THE ELECTRICAL CONDUCTIVITY OF THE ATMOSPHERE AT TERRE HAUTE, INDIANA

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Introduction. Experiments having to do with atmospheric electrical conductivity date back to the time of Coulomb, 1785. He showed that if a metallic conductor be placed in air, it would lose its charge gradually, not only on account of faulty insulation but also on account of the conduction of electricity away from the body into the air.

Very little investigation, however, was carried on with reference to atmospheric conductivity for almost a whole century. We know that this is true because as late as 1880 the false idea that damp air conducts electricity better than dry air was very prevalent. As a matter of fact, it is probably an idea which is prevalent today *amongst* laymen and even *amongst* those scientists who are not fully aware of recent investigations upon the subject of atmospheric electricity.

If a metallic conductor, connected with an electroscope, is charged, a current begins to flow from all sides toward it. This can easily be seen by observing the fall in potential registered by the electroscope. If the conductor is charged positively, then negative ions move toward its surface, thus causing in the vicinity an excess of ions of this sign while the positive ions move away from it. In the neighborhood of the surface of the conductor a free space charge of the opposite sign is formed which causes a distortion of the field in that region.

Various methods have been employed in determining the polar conductivity of the atmosphere. In general, it seems that the greater the capacity of the dissipating body relative to that of the connecting rod, the greater will be the proportion between the dissipation and the conductivity. If the dissipating body be placed too near the electroscope free current will not be obtained. On this account it is best to connect the dissipating body to the electroscope by a long wire with a small capacity.

If K is the capacity of the dissipating body alone, C+K the capacity of the dissipating body and the electroscope together, and V, the initial potential of the system, the loss of the whole system per unit time amounts to $(C+K)\frac{dV}{dt}$.

The polar conductivity will be represented by the following equation:

$$\lambda \pm = \frac{1}{4\pi}\left(\frac{C+K}{KV\pm}\right)\frac{dV}{dt}.$$

Where λ stands for the conductivity and the + sign for λ corresponds to a negative charge on the dissipating body and vice versa, since it is always the ions of the opposite sign that cause the loss of charge of the body.

Description of Apparatus and Method of Procedure. The present experiment was carried out at the Indiana State Teachers College at Terre Haute, both in the Physics Laboratories and at points in the vicinity of the

Science Building during the summer of 1929. The observations were made over a period of about five weeks and since good weather is quite essential for such measurements, observations on the outside could not be made every day. However, enough outside observations were made to enable one to form a fairly definite conclusion as to the average conductivity both for positive and negative ions.

The apparatus consisted of an alpha ray electroscope which had been redesigned expecially for the purpose. In the first place the usual insulated key was found to be entirly too conducting. Therefore, this entire key was removed and a sulphur plug was inserted through which was led a small wire and this wire was connected to the gold leaf system. It was found by several experiments that the leakage due to faulty insulation due to the conductivity of the sulphur was quite negligible when compared to the values which were to be measured.

The electroscope was first calibrated to read in volts. The capacity of the electroscope was then experimentally determined in the following manner:

The electroscope was charged with a negative potential of from 600 to 700 volts. A sphere whose potential was O was brought in contact with the wire connected to the terminal of the electroscope. The quantity of electricity thus distributed itself over both the sphere and the electroscope. The voltage was again noted. From the data thus obtained from a number of observations the capacity of the electroscope was calculated.

If C_1 be the capacity of the electroscope, C_2 the capacity of the sphere, V_1 the potential of the electroscope, V_2 the potential of the combination, then

$$C_1V_1 = (C_1+C_2)V_2 \therefore C_1 = \frac{C_2V_2}{V_1-V_2}.$$

Two spheres whose capacities were 1.3 and 1.56 electrostatic units respectively, were used in a set of about twelve observations. A mean value of 3.33 electrostatic units was determined for the capacity of the electroscope.

The electroscope was now set up in the laboratory and an insulated spherical body whose capacity was known was connected to the electroscope by means of a wire, the capacity of which was known. A charge was then placed upon the insulated system and the deflection of the gold leaf of the electroscope was noted. Now the time rate of discharge of the electroscope was taken over a period of several minutes. The electroscope was first charged with one sign and then with the other and comparative values were noted.

The electroscope and the insulated system were now moved to another room and other observations were taken. The results of these observations are shown in the table following.

The electroscope and insulated system were then moved to a point well protected from the earth's field near the Science Building on the east side and again to a point on the west side of the Science Building, out in the open on the ground. Again the electroscope was moved to a point entirely removed from the Science Building and again care was taken to have the electroscope protected from air currents and other disturbing elements. The results of all these observations taken over a period of several days are shown in the table to follow.

It will be noted that one set of observations was taken on August 14 over a period of the entire day. Observations were taken several times during the hour and the mean for each hour of the day is indicated in the table. This was done in order to procure a diurnal curve Again the values for both negative and positive ions were taken.

DATA SHEET
Readings in Open Air

Time	Date	Place of Observation	$\lambda+$	$\lambda-$	$\lambda++\lambda-$	$\frac{\lambda+}{\lambda-}$
	Aug. 1	Between S. H. & Library	.93 x10^{-4}			
P.M. 1-3	Aug. 6	Between S. H. & Library		.99 x10^{-4}		
P.M. 3-5	Aug. 6	Between S. H. & M. D. Res	1.04 x10^{-4}			
P.M. 1-3	Aug. 8	Between S. H. & M. D. Res		1.05 x10^{-4}		
P.M. 3-4	Aug. 8	Between S. H. & M. D. Res	1.08 x10^{-4}			
P.M. 1-3	Aug. 13	538 North 5th Street	1.11 x10^{-4}	.87 x10^{-4}	1.98 x10^{-4}	1.28
A.M. 6	Aug. 14	538 North 5th Street	1.12 x10^{-4}	1.2 x10^{-4}	2.32 x10^{-4}	.93
A.M. 7	Aug. 14	538 North 5th Street	1.15 x10^{-4}	1.1 x10^{-4}	2.25 x10^{-4}	1.05
A.M. 8	Aug. 14	538 North 5th Street	.90 x10^{-4}	.9 x10^{-4}	1.8 x10^{-4}	1.
A.M. 9	Aug. 14	538 North 5th Street	.926x10^{-4}	1.08 x10^{-4}	2.006x10^{-4}	.86
A.M. 10	Aug. 14	538 North 5th Street	1.01 x10^{-4}	1.12 x10^{-4}	2.13 x10^{-4}	.98
A.M. 11	Aug. 14	538 North 5th Street	1.11 x10^{-4}	1.03 x10^{-4}	2.14 x10^{-4}	1.08
A.M. 12	Aug. 14	538 North 5th Street	1.2 x10^{-4}	1.15 x10^{-4}	2.35 x10^{-4}	1.04
P.M. 1	Aug. 14	538 North 5th Street	.99 x10^{-4}	.91 x10^{-4}	1.9 x10^{-4}	1.09
P.M. 2	Aug. 14	538 North 5th Street	1.01 x10^{-4}	1.03 x10^{-4}	2.04 x10^{-4}	.98
P.M. 3	Aug. 14	538 North 5th Street	1.18 x10^{-4}	1.07 x10^{-4}	2.25 x10^{-4}	1.1
P.M. 4	Aug. 14	538 North 5th Street	1.08 x10^{-4}	1.13 x10^{-4}	2.21 x10^{-4}	.96
P.M. 5	Aug. 14	538 North 5th Street	.91 x10^{-4}	.91 x10^{-4}	1.82 x10^{-4}	1.

Readings Inside A Room

Time	Date	Place of Observation	$\lambda+$	$\lambda-$	$\lambda++\lambda-$	$\frac{\lambda+}{\lambda-}$
P.M. 1-4	July 24	Room S-C-41	.5 x10^{-4}			
P.M. 1-4	July 26	Room S-C-41		.58 x10^{-4}		
P.M. 1-4	July 26	Room S-C-50	.48 x10^{-4}			
P.M. 1-4	July 30	Room S-C-50		.65 x10^{-4}	1.37 x10^{-4}	.8

Note: All values for $\lambda+$ and $\lambda-$ are the mean of several values taken within the indicated period.

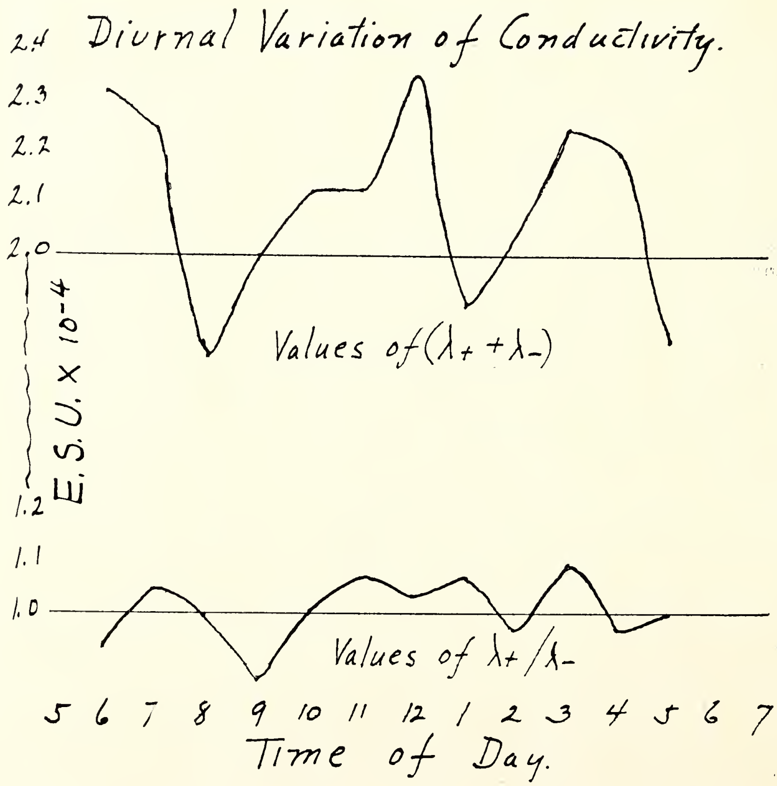
Remarks Concerning the Data Obtained. A study of the data submitted brings forth a few outstanding conclusions. It must be admitted, however, that not enough observations have been made in some instances to warrant any definite conclusions. In the case of the measurements made inside the laboratories it appears that the values of $\lambda+$ and $\lambda-$ are only about one half the values which are found outside, and since the building in which the measurements were made is somewhat filled with a network of pipes, it may be considered as partially shielded from atmospheric electrical effects. Therefore, no definite conclusions should be reached concerning the inside measurements. A further study, however, of these values might bring forth some facts upon which a definite conclusion might be reached.

A study of the values for the outside measurements in the table show that as a general rule the values for $\lambda+$ are greater than for $\lambda-$. This would indicate that there is usually an excess of positive ions in the locality where the observations were made. It may also be noted that the total conductivity $\lambda+ + \lambda-$ within a room, is only about one half of that outside, and the figures show that the values for $\lambda+$ are less than for $\lambda-$. It must be remembered, however, that the values for the conductivity in the laboratory were not obtained over a long enough period of time to be conclusive. The greater part of emphasis, therefore, in this paper should be put upon the values obtained on the outside.

A study of the values obtained for positive and negative conductivities on the outside reveals the fact that here the values for $\lambda+$ are larger than those for $\lambda-$, and this is in agreement with theory and with other experimental values obtained by other investigators.

The sum of the values indicated in the + and − columns may be taken as the total atmospheric conductivity at the time in question. It appears, therefore, that the mean of these values found on the outside is about 2.15 x 10^{-4} electrostatic units. This value is in close agreement with the values found over land in Europe which is about 2.1 x 10^{-4} electrostatic units. According to the measurements of the Department of Terrestrial Magnetism the mean value over the Continent of America is about the same as that of Europe. It may be pointed out, however, that the value obtained by the Department of Terrestrial Magnetism was arrived at by taking the average of several values found over the Continent of North America but the greater number of these observations were made in and around Washington and the Atlantic Sea Coast. Up to the present time no other measurements have been recorded for Indiana. It appears, therefore, that the mean values obtained in this experiment are in very close agreement with those found over Europe and with those found by the Department of Terrestrial Magnetism at Washington.

As was indicated in the Introduction, a series of readings was made over a period of twelve hours beginning at 6:00 a.m. and ending at 6:00 p.m. on August 14. Readings were taken for both the positive and negative values a intervals of about ten minutes. The values thus obtained were averaged for



each hour as is shown in the table and in the curves which follow. Figure 1 shows the diurnal curve for the day mentioned. This curve shows a variation of about $.45 \times 10^{-4}$ electrostatic units from the high period to the low period. The high points for the day are at 6:00 a.m., 12:00 noon, and between 3:00 and 4:00 p.m. The low points occur at 8:00 a.m., 1:00 p.m., and 5:00 p.m.

Further similar study indicates that the conductivity undergoes everywhere a regular daily change which is in general dependent upon the locality. It might be interesting, however, to conduct further studies of this character in the vicinity of the location where this experiment was carried on to see if this locality has a particular type of diurnal curve as regards its atmospheric electrical conductivity.