Physics. — "*Electric phenomena in the atmosphere*". By Dr. J. CLAY. (Communicated by Prof. H. KAMERLINGH ONNES).

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§ 1. All investigators of the electric phenomena in the atmosphere agree that in the first place we want observations at different places and of long duration, as we have not yet a sufficient insight in these phenomena.

It seemed to me of importance to make observations at a place, where the meteorological states vary more regularly than in the temperate regions where until now most data have been collected. Especially I intended to investigate the different parts of the phenoma at the same time.

The different phenomena to be investigated are:

1st. the value and the variation of the electric charge of the earth, which can be determined by the potential gradient,

2nd. the charge and the conductibility of the atmosphere and their variation,

3rd. the percentage of emanation in the air and in the earth,

4th. the penetrating radiation of the earth and of cosmic origin. These two latter phenomena cause the ionisation of the air,

5th. the electric charge of the rain.

These are the electric phenomena that have been put on the preliminary working programme of the Bandoeng laboratory.

Since a few months we have started a photographic registration of the potential gradient, as well as also determinations of conductibility and number of ions, while preliminary experiments are made on the percentage of emanation, on the penetrating rays and on the electric charge of the rain.

§ 2. As to the potential gradient, this is determined by means of a ionium collector projecting 75 cm. above the *top* of the physical institute while the ridge itself is earthed by means of two thick iron wires.

The collector is isolated on amber, which has been dried by means of sodium brought into its immediate neigbourhood in a glass tube.

The connecting wire of the electrometer is lead through a glass tube; through the roof and the ceiling, it directly goes to the electrometer.

The electrometer has been made in the Bandoeng laboratory; it is a binant electrometer of the CURIE type but it has a fixed and a rotating cylinder instead of a box with a needle. Further it has the advantage that by means of a mirror the rotation of the cylinder can be registrated, while quite independently a second mirror makes continuous direct reading on a fixed scale possible.

In order to fix the absolute value we compared during several days the obtained values of the potential gradient with those found at different places of the open land belonging to the Technical Highschool. The reduction factor proved to be 2,2. This means that the value of the potential at the roof has to be divided by this factor.

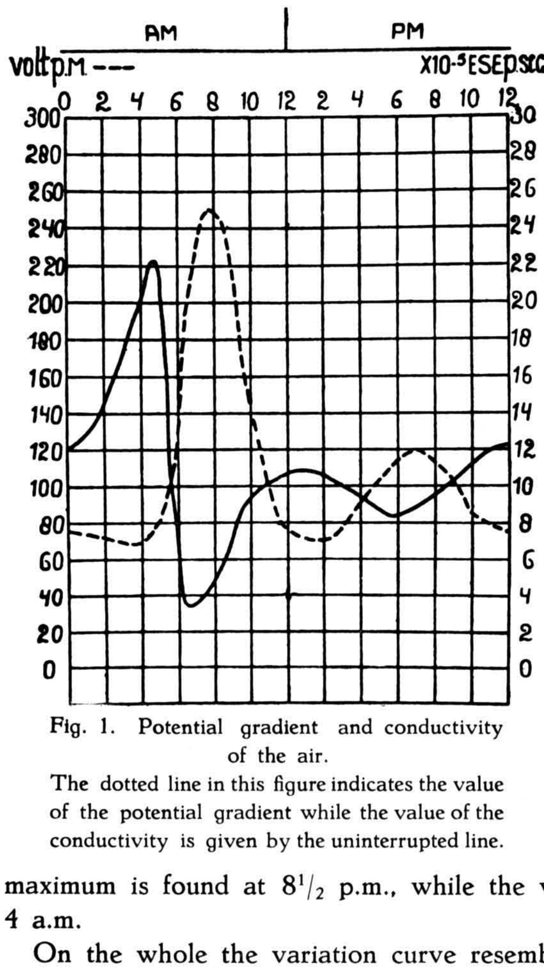

Fig. 1. Potential gradient and conductivity of the air.

The dotted line in this figure indicates the value of the potential gradient while the value of the conductivity is given by the uninterrupted line.

From fig. 1 we see the most striking feature of the diurnal variation of the potential gradient. It is a highly developed maximum at $8^1/_2$ a.m. local time. This maximum is about 2 to 2,5 times as high as the mean value over the day and about 4 to 5 times as great as the immediately preceding and following values.

The mean value is about 90 volt, the maximal value 250 volt pro meter.

A second much smaller maximum is found at $8^1/_2$ p.m., while the weak minimum lies of at about 4 a.m.

On the whole the variation curve resembles very much that found by KÄHLER in July at Potsdam. The only difference is that at Bandoeng the a.m. maximum is much stronger developed.

The time of this maximum does *not* agree with the results of the investigations of S. J. MAUCHLY [1]), who compares the data collected on the cruisades of the „Carnegie" through different oceans and also those found at the coast stations. He comes to the conclusion that the diurnal variation has a maximum which occurs for all stations at about the same time viz. at about 17 G.M.T. For Bandoeng this would be at about midnight local time.

The theory of EBERT explains the negative charge of the earth.

[1]) S. J. MAUCHLY. On the diurnal variation of the potential gradient. Terr. Magn. a. Atm. Electricity Vol. 28, p. 61, 1923.

According to it the high potential gradients should occur *after* the falling of the barometer, which does not agree at all with the Bandoeng results.

How to explain then the high maximum?

To this purpose we shall want in the first place other simultaneous data f.i. on the conductibility and the number of ions.

We have tried whether the great variation of the gradient is connected with the change of the degree of moisture. During the time of the measurements (dry season) the amount of water vapour varied from 6—9 in the morning on an average from 11.5 to 14.5 that is by 25 %. This might reduce the mobility of the ions somewhat, but not enough to explain the change of the conductibility.

In the meantime the relative degree of moisture fell from 90% to 50%.

§ 3. Finally we may remind that recently from different sides a connexion has been sought between the value of the potential gradient and the solar activity. HUNTINGTON's "Earth and Sun" (published in the beginning of 1924) gives a detailed account of these investigations. He wants to prove that it is of great importance to investigate the variation of the gradient in order to have a measure for the solar activity, which again strongly influences all meteorological factors.

March 1924 L. A. BAUER [1]) published a calculation according to which during the two last sun spot periods 1901—1923 a variation of the sun spot number by 100 corresponds to an increase of 20 to 35 % of the mean potential gradient. For the correlation coefficient he gives 0.75, which suggests an intimate connexion.

§ 4. The electric state of the atmosphere was determined by two different methods. First by measuring the dispersion of the electricity by a conductor of 14,4 cm. capacity connected with a bifilar Wulf electrometer. According to theoretical considerations of SWANN [2]) the form of the electrically charged body is of no importance, while the charge, emitted by a body with charge Q is given by $4\pi Q n e v$, where v denotes the mobility of the electric charges, e the charge and n the number of charges pro cm^3. When we write for the capacity of the conductor as far as it is surrounded by air C, for the capacity of conductor and electrometer together C_1, for the potential V, we have

$$-C_1 \frac{dV}{dt} = 4\pi C V n e v.$$

or integrated

$$C_1 \, lg \frac{V_1}{V_2} = 4\pi n e \, VCT,$$

[1]) L. A. BAUER. Correlations between solar activity and atmospheric electricity. Terr. Magn. a. Atm. Electr. March 1924 p. 23.

[2]) W. F. G. SWANN. The theory of electrical dispersion into the free atmosphere. Terr. Magn. a. Atm. Electr. Vol. 19. p. 81 1914.

when V_1 is the initial potential and V_2 the potential after T seconds.

By means of this formula $n e v$ can be calculated. This quantity is called the conductibility of the air. Both for positive and negative charges it was determined during several days with intervals of a few hours, so that the diurnal variation could be found. This conductibility too was proved to vary strongly.

From fig. 1 we see, that at four o'clock in the night a strongly defined maximum occurs, which is shortly followed (at about half past six) by a minimum. Generally the potential gradient has a maximum, when the conductibility shows a minimum, as might have been expected. It is of importance to find out which of the two is primary and perhaps the cause of the other. It is most suggestive that the variation of the potential gradient is caused by that of the conductibility.

It is interesting to investigate which is the cause of the variation of the conductibility as we have two factors that may undergo a change viz. the number of charges pro unit of volume and the mobility.

To this purpose it is desirable to determine at the same time both conductibility of the air and the number of ions pro cm^3., which may be done by the method of EBERT. We took a cylindrical tube of 1 m length and 15 cm. diameter in which an isolated tube is suspended.

The air is pumped through this tube, which is kept at a potential of 200—300 volt, so that *all* charges of the same sign are driven towards the rod, which is connected with a binant electrometer. The capacity of rod and electrometer as a whole is 75 cm. The sensibility of the electrometer is 120 mm. pro volt. Generally the charge is measured up to 200 mm. Before the natural leakage has been determined. The quantity of air pumped through the tube is sufficient to cause a charging of the electrometer to 1,66 volt in 1—2 minutes. The velocity of the air is controlled by a tested venturimeter.

In this way the charge of a definite kind of ions pro unit of volume of the air is determined directly, so that the quantity *ne* is known.

On different days the conductibility does not vary in the same way exactly as the number of ions, though these two quantities often correspond very well. So we found f. i. on one day for the ratio between the conductibilities at noon and at 8 a. m. 1,30, and for the ratio of the number of ions at the same moments 1,29.

From these data we find for the mean number of positive ions pro cm^3. 260 and for that of negative ions 220 both at noon.

Several recent researches suggest that the different variation of the mobility on different days is due to the different degree of moisture of the air. As has been found by J. J. THOMSON and stated by a recent research of NOLAN [1]) the ions are bound to small clumps of 14—36 water molecules, which give a mobility of resp. 1,87—2,24 cm. sec. pro

[1]) J. J. NOLAN. The constitution of gaseous ions. Physical Review July 1924 p. 16.

unit of potential gradient. The above mentioned value of 260 ions gave a mean mobility of 2,4 cm., which can be explained partially by the higher temperature and the lower pressure, compared with those used by NOLAN.

A better insight will not be possible before numerous other observations will have been collected.

§ 5. Further we must investigate by which ionising actions the ionisation of the air is maintained.

A few observations have been made already on the percentage of emanation of the air.

Through a second cylinder equal to the first one air was pumped during 2—3 hours, while the rod was kept at 1500 volt, so that the emanation settles down on the rod. Afterwards the loss of charge of the rod is measured. The quantity of air passed through the tube was known, while the loss of charge could be compared with that found, when a known quantity of emanation from a standard solution of RUTHERFORD was introduced into the tube. For the emanation we found in this way 3.10^{-19} Curie pro cm^3. This is a rather low value, which agrees with the small number of ions that was found.

§ 6. Incidentally the potential gradient and the conductibility were measured at some mountain tops of Java, from which then the number of ions was derived. We were struck by the exceedingly high gradient as well as by the fact, that the number of negative ions sometimes exceeded that of the positive ones.

On the Tjikoray (2824 m.) we found in October as 7 a. m. 400 volts pro meter, at noon 700 volt pro m. at 5 p. m. 800 volt pro m. Thus the variation is quite different from that on the plateau of Bandoeng.

In May we found on the Pangerango (3025 m) 350 volt at 7 a. m. gradually rising to 450 volt at 5 p. m. Both here and on the Tjikoray it was impossible to measure during the night because of the condensation of watervapour on the supporting rod by the strong heat radiation. For the number of ions pro cm^3. we found:

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October	Tjikoraj	2824 M.	347	425
May	Pangerango	3024 M.	207	365
June	Patoea	2400 M.	85	151
May	Weltevreden	10 M.	212	179
Aug.	Bandoeng	760 M.	260	220

These detached data do not yet allow many conclusions. It is only evident that generally the number of ions is small.

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