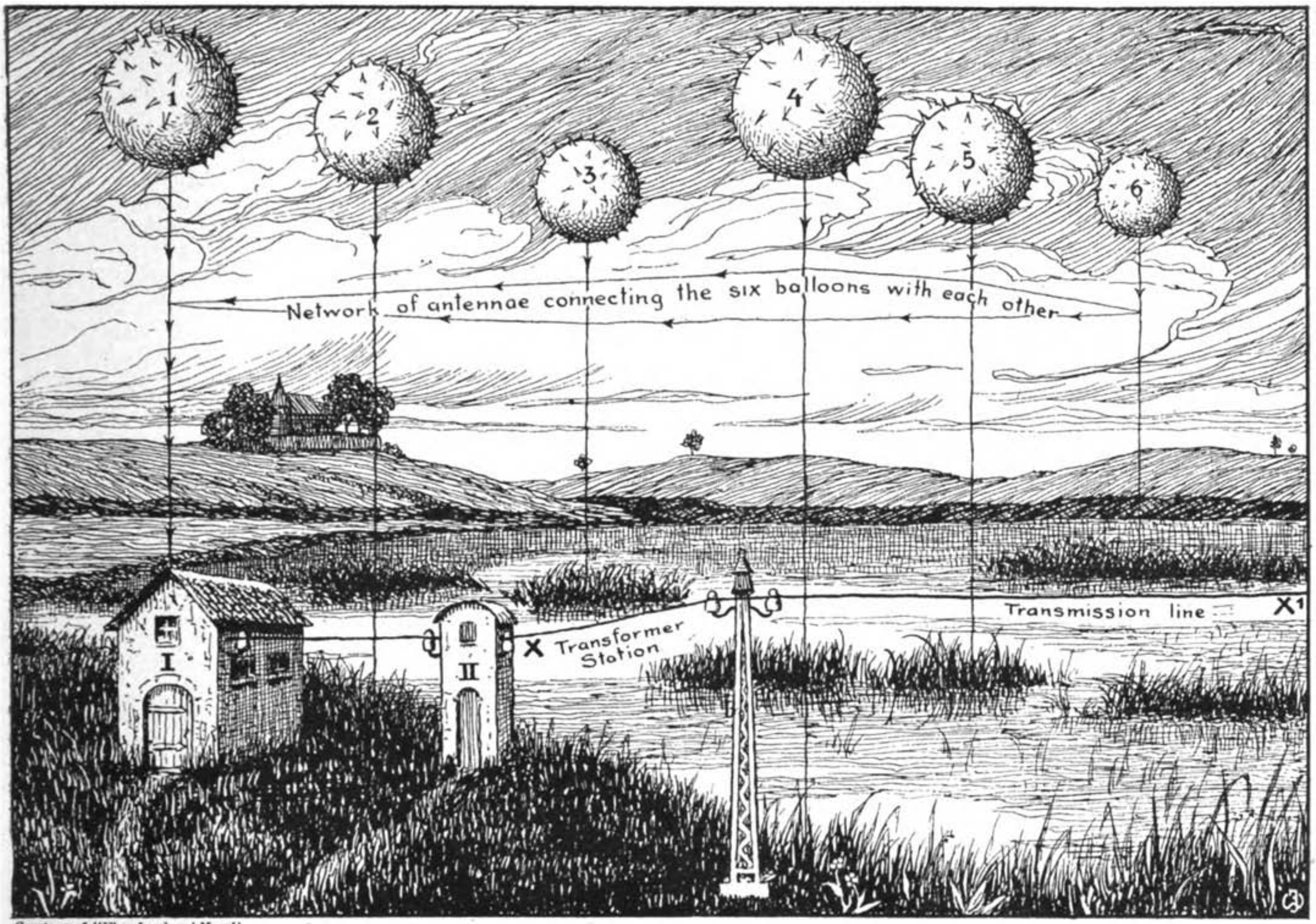

Courtesy of "Uber Land und Meer"

PLAUSON'S PROPOSED BALLOON PLANT FOR COLLECTING AND UTILIZING ATMOSPHERIC ELECTRICITY

The electricity is periodically discharged, producing a high frequency current which flows from the collecting station I through the transformer X to the transmission line.

Capturing Electricity from the Air

Recent Studies Regarding Atmospheric Electricity and Its Possible Utilization

By T. A. Marchmay

OLD KING COAL has served mankind well but at the present hour his services are coming uncommonly high. Small wonder then that our inventors and men of science are becoming increasingly keen in their endeavors to find some source of energy which may replace, at some future day, if not in the immediate present, those stores of fossil sunlight, which within but little more than a century have revolutionized human activities and made modern actualities of Arabian Nights dreams.

One of the newest propositions of this sort, which is attracting widespread interest on the continent of Europe, where the pinch of fuel shortage is even more keenly felt than in our own richer country, is the suggestion to make use of what is believed to be the inexhaustible storehouse of static electricity contained in the upper reaches of our atmosphere. In normal weather the terrestrial atmosphere constitutes a practically uniform electric field in which the surfaces of equal potential are parallel to the earth and the lines of force are vertical. The degree of the potential increases with comparative regularity—except during periods of violent atmospheric disturbance—in proportion to the distance above the level of the ground. This difference of potential varies also according to the season of the year, being estimated at 100 volts per meter during the summer, on an average, and 300 volts during the winter. A Hamburg scientist named Plauson, who has been studying this subject for a number of years, has proposed an ingenious scheme by means of which this energy of the upper air may be captured and set to work. He has already demonstrated, in fact, that at altitudes exceeding 300 meters it is possible to capture an average of 200 horse-power per square meter; his latest experiments, indeed, have yielded as much as 400 to 500 horse-power.

He proposes to make use of a system of huge balloons having a metallic surface and connected with each other by an aerial network of conducting wires. These balloons act as collecting antennae and, that they may the better fulfil this function, they bristle with a series of points as shown in the accompanying illustration, so that they somewhat comically resemble those queer puffer fish which can inflate themselves like rubber balloons, and which likewise bristle with sharp points. Further to increase their power of capturing energy he proposes to impart conducting power to the air by ionization, and he proposes to secure this by means of radio-active salts such as radium, polonium, etc., placed at the extremities of the antennae. Each system of balloons is connected with the earth by means of non-conductors, and the vast supplies of energy thus collected in the upper strata of the air are discharged at brief intervals so as to produce a high frequency current.

This current can be utilized immediately in the preparation of nitric acid and ozone from the air; hence if it proves practical mankind's other fear of exhausted fertility of the soil will be set at rest. By making use of suitable transformers the aforesaid current can also be employed in electro-chemistry and electro-metallurgy. A well-known French writer, M. Matignon, writing upon this subject in *Chimie Industrie* (Paris) for April, 1920, states that it is possible to produce 5 tons of carbide in 24 hours by means of the power thus captured upon a surface of 6 sq. km. Other interesting figures given by M. Matignon are found in his estimate that assuming an attainable power of 100 hp. per kilometer, the total surface of France would yield 100 million horse-power. A German writer, Fredrich Otto, writing in *Ueber Land und Meer* (Berlin) for October 31, 1920, estimates similarly that an area equal to the surface of Germany would yield 720 million hp. per day.

It would obviously be impossible, however, to devote the entire area of the country to the anchoring of flocks of huge balloons. Herr Plauson proposes to employ as locations for collecting stations such barren localities as seas and lakes, heaths, moors, deserts, steppes, mountainous areas, etc. He estimates that about one-third of the surface of Germany could thus be employed for the collecting of atmospheric electricity without interfering in the slightest degree with agricultural interests.

But what would be the expense if this grandiose enterprise were to be carried out upon the scale which its inventor enthusiastically hopes for. Herr Plauson admits that the initial cost would undoubtedly be very great, and yet he does not hesitate to assert that this aerial electrical current would be in the long run, and all things considered, considerably cheaper than that obtained from coal. He expresses the hope that the enterprise may be taken up by the government, the first steps, of course, to consist in the erection and establishing of suitable experiment stations. Such a station is shown in the picture which accompanies the text, and which was drawn by W. Jacobs.

It must be admitted that there are certain hard-headed men of affairs who fail to share the inventor's enthusiasm concerning this novel idea, but as Herr Otto justly points out incredulity has been the common fate which has attended novel ideas throughout the course of human history. Even in the early part of the present century many wiseacres considered Count Zeppelin's plans for huge dirigibles merely a colossal joke. Galvani, whose name is enshrined among the potent terms of electricity, wrote sadly in 1792, "I am attacked by two sets of men—by the wise men and by the fools." Philippe Lebon, who discovered the process of illumination by gas, was considered a perfect fool for believing that any light could burn without a wick. The Royal Medical College of Bavaria solemnly declared that steam engines and railroads constituted a crime against the public health. But it is needless to cite further examples of the obstinate conservatism of the human mind with regard to new ideas. Let us turn rather, for further light upon the potentialities of this vast project, to a consideration of the recent researches by other investigators in the fascinating field of the nature and origin of atmospheric electricity.

NATURE AND ORIGIN OF ATMOSPHERIC ELECTRICITY

Many men in many lands have followed the clue given by Franklin in 1752, with regard to the character of the mysterious and terrifying phenomenon of lightning, whose power to impress the imagination of man is borne witness to, alike in the folk lore of the savage and the loftiest literature of civilized races. Among these we may mention among the moderns Becquerel, Lord Kelvin, Peltier, Pellat, Saussure, and more recently, since the theories of ionization and of radioactivity have given a new slant to the subject, Eve, Simpson, Wilson, Birkeland, Ide, and Swann. The last named authority has been studying this subject for more than fifteen years, with all the advantage of the most admirable equipment. He has conducted his studies, both by land and by sea, in the latter case upon the boats *Galileo* and *Carnegie*, belonging to the Carnegie Institution.

In giving an account of Mr. Swann's remarkable observations in this domain, for information concerning which we are indebted to an article recently published by the *Journal of the Franklin Institute*, it is advisable, perhaps, though at the risk of some repetition, to give a brief résumé of the knowledge possessed on the subject.

The ground is not an electrically neutral body. Its surface may be considered to be covered with a layer of negative electricity and this gives birth in the atmosphere to an electrical field of considerable importance. As we have said in the earlier part of this article the difference of potential increases with the altitude; this increase is at the rate of about 150 volts per meter. This is known as the *gradient of the potential*, and is the subject of regular measurements in all observatories.

Variations of potential in the atmosphere.—Save in exceptional cases the gradient of the potential always takes the direction which results from the existence of a negative charge upon the ground. But this is not an invariable quantity; it undergoes both daily and annual variations, and is always higher in winter than in summer. As stated above the gradient decreases in proportion to the altitude. Observations have been made by means of sounding balloons up to a height of 9 km. at which level the gradient is only 2 volts per meter instead of 150, as upon the ground.

The existence of the gradient and its gradual diminution up to a height of 10 km., may be explained by assuming that this atmospheric stratum, 10 km. in thickness, contains a positive charge, which is exactly equal to the negative charge spread over the surface of the earth. Experiment has shown the existence of this positive charge, in fact.

If the atmosphere formed a perfect insulator the system constituted by a negative electric charge upon the surface of the ground and a positive charge in the surrounding atmosphere, might continue indefinitely. But this is not the case. While it is true that the electrical conductivity of the air is extremely feeble, it would, nevertheless, be sufficient to occasion in less than 10 minutes a discharge of 90 per cent of the electric charge of the ground, were it not reconstituted in some manner. It is the method by which this charge is constantly reconstituted, which has long proved a puzzle to students of electric phenomena.

The conductivity of the atmosphere.—This conductivity, compared to that of a metallic substance, like copper for example, is extraordinarily weak. Mr. Swann calculates that a column of air 1 centimeter in length offers to the passage of the current the same resistance as a copper cable of the same section, and of a length of 15 billions of millions of kilometers, that is to say, 8 times as long as the distance from the earth to Arcturus and back.

But no matter how feeble it may be the conductivity of the air is by no means nil, and modern theories of electricity are quite capable of explaining the mechanism thereof. According to these theories matter is composed mainly, if not exclusively, of positive and negative electrical particles, the latter, the electrons, carry the same charge and are the same as to dimensions and as to mass. Certain agents are capable of separating an electron from the molecule, which thereupon appears to be charged with positive electricity and constitutes the positive ion. The electron is capable of traveling a certain distance in freedom, but sooner or later attaches itself to a neutral molecule or group of molecules to form a negative ion.

It is these ions which render the air a conductor. Under the influence of an electrical field, the positive and negative ions move in opposite directions, some toward the negatively charged body and the others toward the positively charged body and become discharged. But let us suppose that some permanent source of ions exists in the atmosphere. The number of ions contained per cubic meter of air would constantly increase, unless the negative and positive corpuscles tended to recombine because of their mutual attraction; the more numerous they are the more rapid this combination. We must assume, therefore, that an equilibrium is established between the number of ions produced and the number which are recombined: thus, it is supposed that six pairs of ions are produced in the atmosphere per second per cubic meter. When the number of pairs of ions per cubic meter reaches 2,400 it is found that six pairs of ions recombine in one second; at this moment equilibrium is attained and the number of ions can no longer increase.

The origin of atmospheric ions. Swann attributes the continuous production of ions in the atmosphere to two causes:

1. *Radio-active emanations* in the air;
2. The so-called *"Penetrating radiation."*

All of these radiations possess the power of ionizing either directly or indirectly any gas through which they may pass; the *alpha* particles being especially efficient so that they expend all their available energy in the process and come to rest after passing through only a few centimeters of air. The *beta* particles are much less efficient and may travel several meters before coming to rest. The *gamma* rays are still more penetrating and less efficient as ionizers, so that after passing through 100 meters of air they still retain 36 per cent of their initial value. Mr. Swann thus elaborates these ideas in an article presented by him originally at a joint meeting of the electrical section and the Philadelphia section of the American Institute of Electrical Engineers, held November 1, 1917. At the time this lecture was given Mr. Swann, who is now professor of physics at the University of Minnesota, was chief of the Physical Division in the Department of Terrestrial Magnetism in the Carnegie Institution at Washington. The following excerpts are taken from the paper as published in the *Journal of the Franklin Institute*, for November, 1919.

Now the soil contains radium and other substances of this nature, and these give rise to active gaseous emanations which diffuse out into the atmosphere. During the disintegration of these emanations in the atmosphere, α, β and γ rays are emitted with the result that the air becomes ionized and is rendered conducting. The amount of radium emantion in the atmosphere varies very much from time to time. It is, however, always extremely small. In a shell of the atmosphere extending over the whole of the earth's surface and comprised between that surface and an altitude of one kilometer, we shall find only about 250 grammes of radium emanation. Or, expressing this magnitude in another form, we may say that each cubic centimeter of the atmosphere contains on the average only between one and two molecules of radium emanation, as compared with the thirty million million million molecules of air which it holds. Nevertheless, by adding up the ionization produced by the α, β and γ rays from the emanation and its products we are able to account for the production of 1.7 ions per second in each cubic centimeter of the atmosphere. In addition to radium emanation, another radio-active gas, thorium emanation, is also found in the atmosphere and contributes to the ionization. Again, a certain amount of atmospheric ionization is attributable to the radio-active materials in the soil. Here we are only concerned with the γ ray ionization, since α and β rays are so readily absorbed that they never succeed in getting out of the soil. The soil contains, on an average, about 4×10^{-12} gramme of radium per cc., and, by calculating the amount of γ radiation which can be accounted for, after allowing for the absorption of the rays coming from different depths in the soil, we find enough to provide for the production of 0.80 ions per cc. per second. In a similar way, the thorium in the soil is found to be capable of accounting for a rate of production of 0.80 ion per cc. per second.

These results on the amount of ionization which the radio-active material is capable of accounting for are summarized in a table prepared by A. S. Eve; and it appears that, altogether, a rate of production of 4.35 ions per cc. per second can be accounted for in this way. From a knowledge of the rate at which ions recombine we can calculate the number to which they would build up in the atmosphere on account of a rate of production of 4.35 ions per cc. per second, and the result comes out to 1,320 ions of each sign per cc.

Measurements of the numbers of ions per cc. in the atmosphere are attended with considerable difficulty, for all sorts of different types are present. In particular, there is a class of ion which is very sluggish in its motion, and which is probably nothing more than an ordinary ion which has attached itself to a dust particle. On account of their sluggishness, these ions contribute very little to the conductivity, but they nevertheless influence the requirements in the matter of the rate of production of ions; for they contribute to the rate at which the ions recombine. It has been customary to measure the numbers of ions per cc. by a method which takes account of the most mobile ions only, and it appears that about 800 pairs of these exist per cc. Thus, quite apart from the direct evidence of the existence of the sluggish ions, we may conclude that ions of this type must be present, since the radio-active material in the air and soil is alone capable of accounting for 1,320 ions per cc.

The uncertainty of our knowledge of the true average values for the total numbers of ions of all kinds, and of the appropriate rates of recombination, prevents us from doing more than to say that, as far as measurements on land are concerned, the radio-active material in the air and earth is sufficient to account for the whole of the ionization produced. A difficulty presents itself, however, when we consider the results of observations made over the sea. Those who have made observations over the ocean have found very little radio-active material. Some of the most recent observations have been made on the yacht *Carnegie*, owned by the Carnegie Institution of Washington; and, as a result of observations extending over about 30,000 miles in the Pacific and Sub-Antarctic Oceans, an average radio-active content was found, for the atmosphere, amounting to only 2.6 per cent of that found on land, and the radio-active content of the sea water collected in regions remote from land was immeasurably small. Nevertheless, the number of the more mobile ions found per cc. over the ocean is as great or greater than that found over land, as shown in a table which represents a comparison of the results of the *Carnegie's* fourth cruise with those obtained by other observers at sea, and with land values. The number of ions is much larger than can be accounted for by the small quantity of radio-active material in the ocean air.

What, then, is the agency responsible for the ionization over the ocean? It appears to be the so-called "penetrating radiation." If a hermetically sealed vessel is freed from radio-active air, we nevertheless find that ions are produced in it at a fairly constant rate of about 10 ions per cc. per second over the land. An appreciable proportion of this ionization is due to the α ray radiation which comes from the soil and passes through the walls of the vessel. That the whole of it is not due to this cause is, howsver, borne out by several circumstances. In the first place, ionization in closed vessels is found to take place over the ocean, where there is practically no radio-active material, and it there amounts to about 4 ions per cc. per second in a copper or a zinc vessel. Scondly, if, in experiments on land, the apparatus is surrounded by a wall of water of sufficient thickness to shield off practically completely the α ray radiation from the earth, there still remains a rate of production of about 4 ions per cc. per second. But *strongest evidence of the reality of the penetrating radiation* is to be found in the results obtained in balloon ascents by W. Kolhörster. It appears that, with increase of the altitude, the ionization within a closed vessel at first diminishes up to an altitude of 700 meters. This we should expect as a result of the absorption of the earth's γ ray radiation by the atmosphere. Above this altitude an astonishing thing happens, however. The ionization commences to increase, and goes on increasing with greater and greater rapidity until, at an altitude of 9,000 meters, the intensity of ionization is in excess of that at the earth's surface by about 80 ions per cc. per second. An increase of 20 ions per cc. per second takes place in the last kilometer, and the rapidity of the increase at these higher altitudes is such as to suggest that very large values of the ionization would be obtained at altitudes not very much greater.

It thus appears that there is some source of ionization other than the radio-active materials in the soil and lower atmosphere; and this agency, whatever its origin, appears to be the sole source of ionization over the ocean. The rate of production of ions must certainly be greater over the land than over the ocean by the amount attributable to the radio-active materials on land. It is probable, however, that over the land, where dust nuclei are more plentiful than over the ocean, a much larger proportion of the ions produced join the slowly moving class than in the case with the ions produced over the ocean; and it is to this cause that we must attribute the fact that the ionic density for the more mobile ions is no greater over the land than over the sea.

To return to the remarkable increase with altitude shown by the ionization within closed vessels. Such a variation at once suggests a radiation coming from some source external to our globe, or from some active agency in the upper regions of the atmosphere, the decrease in intensity encountered as we *descend* into the atmosphere being accounted for by absorption. The rapidity of the absorption can be calculated from the observations on the variation of intensity with altitude; and it appears that the observations require us to assume for the radiation a penetrating power ten times that of the most penetrating γ rays known in radio-active substances. We must not be too skeptical as to the possibility of the existence of so penetrating a radiation, for light itself is extremely penetrating as regards air, since we can see the stars through the whole thickness of our atmosphere. The "penetrating radiation" is not light, however, for it can pass through the walls of a metal vessel. Its true origin remains one of the most interesting speculations of atmospheric electricity. Linke has suggested a layer of strongly radio-active cosmical dust in the atmosphere at an altitude of 20 kilometers. For my own part, it seems more natural to seek an explanation from another standpoint.

It is generally supposed that the Aurora is due to light generated by the impact, with our atmosphere, of negative electrons shot from the sun. The stream of electrons is not confined to the sunlit side of the earth, since the paths of the electrons are bent in passing through the earth's magnetic field, and some enter our atmosphere on the side remote from the sun. Now it is a well-established fact that when electrons strike molecules of matter X rays are produced. The greater the velocity of the electrons, the higher the penetrating power of the X rays produced. γ rays themselves are nothing more than a particularly penetrating type of X rays. Modern developments in our knowledge of X rays and γ rays have taught us how to calculate the velocity which an electron must have in order to produce γ roys of any given degree of penetration. Now, from considerations of the theory of the Aurora, into which time will not permit me to enter, Birkeland has shown that it is necessary to assume that the electrons which are responsible for this phenomenon have an energy enormously greater than that of even the swiftest β rays with which we are familiar in the laboratory; and, if we invoke the assistance of these high-speed electrons necessitated by the theory of the Aurora, we find that their speed is sufficiently great to account for the production of a γ ray radiation of a degree of penetration fully as great as that of the "penetrating radiation." The electrons themselves are not the "penetrating radiation" for, in spite of their great energy, they could not travel right through our atmosphere. By conversion of their energy into the γ rays, however, a radiation of much greater penetrating power is created.

The cause of thunderstorms.—In any discussion of atmospherical electricity, naturally, the origin of thunderstorms must take an important place. The most successful theory to afford a full explanation of these phenomena, is that suggested by G. C. Simpson, which has been further developed on the meteorological side by W. J. Humphreys.

The theory is founded on the experimental fact that if water is broken into drops by allowing it to fall upon a rising column of air, the drops are found to be positively charged while the air receives a negative charge. Now experiment has shown that it is impossible for drops of water to fall through air which is rising with a velocity greater than 8 meters per second. If the drops are very small they will be blown up by a rising column of air, and it is in general necessary for a drop to have a certain minimum mass before it can fall through a column of air rising with specified velocity. If the velocity is as high as 8 meters per second, however, the size which the drop would have to attain in order to fall through the column would be so great that the drop would be broken up by the air stream, even if it succeeded in attaining the necessary size temporarily. The smaller drops formed as a result of the disintegration would, of course, be carried upward by the air stream.

Now it is a matter of common experience that thunderstorms are always preceded by high winds, and a close examination of the phenomena shows that, in the storms which give rise to electrical discharges, columns of air are to be found rising with very considerable velocity. We may liken one of these columns of air to an hour-glass, or dice box. At the bottom the column is wide. At the narrowest part of the column the air attains its maximum velocity, while at the top it fans out and the velocity again becomes small. Now in the period prior to a thunderstorm, the air is very humid. As this air rises and becomes cooled in the process, it eventually reaches a temperature at which drops of water begin to condense out. At first, these drops are carried upward with the stream; but, as they grow, they eventually reach a size at which they start to fall. Suppose that when this occurs, the drops are some distance above the narrowest part of the air column. Then, as they fall and continue to grow in size they eventually reach a place where the velocity is sufficiently great to break them up. The smaller drops become positively charged in the process and the air receives a negative charge. The small drops now start their ascent again, although, of course, with velocity less than that of the air. As they rise they grow, and eventually the whole process is repeated again. The cycle may be gone through several times, the drops becoming charged more and more each time. The free negative ions which ascend with the rising air eventually coalesce with the finer water drops to be found at the top of the cloud, so that we eventually attain a state of affairs in which the water at the top of the cloud is highly charged negatively, while that in the middle of the cloud is highly charged positively. When the accumulations of charges are sufficient to result in a field which will break down the insulation of the air at some point a lightning flash follows. It thus appears that the high winds which are associated with the thunderstorm are in no sense a result of the electrical manifestations; the electrical phenomena are themselves secondary features resulting from the air motion.

During the turbulence associated with the storm, some of the large drops of positively charged rain which have gone through the cycle of breaking and reformation several times get carried to places where the velocity of the upward current is not sufficient to break them up, and they fall to earth. In this way we find the explanation of the experimental fact that the heavy rain of the thunderstorm is found to be positively charged. On the other hand, the rain which accumulates at the top of the cloud, and which is negatively charged is of the finer type, and may be expected to fall to earth only in the lulls between the periods of most violent activity, or at places somewhat remote from the storm center. Here, again, experiment supports the conclusions in showing that the finer rain which falls during the quiet periods of the storm is negatively charged.

HOW THE EARTH'S CHARGE IS MAINTAINED

Since the earth is constantly losing negative electricity because of the action of the potential-gradient operating in the conducting atmosphere, it is of importance to inquire how its charge is maintained. The current from a square centimeter of the earth's surface is only about 2 x 10^{-16} amperes. The current from the whole earth is only about 1,000 amperes, or about as much as is taken by 3,000 incandescent lamps. It is nevertheless sufficient to insure that 90 per cent of the earth's charge would disappear in ten minutes if there were no means of replenishing the loss. How then is the loss replenished?

One of the earliest suggestions was made by G. C. Simpson, who supposed tentatively, that the sun emitted positive and negative corpuscles of a very high penetrating power. He further supposed that the penetrating power of the negative corpuscles was greater than that of the positive corpuscles, and sufficient to enable them to reach the earth's surface, while the positive corpuscles were caught by the atmosphere. In this way the attempt was made to account for the negative charge of the earth and the positive charge of the atmosphere.

As a matter of fact, it is unnecessary to go to any special pains to account for the maintenance of the negative charge on the surface of the earth. For it is an experimental fact that the atmospheric conductivity increases with altitude until its value at an altitude of nine kilometers is about thirty times the value of the earth's surface. It follows from this that if the potential-gradient were the same at an altitude of nine kilometers as it is at the earth's surface, more negative electricity would be driven outward through a sphere at the altitude of nine kilometers and concentric with the earth than would be driven out of the earth's surface into the atmosphere. The shell of air below the altitude in question would consequently acquire a positive charge, so that the potential-gradient at the altitude of nine kilometers would become less than that at the earth's surface. The process would continue until the diminution of potential-gradient with altitude was just sufficient to compensate for the increase of conductivity with altitude so as to leave the conduction current-density independent of altitude.

The chief objection to Simpson's tentative theory, however, is one which he himself supports in a recent publication (*Some Problems of Atmospheric Electricity.* *Monthly Weather Review*, vol. xliv. pp. 115-122, 1916), viz., that it postulates a degree of penetration for the corpuscles so enormously great compared with any corpuscular penetration we have become acquainted with in the laboratory since the suggestion was put forward, that one hesitates to make this hypothesis without further evidence.

Other hypotheses have been formulated by various scientists, particularly the German, Elster and Geitel, and the English physicist C. T. R. Wilson. To go into these various theories would take us too far afield but that of Wilson is worth mention, because it is connected with his important discovery in regard to the part played by ions in the condensation of water vapor. His hypothesis is that the ions act as nuclei which promote the condensation of water vapor, and he observed that the vapor is condensed more readily upon the negative than on the positive ions. He, therefore, argued that rain should be on the average negatively charged. Swann, however, points out that unfortunately 75 per cent of the charge brought down by rain is of the positive sign; he, also, raises several other objections to this theory which he considers fatal.

PENETRATING RADIATION

Swann himself finds the explanation of the electric charge of the ground in *penetrating radiation*. The study of the γ rays has shown that the ionization occasioned by them consists of an emission of electrons projected in the direction of the incidental γ rays and which are themselves endowed with a power of penetration, whose degree varies in proportion to the penetrating power of the radiation to which they owe their origin. Hence, electrons produced by the ionization of an extremely penetrating radiation may travel a considerable distance before coming to rest.

Thus the successive strata of the atmosphere are traversed by electrons set free from the upper layers; these corpuscles in their turn come in violent contact with molecules of matter, thereby giving rise to a penetrating radiation which occasions the emission of new electrons directed toward the ground—and thus we come nearer and nearer to the ground, which finally receives the electrons sent forth in the layers of air in its immediate proximity. At every point of the atmosphere, therefore, we must suppose that there is a current of electrons passing from the top to the bottom and animated with great velocity by the penetrating radiation; and, likewise, that there is a conduction current moving in the opposite direction carrying the negative electricity of the ground to the atmosphere, so as to establish a state of equilibrium.

Mr. Swann's article also contains a section upon atmospheric-electric measurements, including that of the penetrating radiation, which is somewhat too technical to be included in this brief account of his valuable researches.

ELECTRICAL CONCENTRATOR IN SULPHURIC ACID MANUFACTURE

AN electrical concentrator has been installed by the Chemical Construction Company at Mount Holly, N. C., and has been operated intermittently for several months with good results. During 1918 a one-ton capacity unit was installed at a chemical plant at St. Albans, W. Va.

This concentrator is designed for small capacities where electrical current is available and comparatively cheap. It consists of a small bath space built of acid-proof masonry in which are placed two electrodes of acid-proof iron spaced about 2 or 3 feet apart, the electrodes being adjustable. The bath of acid is also so arranged that the level may be lowered or raised. There is a dam of acid-proof masonry between the electrodes. The weak acid is fed in at one end of the furnace near the electrode and flows over the dam to an outlet at the other end. The electric current between the electrodes passes through the thin layer of acid flowing over the dam and heats this thin layer to the point where the water is evaporated at a rapid rate.—A. E. Wells and D. E. Fogg, Manufacture of Sulphuric Acid in the United States; 1920 Bureau of Mines Bulletin, No. 184.

TRANSMISSION OF ELECTRICITY FROM NORWAY TO DENMARK AND SWEDEN

THE possibility and practicability of harnessing the waterfalls in southern Norway and distributing 3-phase current of 50 periods at a pressure of 220 kilovolts to southern Sweden by aerial lines and to Jutland through a 45-mile long cable across Kattegat from Gothenburg to the Skaw, is discussed by Eivind Hanssen in *Teknisk Ukeblad*, June 11, 1920.

Sealand and Copenhagen could be supplied by extending the overhead line south across the Sound by a cable three miles long near Elsinore. The total length of the aerial line will be not less than 500 miles. The author admits that the highest voltage at present in use is 155 kv., but is of the opinion that an increase to 220 kv. would not cause insurmountable difficulties. Two American lines, which work at a pressure of 155 kv., have been found quite satisfactory, and it has recently been proposed to transmit 1.5 million kw. at a pressure of 220 kv. in one of them. The Norwegian-Danish line would, as a first installment, carry 155,000 kw., there being no difficulty in selling this output in Denmark.—Abstracted by the *Technical Review*.