3)	14-15	0.38	0.42	0.80	1.25	273	.....	7.3	
	15-16	0.29	0.32	0.61	1.64	307	.....	6.2	
	16-17	0.22	0.24	0.46	2.17	319	.....	4.9	
Mean		0.30	0.33	0.62	1.69	300	12.7(c)	6.1	925
(4)	19-20	0.14	0.16	0.30	3.33	362	.....	3.6	
	20-21	0.14	0.16	0.30	3.33	374	.....	3.7	
	21-22	0.14	0.16	0.30	3.33	357	.....	3.6	
Mean		0.14	0.16	0.30	3.33	364	12.3(c)	3.6	915
(5)	22-23	0.12	0.14	0.26	3.85	299	.....	2.6	
	23-24	0.14	0.16	0.30	3.33	284	.....	2.8	
Mean		0.13	0.15	0.28	3.59	292	10.6(c)	2.7	1011

(a) $\lambda + = 1.10\lambda -$. (b) $h_u = (i_n - i_u)R_n/i_u(\rho_u - \rho_n)$, where $R_n = 1.11 \times 10^9$ esu, and $\rho_u = 0.391 \times 10^4$ esu. (c) Values for i_n assumed from 11h to 24h, in accordance with universal-time diurnal-variation characteristics of figure 14.

approximations to normal values become 11.6, 12.7, 12.3, and 10.6. These values of i_n may be taken with some confidence as correctly representing the current-density values that would have existed on this occasion had not a disturbing element been present. A period of hours rather than days is involved here, unlike the situation in the previously discussed cases, making it possible to establish the values of i_n with reasonable accuracy. In this case, then, the values of i_n for groups (2) to (5) in table 5 are accepted as known, and the computation of appropriate values of h_u for these groups is readily accomplished from equation (12). In the computation, the value of ρ_n was taken as 0.39×10^4 esu, as obtained from group (1) in table 5, and R_n was taken, as before, as 1.11×10^9 esu. The computed values of h_u are shown in the last column of table 5.

Within each group, except (3), in table 5, a certain stability of values of both conductivity and potential-gradient will be noted, as if the changes proceeded in definite "steps" through the day. Group (3), the exception, shows continuous change from hour to hour, but the three hours are nevertheless treated as a group. As only negative conductivity was recorded, values of positive and total conductivity for table 5 were computed on the basis that $\lambda + / \lambda - = 1.10$.

The values of h_u for groups (2) to (5) give the interesting result that the thickness of the layer in which the disturbing element existed was, except in the first three hours, about 1 km, although there was continuous change of potential-gradient and conductivity over a much longer period. In the first three hours, however, the height appears to have been only seven hundred and fifty meters, and, if the first hour only is considered and the value of i_n for that hour is taken as 11.3×10^{-7} esu, the value of h_u is found to be about five hundred meters. Thus, a wedge-shaped layer appears to have been entered on this occasion, with a "front" five hundred meters high. This front was entered suddenly, because the photographic records of both potential-gradient and conductivity show that the change from normal to disturbed conditions took place in only three or four minutes, commencing at 11h 05m and ending at 11h 08m or 09m. At 11h 05m both conductivity and potential-gradient had values very close to the average given in table 5 for 10h-11h, and at 11h 09m both had arrived at the values given as the average for 11h-12h. Stable conditions existed before the disturbed region was entered, and were established again, but on a different basis, four minutes later. During the next three hours stable conditions existed within the layer but the layer thickness changed from five hundred to one thousand meters and then, from 12h to 24h, conditions within the layer changed while the height remained essentially constant. At 24h, the columnar resistance, R, had become 4.31×10^9 esu, or about fourfold as great as that prevailing before 11h.

All through the following day, September 10, conductivity remained at approximately the same value as that found for the last two hours of September 9, and the potential-gradient also remained essentially at the value established at that time, so that a disturbed lower layer of about 1 km thickness is indicated for all of the tenth. When the disturbed region was entered at 11h GMT or 2h LMT on the ninth, the ship was between five and six hundred miles southwest of San Francisco, and in the following ten days or more during which the disturbed region appeared to persist, approximately one thousand miles were traversed. As the ship was sailing in a generally southwest direction the extent of the disturbed region in that direction was one thousand miles; what width the region might have had at right angles to the course cannot be stated, but it is possible that it may have been narrow, perhaps confined only to the width of the steamer lane of the ships regularly plying between San Francisco and Honolulu. Smoke from the ships might be the disturbing factor in this region, although the measurements of condensation nuclei on the Carnegie did not show particularly high concentrations, as indicated by the nuclei data in section V.

In conclusion, one may summarize the preceding discussion of air-earth current density data derived from the atmospheric-electric measurements on cruise VII of the Carnegie, as follows: (1) Air-earth current density varies through the day according to universal time, with minimum values on normal, least-disturbed days not infrequently as low as 5×10^{-7} esu and maximum values as high as 15×10^{-7} esu; (2) when the current density is affected by the presence of a disturbing element in the lower atmosphere, the latter may exist in a layer adjacent to the earth's surface only a few meters thick or as much as a few kilometers thick, and the thickness together with the concentration of disturbing material in the layer, may be such as to reduce the current density to only a small fraction of its normal value; (3) the horizontal extent of the layer containing the disturbing element may be hundreds of miles; (4) the disturbed condition may manifest itself as mist, fog, or haze, but may also have no visible manifestation and yet be equally effective in producing large departures from normal in the atmospheric-electric elements; (5) passage from a normal, least-disturbed region into a disturbed region may be very abrupt.

LITERATURE CITED

1. Gish, O. H. 1939. Terrestrial magnetism and electricity. Physics of the earth, vol. 8, pp. 149-230.
2. Wait, G. R., and H. U. Sverdrup. 1927. Preliminary note on electromotive forces possibly produced by the earth's rotating magnetic field and on observed diurnal variation of the atmospheric potential-gradient. Terr. Mag., vol. 32, pp. 73-83.
3. Ault, J. P. 1945. The work of the Carnegie and suggestions for future scientific cruises. Oceanogr.-IV. Scientific results of cruise VII of the Carnegie during 1928-29 under command of Captain J. P. Ault, CIW Pub. No. 571, pp. 1-17.
4. Gish, O. H. 1942. Further evidence of a latitude-effect in potential-gradient. Terr. Mag., vol. 47, pp. 323-324.
5. Wait, G. R. 1942. Electrical resistance of a vertical column of air over Watheroo (Western Australia) and over Huancayo (Peru). Terr. Mag., vol. 47, pp. 243-249.

During cruise VII of the Carnegie, 755 sets of observations were made with an Aitken nuclei counter. Generally a single set was made each day except when a diurnal-variation series was started. Occasionally several sets were made on some particular day, usually to test some point that was raised in the observer's mind at the time. Of the diurnal-variation series attempted, sixteen were completed or essentially completed during the cruise. Excluding all sets of each diurnal-variation series except the first and last, there was a total of 365 sets of nuclei observations. The values of nuclei content in the 365 sets were distributed as shown in table 1 below. It is thus seen that the majority of the measurements fall into the lower nuclei content groups. On 144 occasions the nuclei were found to be less than 1000 per cc, while on only 15 occasions did the nuclei rise above 10,000 per cc. Nearly three-fourths of all the observations listed in table 1 gave a nuclei content less than 2500 per cc. Thus it is seen that, contrary to what is so frequently found over land, the nuclei over the ocean generally are few in number. The nuclei content varied considerably from one leg to another of the cruise. This fact is brought out in table 2 (1).

Table 1. Distribution of values of nuclei content for cruise VII

Nuclei per cc	No. of sets	Nuclei per cc	No. of sets
100 - 500	72	3500 - 4000	8
500 - 1000	72	4000 - 4500	13
1000 - 1500	42	4500 - 5000	7
1500 - 2000	48	5000 - 5500	2
2000 - 2500	34	5500 - 6000	3
2500 - 3000	16	6000 - 10000	10
3000 - 3500	23	10000 - 20000	14
		20000 - 30000	1

The data in table 2 include all sets in the diurnal-variation series as well as those taken once or only a few times each day. In obtaining the means in the table, six sets taken on July 8 and 9, 1928, at the mouth of the Elbe River, were excluded from the Hamburg-Reykjavik leg of the cruise. The mean of the six excluded sets is 8910. Had they been included with the other values, the mean for this leg would have been increased to 3720 and the average number of nuclei per cc for the five largest values would have been increased to 10,570.

That large values of nuclei were found at the mouth of the Elbe emphasizes the possibility that an industrial region on land can affect the ocean values of nuclei for a considerable distance from shore. This point is still further emphasized by observations taken on the Carnegie as the ship receded from the vicinity of Europe. A map showing this leg of the cruise is given in figure 16. The map gives the number of nuclei per cc measured at various localities, with arrows indicating the direction and force of the wind at each locality. A number representing wind force on the conventional Beaufort scale is inset in the circle attached at the end of each arrow. It is seen that, as the ship left the vicinity of Europe, the nuclei content of the air gradually diminished. It is apparent that even at considerable distances from land, during those occasions when the wind blew from the direction of land on which there was considerable industrial activity, the ocean values are unusually large.

In the Pacific Ocean the nuclei content of the air increased to considerable values shortly before the ship

Table 2. Nuclei content of the air over the oceans from observations on the Carnegie between May 1928 to November 1929

Ocean	Leg of cruise	Dates	No. of sets	Average nuclei per cc: 5 largest values	5 smallest values	All values
Atlantic	Newport News - Plymouth	May 10 - June 8	25	2940	640	1460
	Plymouth - Hamburg	June 18 - June 22	...	......	.....	......
	Hamburg - Reykjavik	July 7 - July 20	20	5160	610	2300
	Reykjavik - Barbados	July 27 - Sep. 16	54	3780	280	1070
	Barbados - Balboa	Oct. 1 - Oct. 11	21	2510	360	1180
	Means		120	3600	470	1370
Pacific	Balboa - Easter Island	Oct. 25 - Dec. 6	123	830	130	382
	Easter Island - Callao	Dec. 12 - Jan. 14	24	450	120	238
	Callao - Papeete	Feb. 5 - Mar. 13	112	4560	350	2170
	Papeete - Apia	Mar. 20 - Apr. 1	30	3260	620	1700
	Apia - Guam	Apr. 20 - May 20	93	10800	450	2910
	Guam - Yokohama	May 25 - June 6	37	22550	4570	13610
	Yokohama - San Francisco	June 24 - July 28	74	4450	700	2490
	San Francisco - Honolulu	Sep. 3 - Sep. 23	18	5670	1380	2850
	Honolulu - Pago Pago	Oct. 2 - Nov. 18	124	2250	310	1100
	Means		635	6090	960	2350
Means for whole cruise			755	5320	810	2200

reached Guam from Apia, and remained so throughout most of the next leg of the cruise. It is of interest to note that during this part of the cruise, the vessel was in the vicinity of volcanos which might be expected to contribute appreciably to the nuclei content of the atmosphere. It seems probable that the unusually high nuclei content of the atmosphere found in this locality was produced by the action of volcanos in the region.

Of the sixteen complete or nearly complete diurnal-variation series obtained during the cruise, none was obtained in the Atlantic. The first series was made between Balboa and Easter Island, on November 13 - 14, 1928, and three additional series were obtained on the same leg of the cruise. Three series were completed between Callao and Papeete, and three between Apia and Guam, one between Guam and Yokohama, two between Yokohama and San Francisco, and three between Honolulu and Pago Pago. It would seem desirable to determine if there is any systematic variation through the day in the nuclei content of the atmosphere over the ocean, when considered either on local or on universal time.

In an effort to ascertain whether any systematic variation exists, the sixteen diurnal-variation series were arbitrarily separated into four groups. Each day was arranged according to local time and the hourly means were obtained for each group. The four diurnal-variation curves are shown in figure 17A. It is easily seen that the four groups are not systematic, that is, similar in the type of variation they display. It is concluded, therefore, that over the ocean the nuclei content of the atmosphere does not vary systematically through the day according to local time. In a similar manner, each day in the various groups was arranged according to Greenwich time and the hourly means were obtained for each group. The four diurnal-variation curves thus obtained are shown in figure 17B. It is seen that in this case, likewise, there is no systematic diurnal variation in the nuclei content of the atmosphere over the oceans according to universal time. Any variation through the day that has been observed, therefore, must have been of accidental nature.

Out of 755 sets of condensation nuclei shown in table 2, there were 225 sets which were made simultaneously or nearly simultaneously with measurements of either positive or negative small-ion content of the atmosphere. These 225 sets of simultaneous data were grouped according to the leg of the cruise, and the mean value for each leg was obtained. For the Atlantic 44 sets were available, while for the Pacific there were 181 sets. A summary of the results is given in table 3. The mean values for all 225 sets are 1776, 522, and 422 per cc, respectively, for the nuclei, the positive ions, and the negative ions. How "ω" was derived will be seen in what follows.

The small ions of both signs should be more numerous than indicated in table 3 if they are being destroyed only through recombinations with each other. In this case, assuming equilibrium conditions to exist, the number n of small ions of either sign per cc, positive and negative ions being assumed equally numerous, can be computed through the well-known equation,

$$q = \alpha n^2 \tag{1}$$

where q is the rate of production of ion pairs and α is the recombination coefficient for small ions. The ionization over the oceans is due essentially to cosmic rays, hence the mean value of q may be taken as about 1.4 ion pairs per cc per second. A generally accepted value of α is 1.6×10^{-6}. Using these quantities, the value of n is found to be 935. To account for the observed smaller values of n, it is necessary to assume that the small ions are being destroyed by some additional process besides recombination. Condensation nuclei are known to destroy the small ions by combining with them. When combining occurs, the uncharged nucleus converts the small ion into a large ion while the large ion neutralizes the charge on the small ion. Assuming that the reduced number of small ions in the air over the oceans is due to the presence of condensation nuclei, it is possible to compute the rate at which the nuclei combine with the small ions and, further, on the basis of certain assumptions, to compute the number of large ions per unit volume in the

Table 3. Derived values of combination coefficient "ω" based on simultaneous values of nuclei and small ions for all legs of cruise VII

Ocean	Leg no.	Leg of cruise	Dates	No. of sets	Mean per cc			ω in 10^{-6} units
					N_a	n_+	n_-	
Atlantic	1	Newport News - Plymouth	May 10 - June 8	5	1390	413	298	2.0
	2	Plymouth - Hamburg	June 18 - June 22	0	......	....	....	....
	3	Hamburg - Reykjavik	July 7 - July 20	7	2839	495	389	0.7
	4	Reykjavik - Barbados	July 27 - Sep. 16	26	1019	576	461	1.4
	5	Barbados - Balboa	Oct. 1 - Oct. 11	6	532	635	490	2.2
Pacific	6	Balboa - Easter Island	Oct. 25 - Dec. 6	12	290	491	373	7.2
	7	Easter Island - Callao	Dec. 12.- Jan. 14	17	204	576	447	7.4
	8	Callao - Papeete	Feb. 5 - Mar. 13	33	2614	503	409	0.8
	9	Papeete - Apia	Mar. 20 - Apr. 1	10	2155	517	454	0.9
	10	Apia - Guam	Apr. 20 - May 20	23	2556	615	545	0.5
	11	Guam - Yokohama	May 25 - June 6	11	10354	507	406	0.2
	12	Yokohama - San Francisco	June 24 - July 28	17	3263	500	385	0.6
	13	San Francisco - Honolulu	Sep. 3 - Sep. 23	18	2846	386	308	1.1
	14	Honolulu - Pago Pago	Oct. 2 - Nov. 18	40	1289	513	417	1.5
Total or means				225	1776	522	422	....

air over the ocean. When nuclei and large ions are present, it has been shown that for equilibrium conditions the equation

$$q = \alpha n^2 + \eta_0 N_0 n + \eta_1 N n \qquad (2)$$

applies where N_0 represents the number of uncharged nuclei per cc, N represents the number of large ions of one sign (positive and negative ions assumed to be equally numerous), n represents, as stated above, the number of small ions of one sign per cc (positive and negative also assumed to be equally numerous), η_0 and η_1 are the combination coefficients between the small ions and the uncharged and charged nuclei, respectively, and α is as defined above. This equation reduces to

$$q = \alpha n^2 + 2\eta_1 N n \qquad (3)$$

and finally to

$$q = \alpha n^2 + \omega N_A n \qquad (4)$$

(2) where N_A is the total number of condensation nuclei, charged and uncharged, per cc. The value of the combination coefficient ω between the small ions and the nuclei is given in the following relation

$$\omega = \eta_1[2/(R + 2)] \qquad (5)$$

where

$$R = N_0/N = \eta_1/\eta_0 \qquad (6)$$

From equation (4), assuming q = 1.4 I, where I is the number of ion pairs per cc in the atmosphere, $\alpha = 1.6 \times 10^{-6}$, and using $N_A = 1776$ and n = 522 from table 3, it is found that the value of ω comes out to be 1.0×10^{-6}. From (5), assuming a value of 5×10^{-6} for η_1, (3) the value of R is 8 and, since $N_0 + 2N = N_A$, $N_0/N_A = 0.80$. This value of N_0/N_A is only slightly greater than the value found for Washington (4), the latter being 0.75. The value of N/N_A accordingly comes out as 0.1 from which one would deduce a value of 178 per cc for the number of large ions of one sign over the ocean.

The cause of ionization over the ocean has been discussed by Swann (5). His discussion involved a question concerning the large-ion content of the air over the oceans. He derived a relation between the ratio of ionization over land and ocean and the ratio of ion content over land and ocean, which was expressed in the following equation

$$(N_L + n_L)/n_S = (q_L/q_S)^{1/2} \qquad (7)$$

where the subscripts L and S refer to land and ocean values, respectively, and the other notations are as given previously. In arriving at this relation it was assumed that there are no large ions in the air over the ocean and that the value of α is the same over the ocean as that over land. It was further assumed that $n_S = n_L$, and that $q_S = 1.6$ I and $q_L = 6.1$ I. The number of large ions per cc over land, on this basis, was found to be about equal to the number of small ions over land, that is, $N_L = n_L$. In reconsidering this matter, on the basis of equation (3), assuming that $2\eta_1 = 6\alpha$ and that there are no large ions over the ocean, it is found that

$$(n_L^2 + 6N_L n_L)/n_S^2 = q_L/q_S \qquad (8)$$

In applying this equation, it seems necessary, in view of the large variation in the values of the elements n_L, N_L, and q_L from place to place, to choose values appropriate to some particular land station. At Washington, D. C. n_L and N_L have been measured over a long interval of time. The value of q_L has been closely estimated from ionization measurements with a thin-walled chamber. For this station the average value of n_L may be taken as about one-third the average value of n_S, whereas the average value of q_L appears to be about seven times that of q_S. From these values it is found that the number of large ions in the air at Washington is about ten times the number of small ions at this station. This ratio, though large compared with the value obtained by Swann, is less than one-half the ratio actually found, on the average, to exist at this station. During the warm season (6) of the year, $n_L = 198$, $N_L = 4010$, or $N_L/n_L = 20.1$, while during the cold season of the year, $n_L = 169$, $N_L = 6010$, or a ratio of N_L to n_L of 35.6. The above values were obtained in measurements from October 1932 to September 1933 inclusive.

Since it was found, from estimates made earlier in this paper, that the large ions over the ocean are not absent but probably average around 178, it seems necessary to reconsider the whole matter of ionization over the ocean and allow for the presence of such large ions. Equation (3) may be assumed to hold over land so that

$$q_L = \alpha n_L + 2\,\eta_L N_L n_L \qquad (9)$$

and, in a similar manner over the ocean,

$$q_S = \alpha n_S + 2\,\eta_S N_S n_S \qquad (10)$$

To simplify these equations, let us assume that $2\eta_L = 6\alpha = 2\eta_S$, that $n_S = 3n_L = 3N_S$, and that $q_L = 7q_S$; then

$$q_L/q_S = (n_L^2 + 6n_L N_L)/(n_S^2 + 6n_S N_S) \qquad (11)$$

from which it follows that $N_L = 31\, n_L$. This ratio of the number of large ions to the number of small ions at Washington is more in keeping with that found, the average ratio from the two seasonal values given above being about 28. The estimate of the value of each element involved, including that of the large-ion content over the ocean, appears to have been reasonably correct; otherwise the resulting check would not have been so favorable.

On the basis of the mean value of condensation nuclei and of small-ion content of the air it is possible, as pointed out in the previous paragraph, satisfactorily to account for a reduced number of small ions through their destruction by the condensation nuclei. When, however, one examines the variation in the nuclei content and the corresponding ion content from leg to leg of the various cruises, such an explanation is not so satisfactory. From the results given in table 3 it is seen that the average nuclei content of the air varies considerably from one leg of the cruise to another. The small-ion content, on the other hand, remains much more nearly constant. This suggests that the nuclei were not always equally effective in the destruction of the small ions. It accordingly appears that, on the average, as the nuclei content of the air increases, the average effectiveness of a nucleus for destroying a small ion diminishes. For a quantitative test of the average effectiveness of the nucleus in destroying a small ion, the value of ω has been calculated. The resulting values are tabulated in the last column of table 3, each value being obtained through the application of equation (4), using mean values of nuclei and positive small-ion content of the air for each leg. The values of ω are seen to vary from about 7 to 0.2×10^{-6}, corresponding to the lowest and the highest nuclei content respectively of the air. It might be pointed out in passing that a similar variation in the value of ω was obtained by Torreson (7) from data obtained at the Huancayo Magnetic Observatory. In that case, however, there was a much greater spread in both the nuclei and the small-ion content of the air. The variation in the value of ω was explained by Torreson as due to a change in size of the nucleus.

The value of ω calculated for the two legs, Balboa to Easter Island and Easter Island to Callao, is much too large if the value of $2\eta_1$ is taken as equal to 10×10^{-6} (3). A value of ω even as great as 5×10^{-6} would require that all nuclei be charged. The large values deduced for ω for these two legs may be the result of incorrect values of nuclei content, as the nuclei counter may not have been functioning properly during that part of the cruise. The receiver of the instrument fell apart from the pump during observations on December 18, a few days after leaving Easter Island. Repairs were soon made and observations continued for the remainder of the leg. At Callao another instrument became available and was used for all subsequent work. The measurements with the second instrument gave noticeably higher values than those with the original instrument, in the ocean region near Callao. The mean of the first ten sets after leaving Callao was 757, whereas the mean of the last ten sets before arriving at Callao (made after December 18) was only 201. It seems probable that the original instrument was making too small a count not only after December 18, but for some time previous to this date, possibly as early as the beginning of November. If one eliminates the data between Balboa and Callao, thus eliminating the impossible values of ω, then the mean nuclei content of the air for the entire cruise, as shown in table 3 will be increased to 2000, while the values of the positive and negative small-ion content of the air will remain practically unchanged. This adjustment would diminish the average values of ω for cruise VII (1.0×10^{-6}) by 11 per cent, and the high values of ω for legs 6 and 7 being thus omitted, the range in values of ω for other legs of the cruise would be 2 to 0.2×10^{-6}.

The results on condensation nuclei and small-ion content of the atmosphere over the oceans may be summarized as follows:

1. The average nuclei content over the oceans (about 2000 per cc) is appreciably smaller than that for the land stations where this element has been measured.

2. There is no systematic diurnal variation in the number of nuclei over the ocean, according to either local or Greenwich time.

3. The average nuclei content of the air appears to be sufficiently great to reduce the average small-ion content by about 44 per cent.

4. The detailed relation between nuclei content and the small-ion content of the air over the oceans found in cruise VII measurements is accounted for, assuming that the usually accepted equilibrium equation holds, through a change in the efficiency with which a nucleus combines with a small ion. A decrease in efficiency accompanies an increase in the nuclei content of the air.

5. Calculations based on the equilibrium equations indicate that, in the air over the oceans, there are on the average, about 200 large ions of each sign per cc.

LITERATURE CITED

1. Wait, G. R. 1930-1931. The number of Aitken nuclei over the Atlantic and Pacific oceans as determined aboard the Carnegie during 1928-1929. Carnegie Inst. Wash. Year Book 30, p. 366.
2. Nolan, J. J., R. K. Boylan, and G. P. deSachy. 1925. The equilibrium of ionization in the atmosphere. Proc. R. Irish Acad., vol. 37, sec. A, pp. 1-12.
   Wait, G. R. 1931. Diurnal variation of concentration of condensation-nuclei and of certain atmospheric-electric elements. Terr. Mag., vol. 36, pp. 111-131.
   Gish, O. H. 1939. Terrestrial magnetism and electricity. Physics of the earth--VIII, pp. 183, 186.
3. Harper, W. R. 1934. On the theory of the combination coefficients for large ions and for uncharged particles at any pressure. Phil. Mag., vol. 18, pp. 97-113; On the theory of the combination coefficients for large ions: A correction. 1935, vol. 20, p. 740.
4. Torreson, O. W. and G. R. Wait. 1934. Measurements of total nuclei, of uncharged nuclei, and of large ions in the free atmosphere at Washington, D. C. Terr. Mag., vol. 39, pp. 47-64.
   Sherman, K. L. 1940. Total and uncharged nuclei at Washington, D. C. Terr. Mag., vol. 45, pp. 191-204.
5. Swann, W. F. G. 1917. Causes of atmospheric ionization over the ocean. Researches of the Department of Terrestrial Magnetism, vol. 3, pp. 414-415.
6. Wait, G. R. and O. W. Torreson. 1934. The large-ion and small-ion content of the atmosphere at Washington, D. C. Terr. Mag., vol. 39, pp. 111-119.
7. Torreson, O. W. 1939. Condensation nuclei in the atmosphere at Huancayo Magnetic Observatory, Huancayo, Peru, and their relation to meteorological observations. Terr. Mag., vol. 44, pp. 59-74.

NOTE ON PENETRATING RADIATION MEASUREMENTS OF THE CARNEGIE'S SEVENTH CRUISE

Measurements of penetrating radiation, or cosmic rays, were made regularly on cruise VII with apparatus no. 1 mounted in the atmospheric-electric house. The apparatus and the observational procedure have been discussed in section II, pages 13 to 15. Apparatus no. 1 was used also on earlier cruises of the Carnegie, but foı the seventh cruise was improved in several respects, the most important improvement being that made to the "balancing condenser" (page 13). Although more than three hundred measurements of penetrating radiation were made on each of cruises IV and VI, accurate values of penetrating radiation itself, in terms of ion-pairs per cc per second in the free atmosphere, were not obtained, owing to uncertainty as to the amount of "residual" ionization of the apparatus. From study of both sets of data, Mauchly (1) estimated the residual ionization to be about 2 ion-pairs per cc, and it was hoped that on cruise VII a more accurate value could be determined.

To determine the residual ionization on cruise VII, a second apparatus, small and portable, designed by Dr. Kolhörster and numbered 5503, was supplied to the Carnegie at Hamburg, Germany, in July 1928. This apparatus was so designed that its residual ionization could be determined by immersion in a sufficient depth of water, and, having such a determination, comparative measurements between apparatus 1 and apparatus 5503 would be expected to yield values of residual ionization for no. 1. The progress reports in section III go far to explain why this expectation was not realized; difficulties were constantly arising with apparatus 5503, the chief difficulty being that of displacement of the "charging arm" within the chamber of the apparatus, which affected the constants and operability of the instrument. The final result of much instrumental adjustment and manipulation, and several intercomparisons, was abandonment of the work with apparatus 5503, so that satisfactory determination of the residual ionization of apparatus 1 was not obtained.

Some indication, nevertheless, may be obtained of the magnitude of the residual ionization from the very earliest intercomparison observations between no. 5503 and no. 1 if, as seems probable, instrumental difficulties had not yet developed in the first two weeks after no. 5503 was received. The Carnegie left Hamburg on July 7 and arrived at Reykjavik July 20; on each of eight days from July 11 to 18, inclusive, a daily intercomparison was made and the values of R (ion-pairs produced per cc per second inside the chamber of the apparatus) for the two instruments show reasonably consistent differences from day to day. The data are shown in table 1.

When apparatus 5503 was supplied to the Carnegie at Hamburg, Dr. Kolhörster gave the value of residual ionization of that instrument as 1.3 ion-pairs per cc per second. This figure had to be corrected later to 1.6 ion-pairs when he corrected the value of capacitance of the apparatus by a factor of 1.243.

With the residual ionization of 1.6 ion-pairs per cc per second for apparatus 5503 and a difference between no. 1 and no. 5503 of -0.1 ion-pairs, the value of the residual ionization for apparatus 1 appears to be 1.5 ion-pairs per cc per second. This result will be seen to be a satisfactory value, when the penetrating radiation data for cruise VII are examined.

Table 1. Intercomparison observations with Carnegie penetrating radiation apparatus no. 1 and Kolhörster apparatus no. 5503, from July 11 to 18, 1928

Date 1928	GMT h m	Ion-pairs per cc per sec PR1	5503	Difference
July 11	10 46	2.71	2.84	-0.13
12	9 45	2.97	2.95	+0.02
13	9 43	2.94	3.06	-0.12
14	12 10	2.41	2.34	+0.07
15	17 56	3.30	3.87	-0.57
16	10 31	3.14	3.29	-0.15
17	10 04	3.30	3.50	-0.20
18	12 49	3.06	2.84	+0.22
Means		2.98	3.09	-0.11

The observations of penetrating radiation, or cosmic rays, made on cruise VII are tabulated in section IV, where 368 values are given. Each value is the result of approximately one hour of measurement with apparatus 1, usually only one measurement being made each day in midafternoon, the time of measurement being made to coincide as closely as possible with the time of observation of other atmospheric-electric elements. On a few occasions several measurements of penetrating radiation were made on the same day; all values obtained on these occasions are given in section IV.

The grand average value for the 368 values is 2.8 ion-pairs per cc per second, and when a residual ionization of 1.5 pairs is deducted, the value of 1.3 ion-pairs per cc per second produced by cosmic rays in the atmosphere near the earth's surface is in good agreement with the now generally accepted value.

When the observations are grouped according to geographic latitude there is some indication that for the northern hemisphere the values in high latitudes are larger than the values obtained in equatorial regions, but the results for the southern hemisphere do not give the same indication, at least to latitudes as high as 40° south. These remarks are based on the data presented in table 2, where the average value is given for each group of penetrating radiation measurements made in each 10-degree latitude belt between 60° north and 40° south. The number of measurements in each group is also indicated.

When the Atlantic Ocean data are regrouped under only two latitude ranges, namely, 0° to 30° north, and 30° to 64° north, the average values of penetrating radiation for these groups become 2.61 and 2.94 ion-pairs, respectively, the value for high latitudes being 12 per cent greater than that for low latitudes. When the data for the northern hemisphere of the Pacific Ocean are regrouped similarly, the high latitude value of 3.02 ion-pairs is found to be 4 per cent greater than the value of 2.89 for low latitudes. For the southern latitude data in the Pacific Ocean, on the other hand, a value of 2.7 ion-pairs per cc per second satisfactorily represents the entire range of latitude in which measurements were made, namely 0° to 40°.4 south. Subtracting the residual, 1.5 ion-pairs, from the various values just given, high northern latitudes give values of 1.4 or 1.5 ion-pairs, low latitudes give values of 1.1 to 1.4 ion-pairs, and southern latitudes a value of 1.2 ion-pairs per cc per second for the free atmosphere near the ocean surface. These values will be recognized as in satisfactory agreement with the work of other investigators in cosmic rays.

In tables 3 and 4 the distribution of penetrating radiation values is shown for the Atlantic and Pacific oceans, respectively. In both tables the values fall chiefly in the range of 2.40 to 3.20; in table 3 the values in this range are 77 per cent of the total, and in table 4 they are 93 per cent. The greater scatter of data for the Atlantic Ocean may be due to the fact that the work in that ocean was done in the early part of the cruise when observational procedures perhaps were not so well established as later. For the Pacific Ocean data 75 per cent, or three out of every four values, lie within the narrow range of 2.60 to 3.10 ion-pairs produced in the instrument per cc per second, for which corresponding values of ion production in the atmosphere would be 1.1 to 1.6 pairs per cc per second. These values, and others given earlier in this paper as representing the rate of production of ions in the free atmosphere, are of acceptable magnitude, indicating that the value of residual ionization of 1.5 ion-pairs per cc per second for apparatus 1, although derived from few data, is close to, if not precisely the correct value.

Table 2. Penetrating radiation measurements of cruise VII in the Atlantic and Pacific oceans, grouped according to geographic latitude

Ocean	60.0-64.1 N	50.0-59.9 N	40.0-49.9 N	30.0-39.9 N	20.0-29.9 N	10.0-19.9 N	0.0-9.9 N	0.0-9.9 S	10.0-19.9 S	20.0-29.9 S	30.0-40.4 S
	R[a]	R	R	R	R	R	R	R	R	R	R
Atlantic	2.96	2.80	3.02	2.93	2.32	2.66	2.31	.....	.....	.....	.....
	(11)[b]	(11)	(15)	(7)	(3)	(42)	(3)	.....	.....	.....	.....
Pacific	.....	3.05	3.01	3.01	2.82	2.91	2.96	2.77	2.75	2.71	2.65
	.....	(6)	(25)	(32)	(34)	(24)	(28)	(25)	(61)	(14)	(27)

[a] R = ion-pairs produced in apparatus per cc per second. [b] Numbers in parentheses indicate number of observations in each group.

Table 3. Distribution of Atlantic Ocean values of penetrating radiation from cruise VII for different latitude belts

R ion-pairs per cc per second	Latitude belts							Total
	60.0-64.1 N	50.0-59.9 N	40.0-49.9 N	30.0-39.9 N	20.0-29.9 N	10.0-19.9 N	0.0-9.9 N	
2.00	..	..	..	1	..	..	..	1
2.00-2.09	..	..	..	..	1	..	1	2
2.10-2.19	..	..	..	..	1	1	..	2
2.20-2.29	..	..	..	..	..	1	1	2
2.30-2.39	..	1	..	..	..	..	..	1
2.40-2.49	1	1	2	2	..	9	..	15
2.50-2.59	..	1	1	..	..	7	..	9
2.60-2.69	..	1	2	..	..	7	1	11
2.70-2.79	3	1	1	2	1	4	..	12
2.80-2.89	..	2	1	..	..	5	..	8
2.90-2.99	2	1	1	..	..	6	..	10
3.00-3.09	1	1	1	..	..	2	..	5
3.10-3.19	1	..	..	..	..	..	..	1
3.20-3.29	1	2	1	..	..	..	..	4
3.30-3.39	2	..	..	..	..	..	..	2
3.40-3.49	..	..	2	..	..	..	..	2
3.50-3.59	..	..	..	..	..	..	..	..
3.60-3.69	..	..	3	1	..	..	..	4
3.69	..	..	..	1	..	..	..	1

Table 4. Distribution of Pacific Ocean values of penetrating radiation from cruise VII for different latitude belts

R ion-pairs per cc per second	Latitude belts										Total
	50.0-59.9 N	40.0-49.9 N	30.0-39.9 N	20.0-29.9 N	10.0-19.9 N	0.0-9.9 N	0.0-9.9 S	10.0-19.9 S	20.0-29.9 S	30.0-40.4 S	
2.00	..	..	..	..	..	..	..	..	..	1	1
2.00-2.09	..	..	..	..	..	..	..	..	..	..	...
2.10-2.19	..	..	..	..	..	..	..	..	..	..	...
2.20-2.29	..	..	..	..	..	..	..	1	..	..	1
2.30-2.39	..	..	..	1	..	1	..	..	1	..	3
2.40-2.49	..	..	1	1	1	..	..	4	1	2	10
2.50-2.59	..	..	1	3	1	..	2	4	2	4	17
2.60-2.69	..	..	2	3	3	7	10	8	3	9	45
2.70-2.79	..	..	1	5	2	4	6	18	2	7	45
2.80-2.89	..	2	3	9	1	2	1	16	3	3	40
2.90-2.99	1	10	6	5	7	3	5	8	..	1	46
3.00-3.09	3	7	9	4	5	3	..	2	..	..	33
3.10-3.19	2	4	6	3	3	1	..	..	2	..	21
3.20-3.29	..	1	..	..	1	2	..	..	..	..	4
3.30-3.39	..	1	1	..	..	2	..	..	..	..	4
3.40-3.49	..	..	..	..	..	..	..	..	..	..	...
3.50-3.59	..	..	..	..	..	1	..	..	..	..	1
3.60-3.69	..	..	1	..	..	1	1	..	..	..	3
3.69	..	..	1	..	..	1	..	..	..	..	2

FIGURES 1 - 17

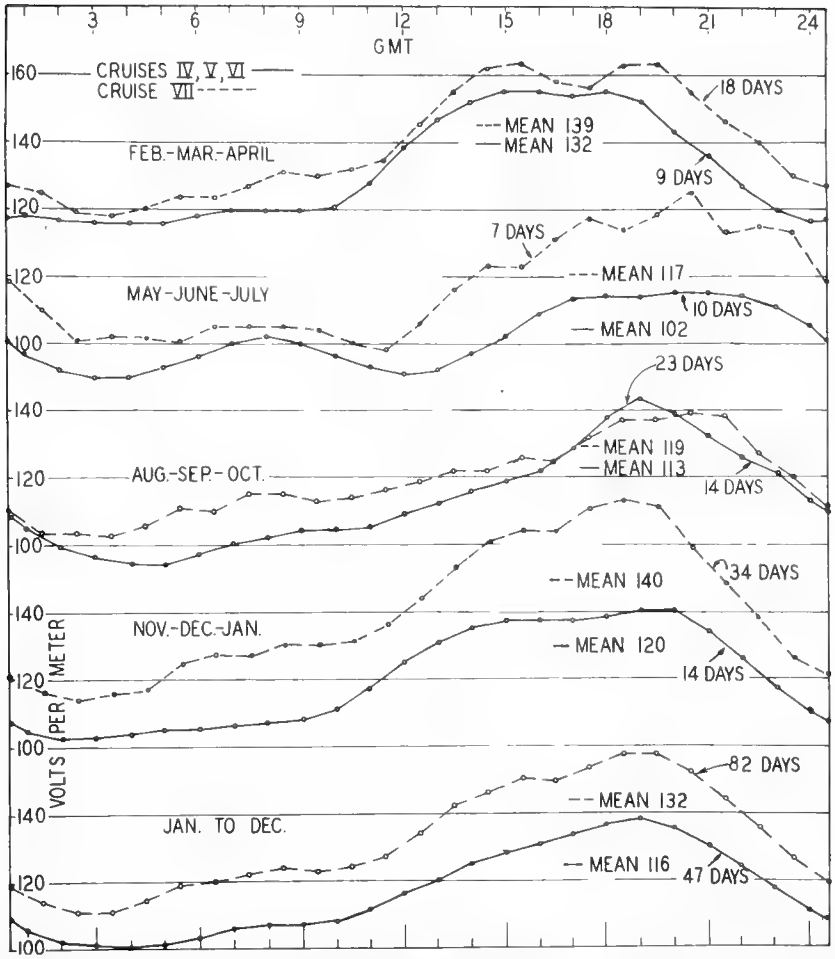


Fig. 1. Mean diurnal variation of potential-gradient for three-month periods from observations on board the Carnegie, 1915-1921 and 1928-1929

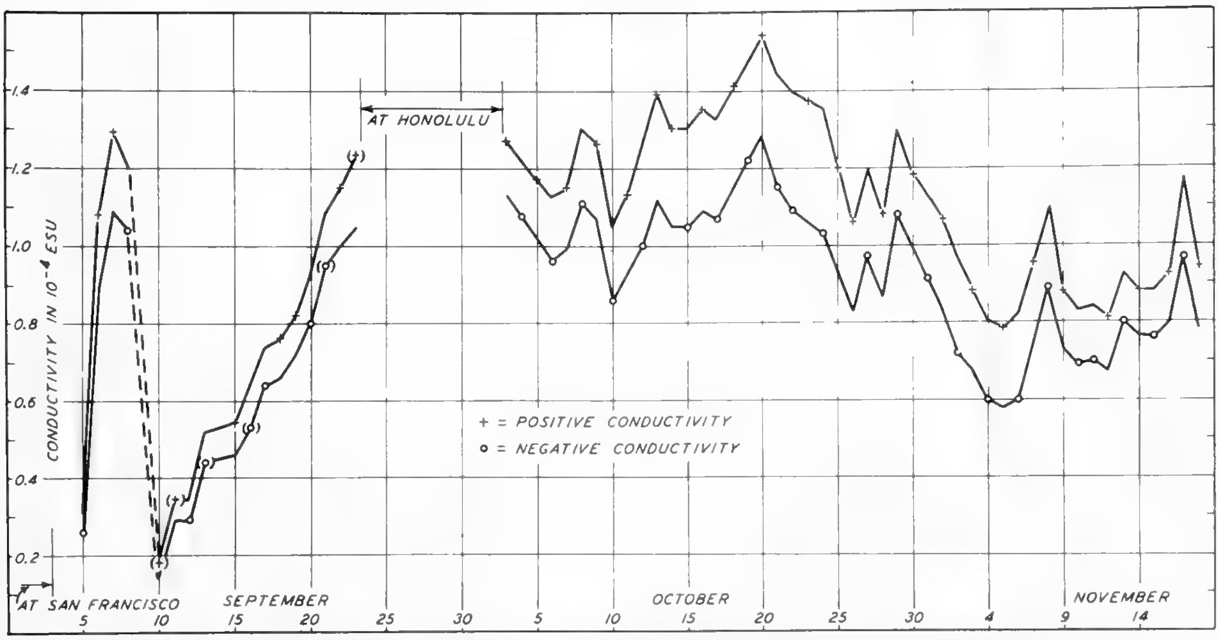


Fig. 2. Daily mean values of conductivity from recorder apparatus CA8A, Carnegie, cruise VII, from measurements in the central Pacific Ocean, September 5 to November 18, 1929

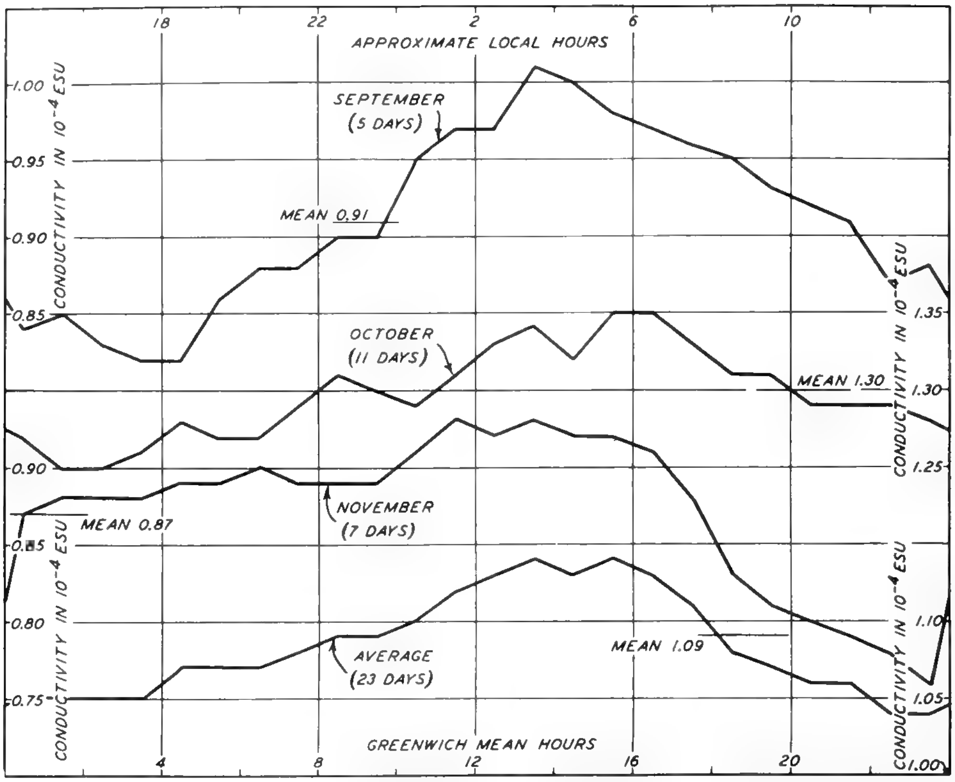


Fig. 3. Diurnal variation in positive electrical conductivity over the central Pacific Ocean from continuous registrations on the Carnegie, cruise VII, September to November 1929

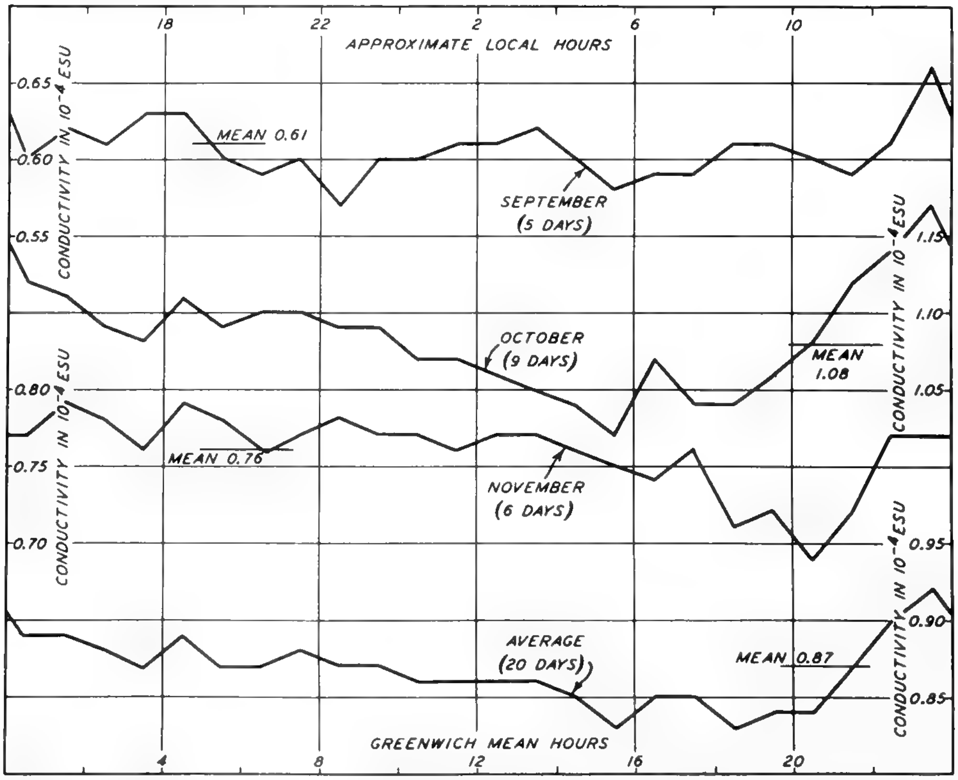


Fig. 4. Diurnal variation in negative electrical conductivity over the central Pacific Ocean from continuous registrations on the Carnegie, cruise VII, September to November 1929

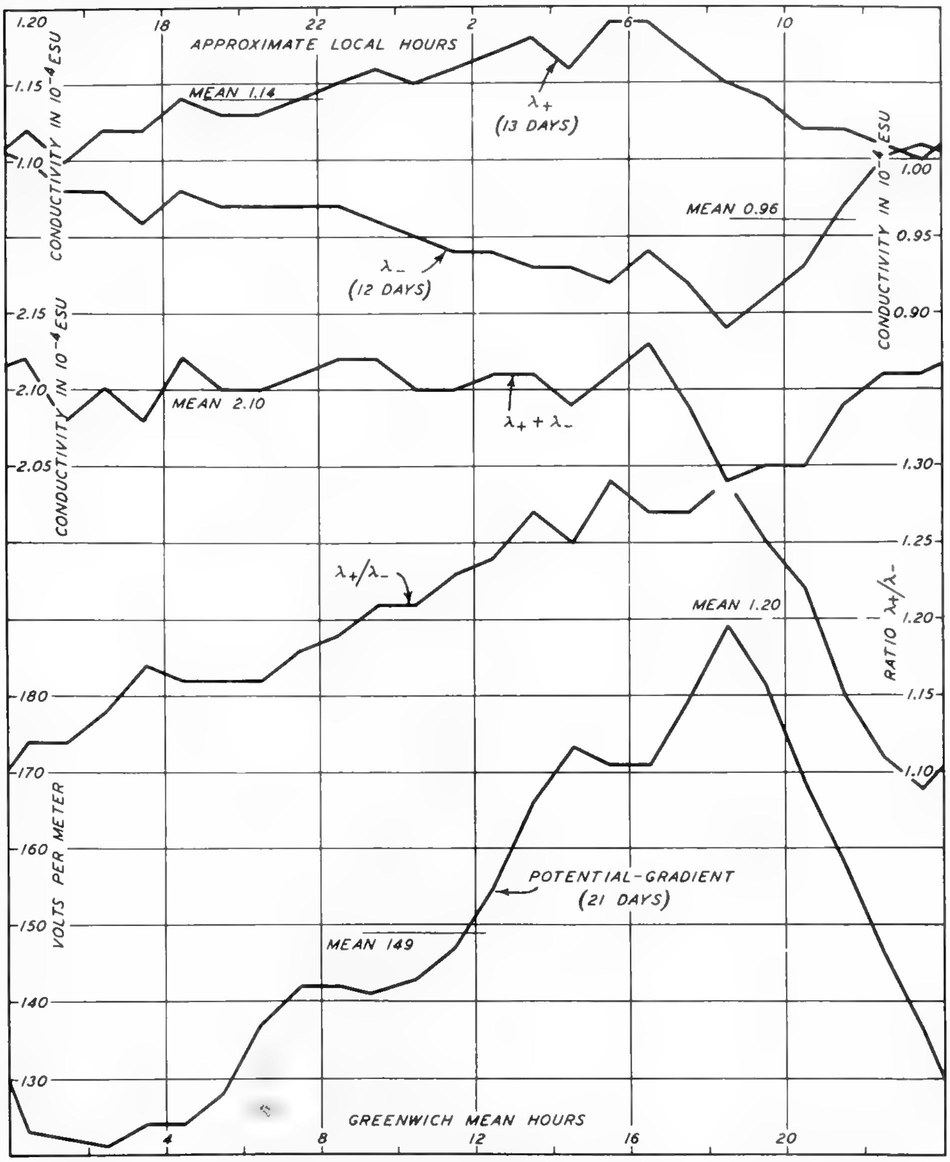


Fig. 5. Electrical conductivity and potential-gradient over the central Pacific Ocean from continuous registrations on the Carnegie, cruise VII, October and November 1929

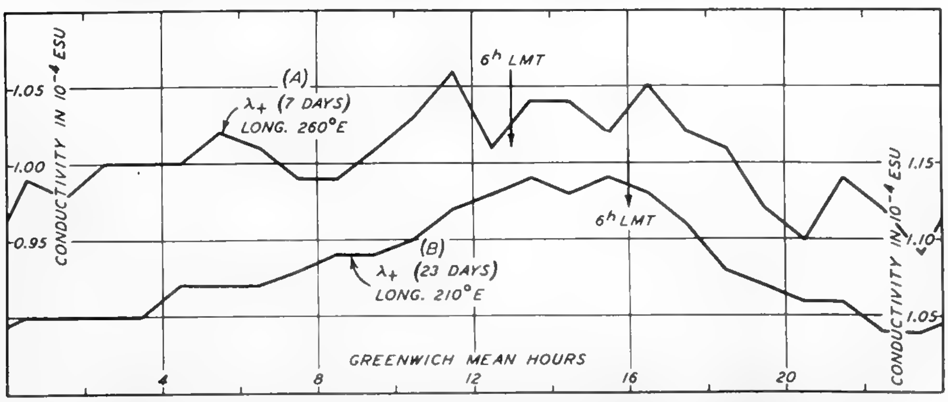


Fig. 6. Diurnal variation in positive electrical conductivity, Carnegie, cruise VII; (A) Over the southeastern Pacific Ocean, November 1928 to February 1929, (B) Over the central Pacific Ocean, September to November 1929

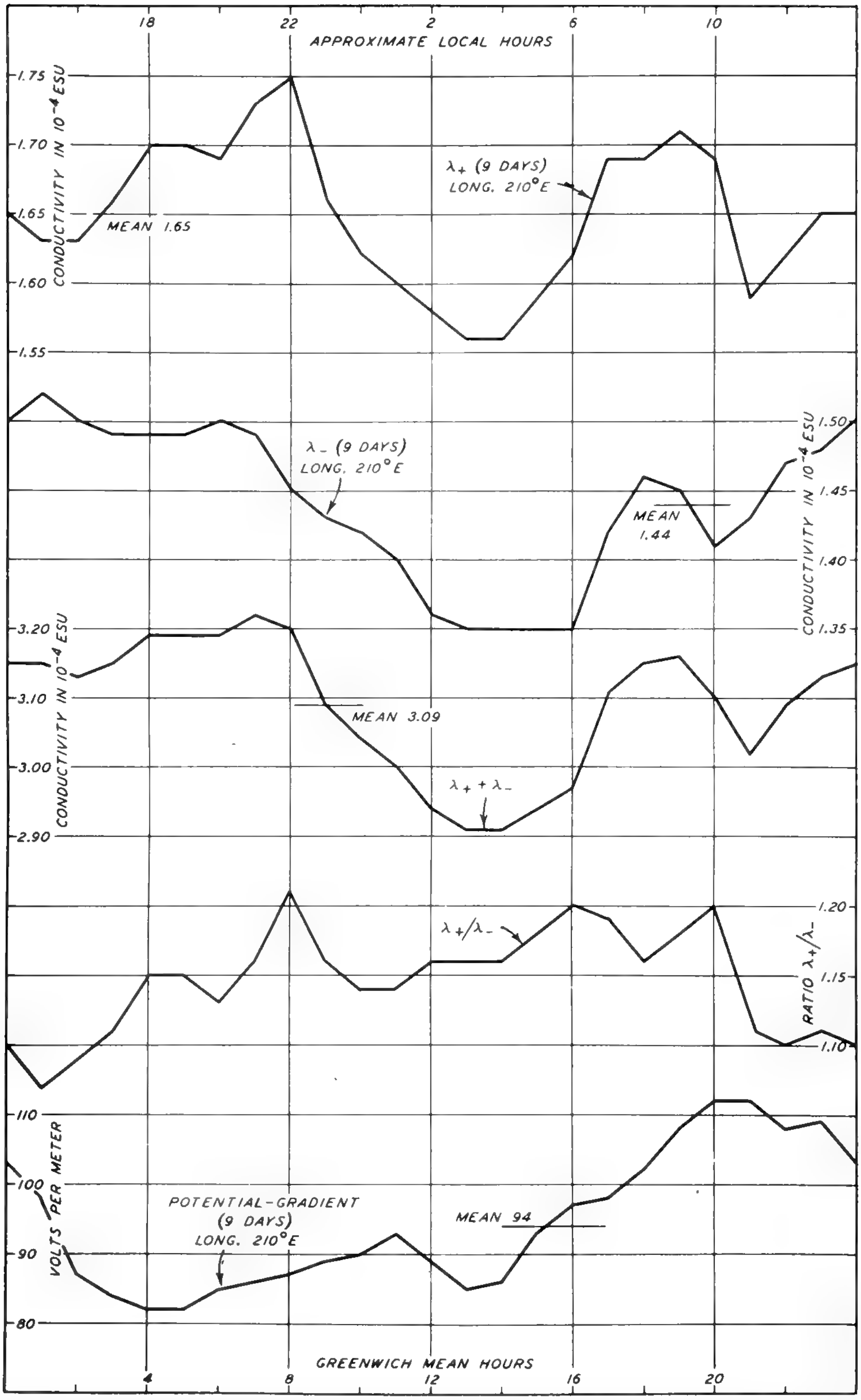


Fig. 7. Electrical conductivity and potential-gradient over the central Pacific Ocean from manual observations on the Carnegie, cruise VI, April to August 1921

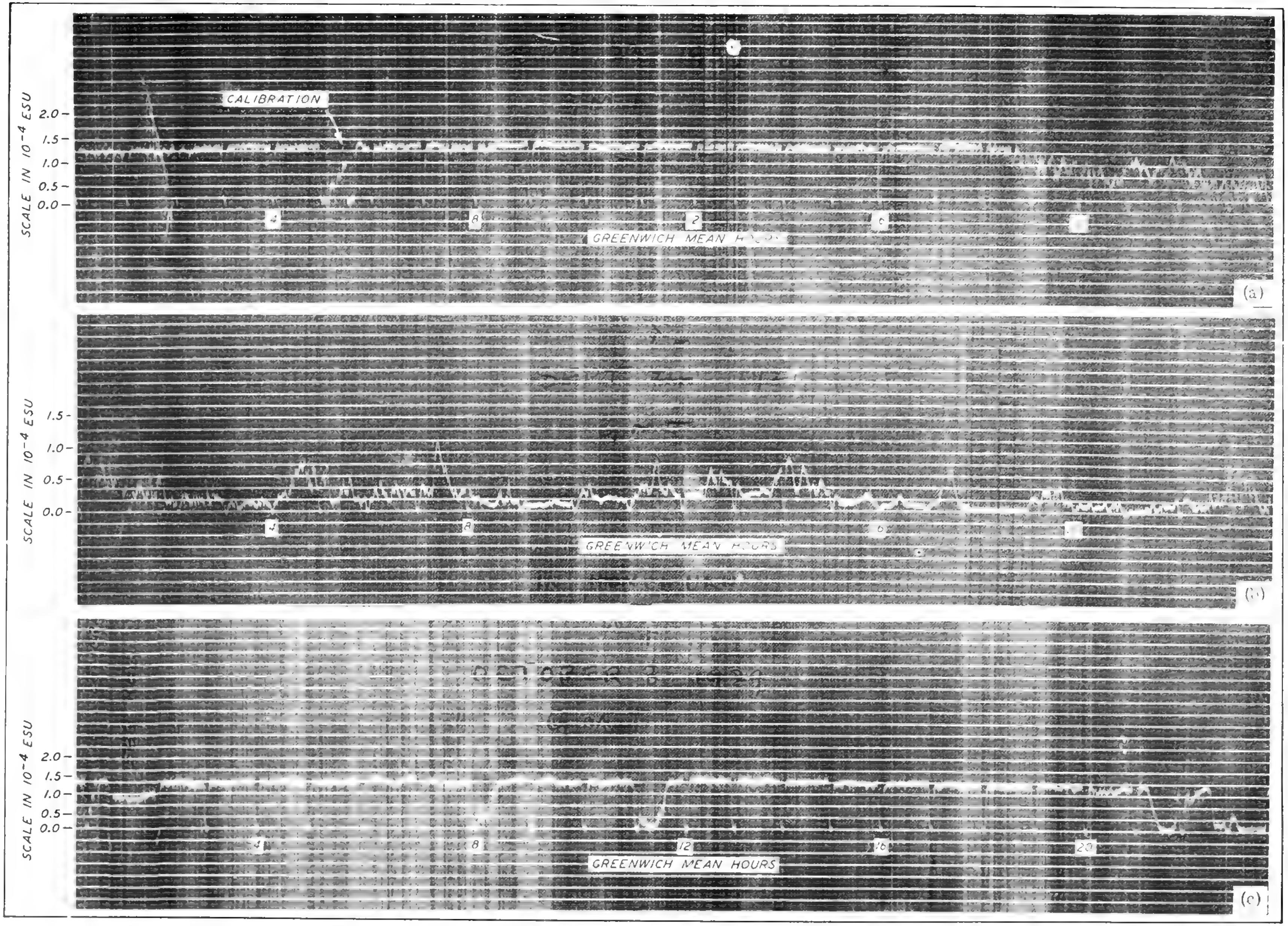
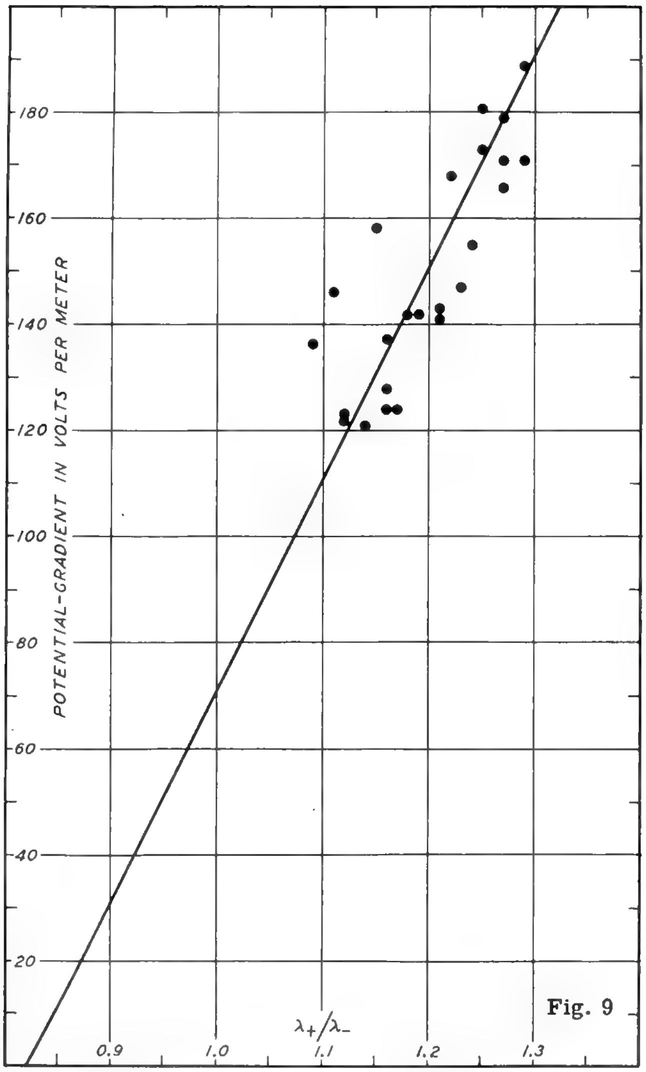


Fig. 8. Air-conductivity records on the Carnegie: (a) $\lambda+$, approaching Honolulu, September 23, 1929; (b) $\lambda-$, in Honolulu harbor, September 24, 1929; (c) $\lambda+$, record at sea, October 30, 1929, disturbed by bad weather



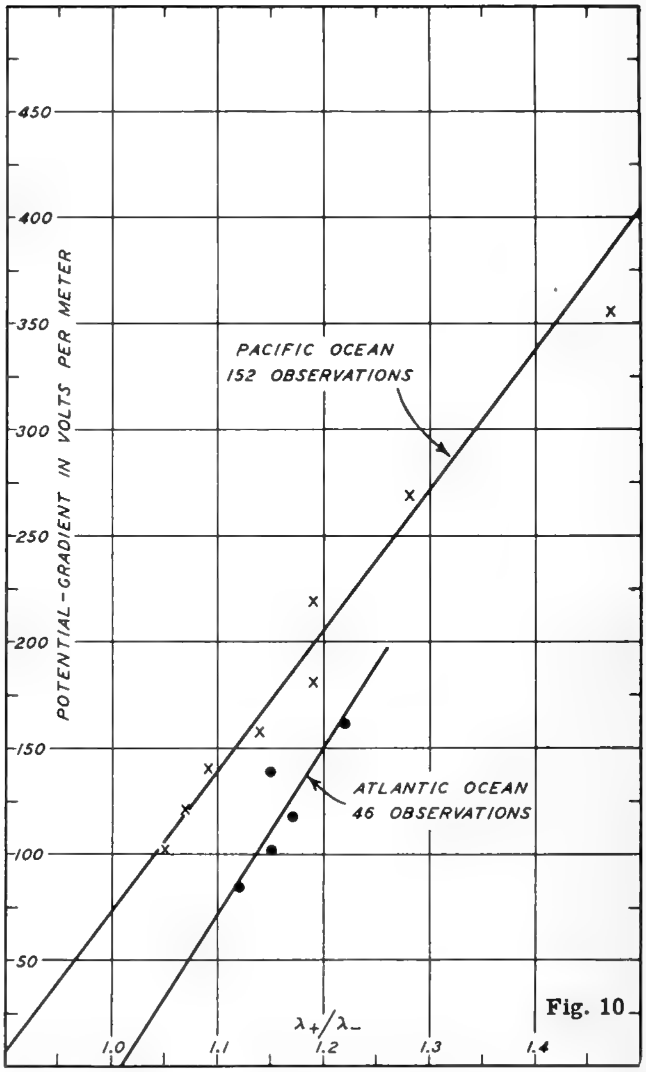


Fig. 9. Change in ratio $\lambda+/\lambda-$ with change in potential-gradient. Points are daily means of recorder values of potential-gradient and corresponding ratios of daily means of recorder values of $\lambda+$ and $\lambda-$. Carnegie, cruise VII, October 5 to November 12, 1929

Fig. 10. Change in ratio $\lambda+/\lambda-$ with change in potential-gradient, using eye-reading measurements of conductivity obtained July 28, 1928 to October 9, 1928 in the Atlantic Ocean and November 5, 1928 to July 28, 1929, in the Pacific Ocean

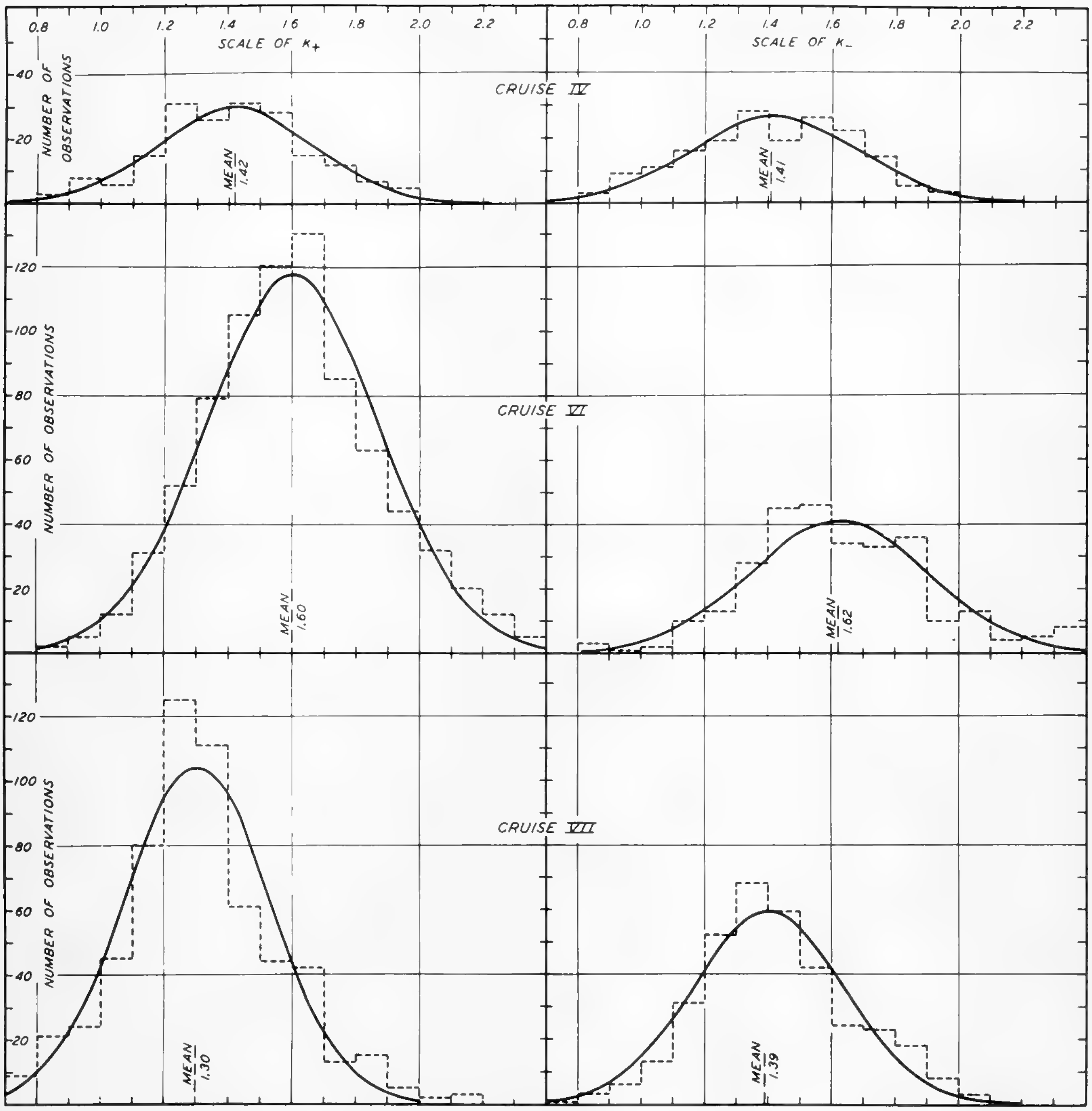


Fig. 11. Frequency curves of computed mobilities, for positive and negative ions, k_+ and k_-, for cruises IV, VI, and VII of the Carnegie, 1915-1929

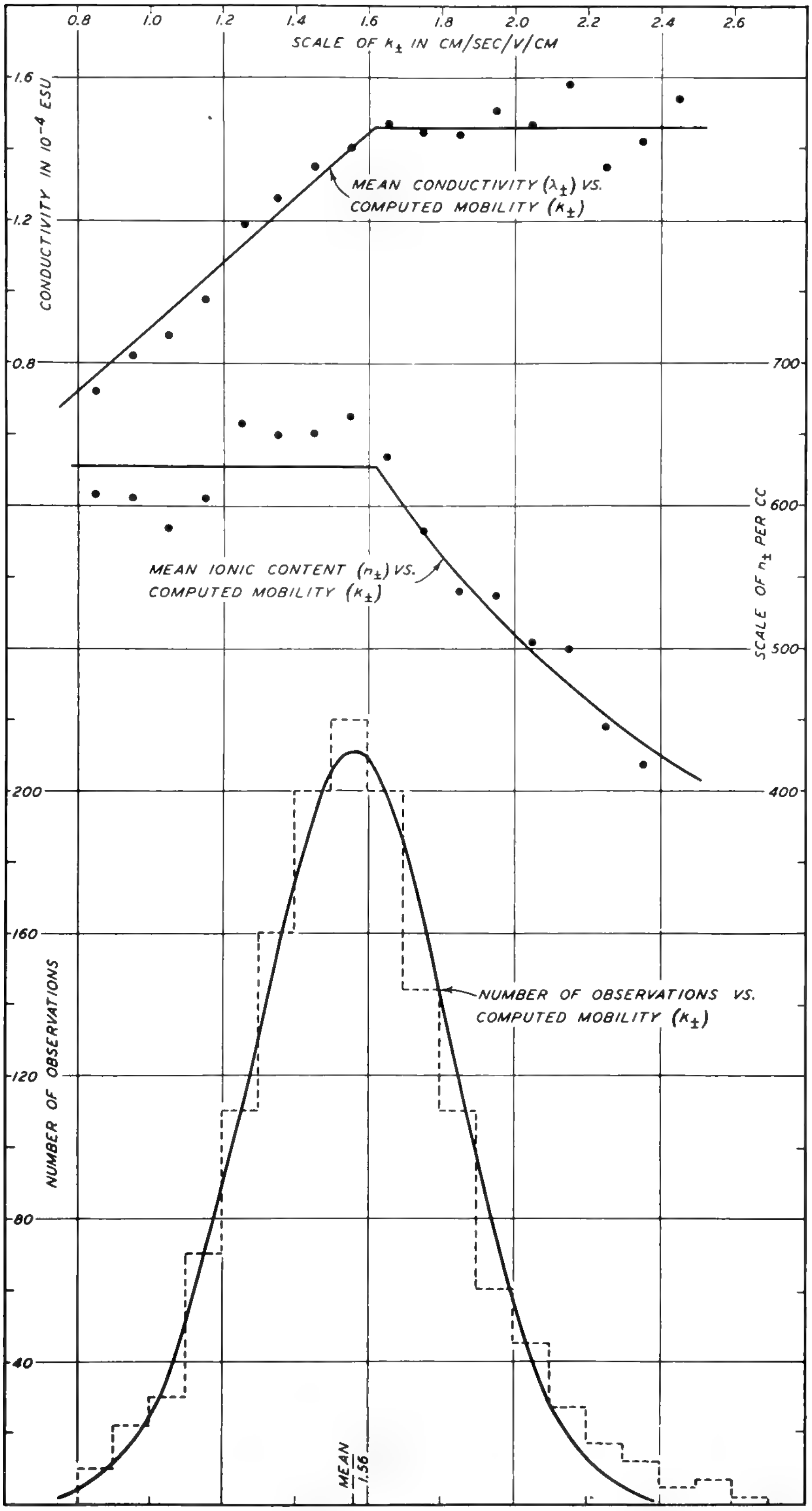


Fig. 12A. Variation in conductivity and ion content with computed mobility, from combined data of cruises IV and VI, using values of both positive and negative components; frequency curve for mobility data at bottom

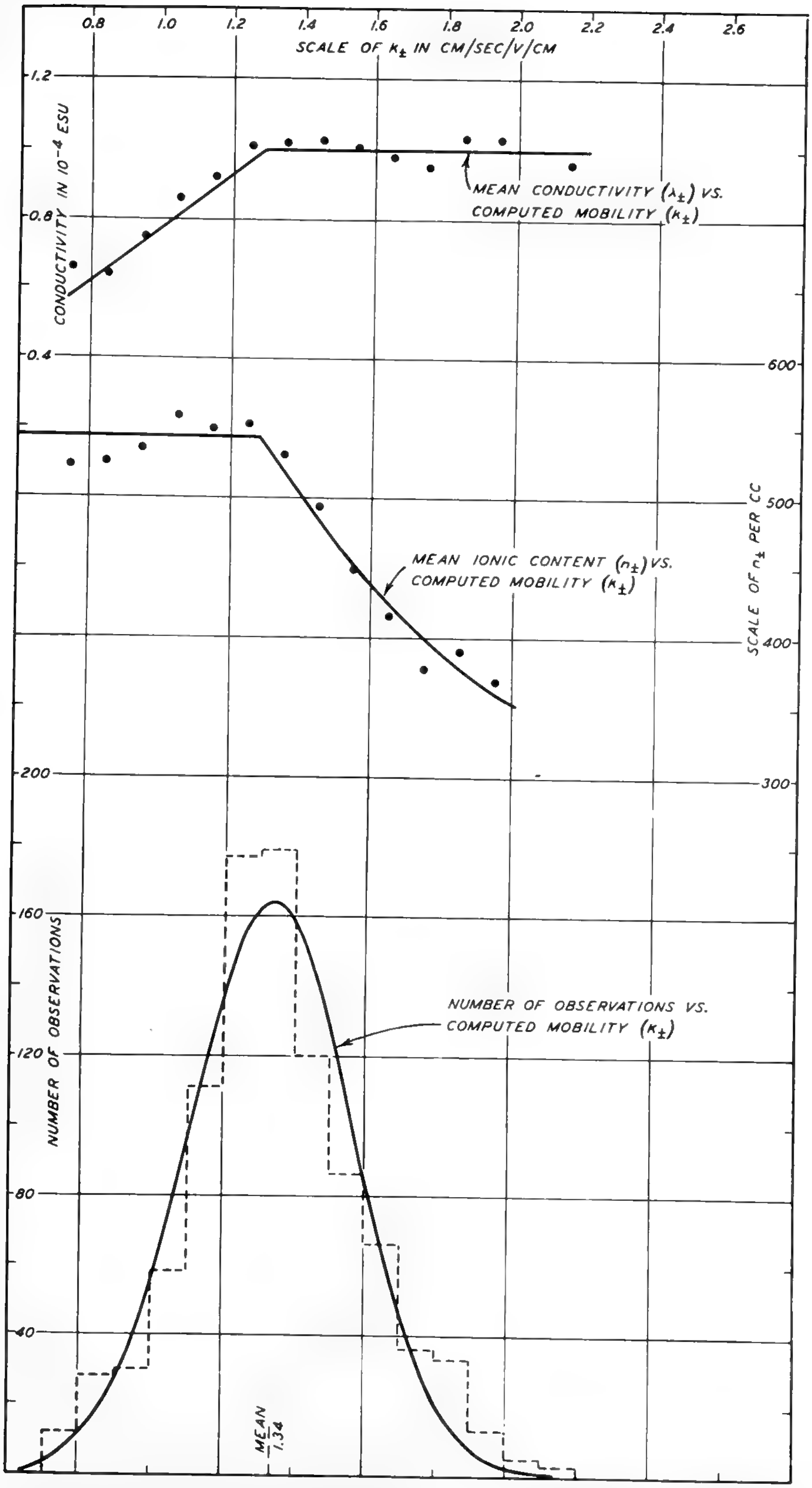


Fig. 12B. Variation in conductivity and ion content with computed mobility, from eye-reading data of cruise VII (May 1928 to July 1929), using values of both positive and negative components; frequency curve for mobility data at bottom

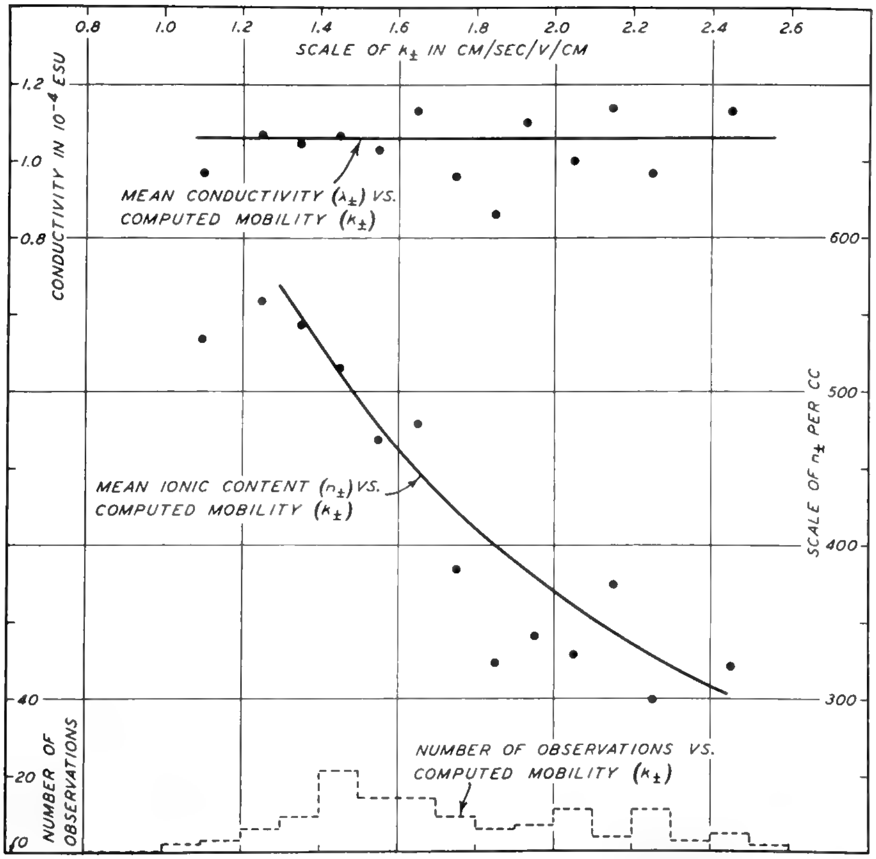


Fig. 13. Variation in conductivity and ion content with computed mobility, after conductivity recording began on cruise VII (September to November, 1929), using values of both positive and negative components; frequency curve for mobility data at bottom

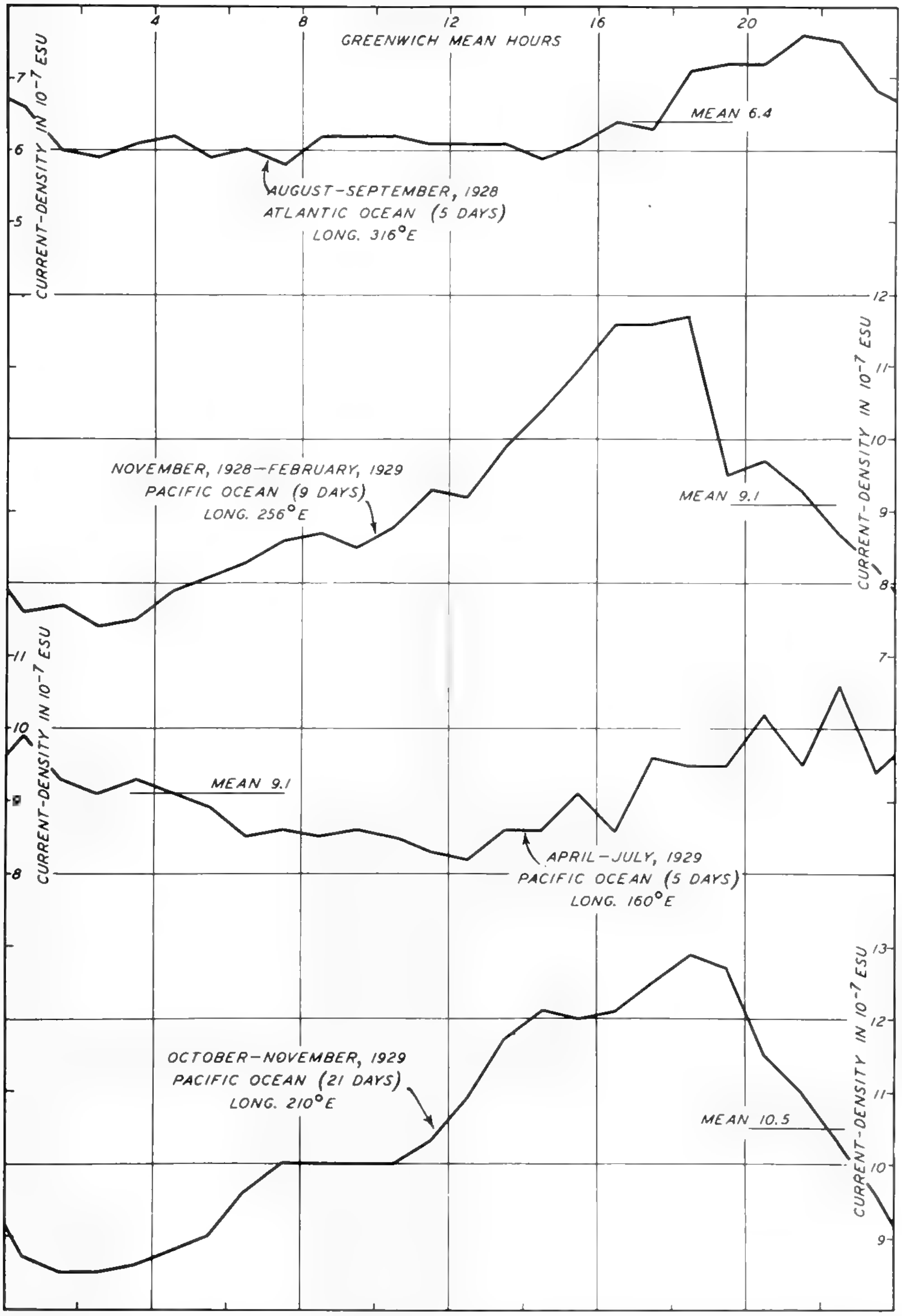


Fig. 14. Diurnal variation in computed air-earth current density, Carnegie cruise VII, August 1928 to November 1929

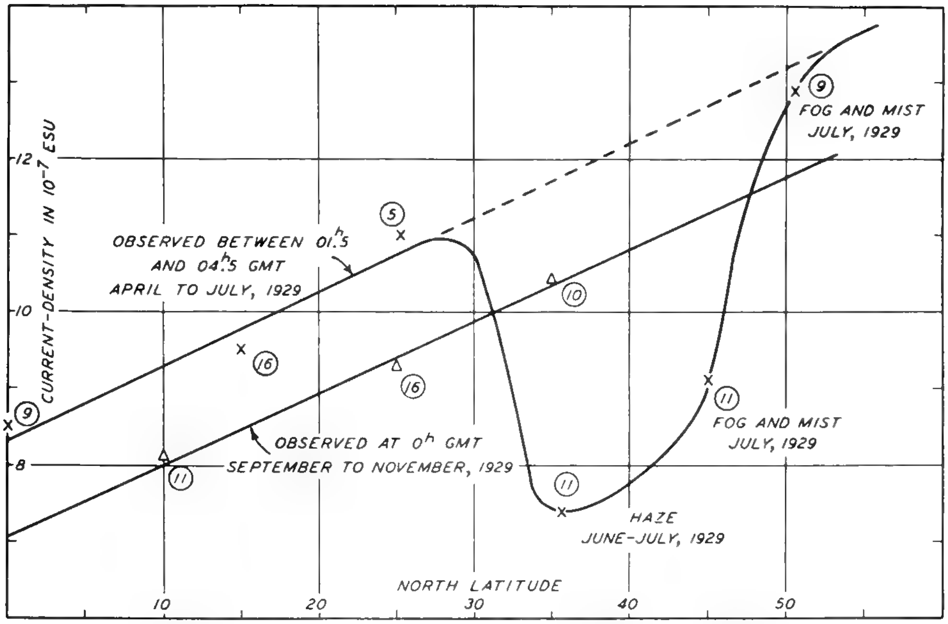


Fig. 15. Variation in computed air-earth current density with change in latitude (Note conspicuous departure during fog, mist, and haze from April-June curve; figures in circles denote number of observations included in each point)

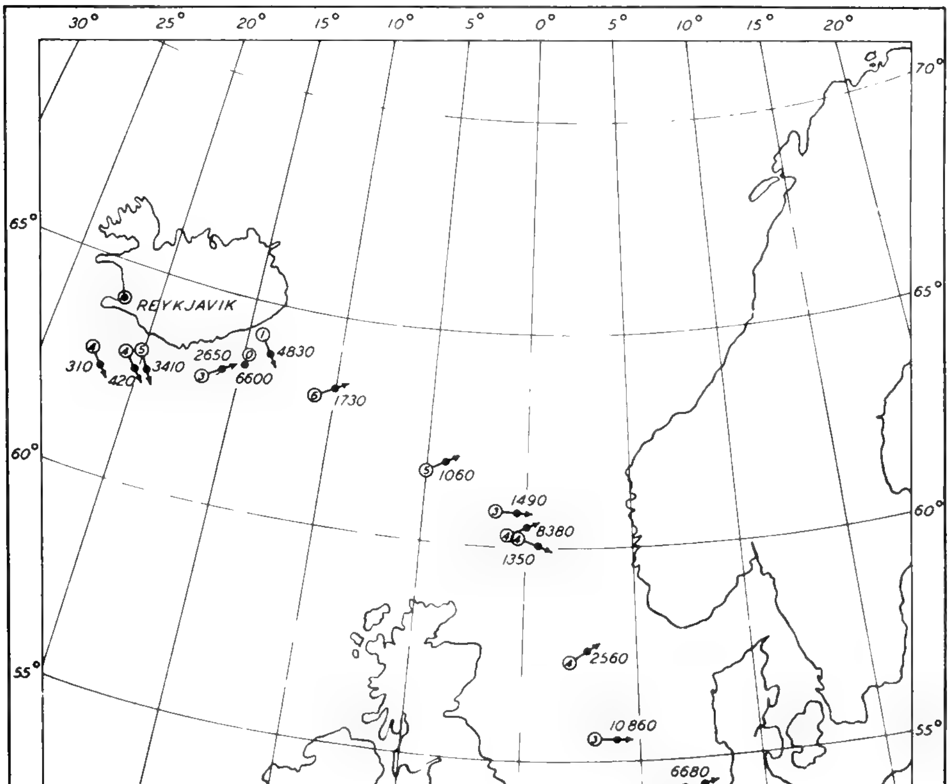


Fig. 16. Wind force (Beaufort) and direction and condensation-nuclei content of the air from measurements aboard the Carnegie, cruise VII, between Hamburg and Reykjavik

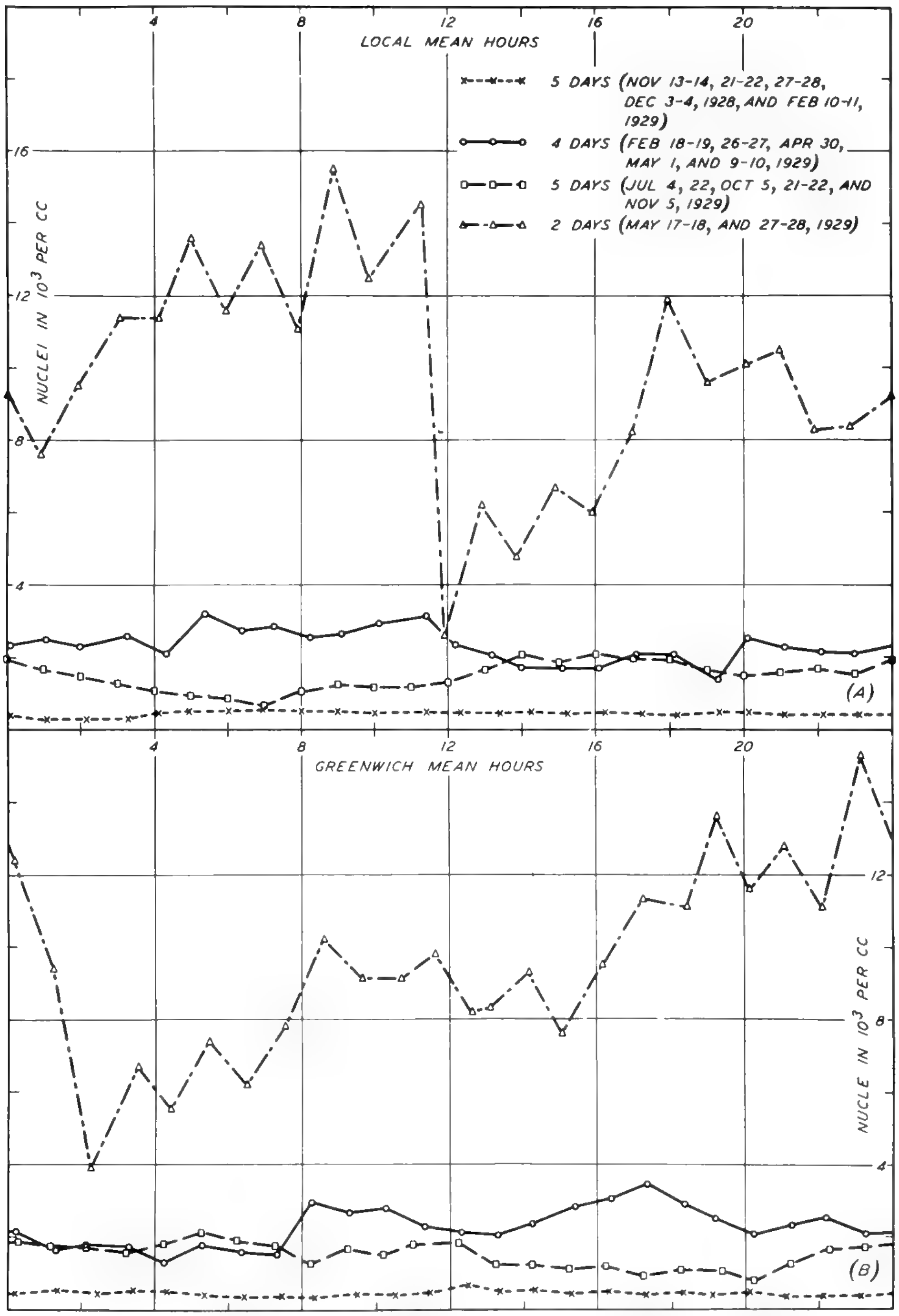


Fig. 17. Diurnal variation in condensation nuclei over the oceans, from cruise VII data of the Carnegie

INDEX