SOME ATMOSPHERIC ELECTRIC POTENTIAL-GRADIENT MEASUREMENTS AT HIGH ALTITUDE.

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Ever since the day of the famous kite experiment of Benjamin Franklin it has been known that electric phenomena associated with thunderstorms are identical with other electric phenomena associated with batteries, dynamos, etc. Since that time a great amount of research has been carried out in the field of Atmospheric Electricity.

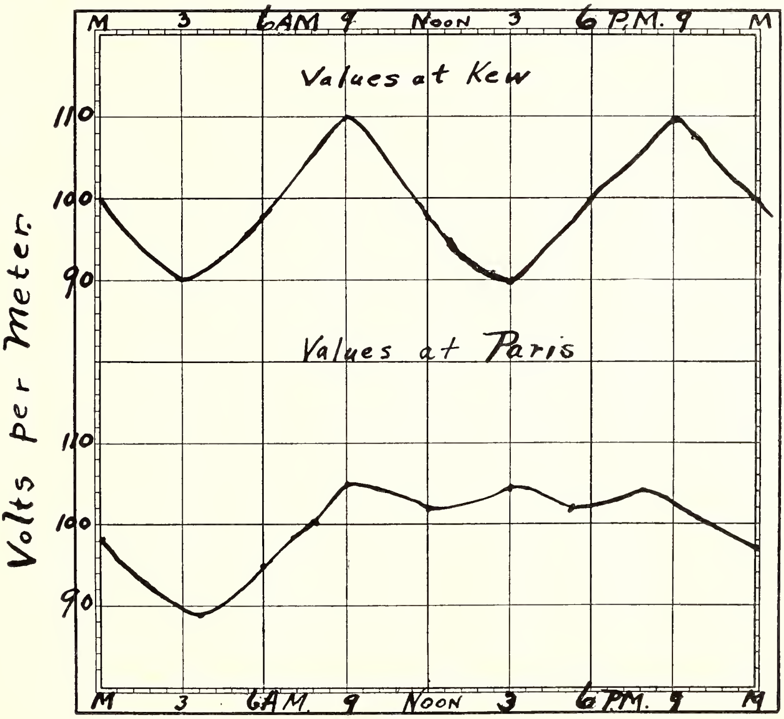

Fig. 1—Curves showing diurnal variations of the potential-gradient at Kew and Paris.

Since the latter part of the last century rather elaborate experiments have been attempted in an effort to associate the earth's residual magnetism and electric potential with electric potentials and charges in the atmosphere. In England, France, Germany and the United States land and sea with the result that we now have a rather complete set of expeditions such as that of "The Carnegie" have been carried out over

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experimental data dealing with this subject. The publications of J. H. R. Wilson, G. C. Simpson, L. A. Bauer, R. E. Watson and W. F. G. Swann have been devoted very largely to phenomena of this nature.

As a result of these experiments and others it is a well-known fact that at different points on the surface of the earth, different potentials exist simultaneously. These differences of potential are not usually of a high order of magnitude but when one takes readings of the potential at points in the atmosphere it is found that a vertical gradient exists which is of the order of 100 volts per meter at points near the earth. This potential-gradient becomes smaller as one ascends and finally becomes negligible at an altitude of a few miles above the surface of the earth.

It has been found that the values for the potential-gradient at such places as Kew Observatory, where a record covering many years has been kept, passes through a cycle of diurnal and annual variations. In general the values are higher in winter than in summer and the potential is of a positive sign. At Kew Observatory the diurnal curve shows maximum points at about 9 AM and 9 PM with well-defined minimum points at about 3 AM and 3 PM. The diurnal curve for values at the Eiffel Tower are similar for night values but vastly different for day values as is shown graphically in figure 1.

Curves showing values for other stations over the earth show variations of a great number. Most of them, however, bear similarities to one or the other of the two curves illustrated. As can be seen, the great difference in these two curves lies in the fact that in the Kew curve there is but one daytime maximum and one daytime minimum, whereas on the Paris curve there are two of each.

Most of the published data concerning the potential gradient are concerned with values near sea level, and in our own Rocky Mountain region very little work has been done along this line. During the summer of 1927 the writer availed himself of the opportunity afforded him by the generosity of the Physics Department at the University of Colorado to make some observations there. The elevation at Boulder is 5,380 feet and the climate there during the summer is especially well adapted to such work.

The recording apparatus used consisted of an Alpha Ray gold leaf electroscope which was redesigned for the purpose and which was extremely sensitive, having a capacity of only one centimeter. In order to determine the potential at a point in the air a brass rod, so designed that its length might be varied at will, was extended out of a window on the third floor of Hale Science Building. On the end of this pointed rod, a collector consisting of a glass bottle, which at one time contained radium, was fastened. This collector was very potent in ionizing the air near the point of the rod and thus the rod came to the potential of the point in the atmosphere in a very short time. Obviously the rod and conducting system were thoroughly insulated, and the case of the electroscope was earthed to a water pipe.

Observations were taken daily over a period of five weeks. These readings were taken at five-minute intervals in the main. Most of the observations were made between the hours of 6 AM and 8 PM. All points on the curves shown represent from twenty to forty observations. The three curves of figure 2 show the results for clear days, cloudy days and all days taken together.

The values represented by the curves for the potential-gradient at Boulder are absolute values. It has been pointed out by Chree[1] that the equipotential surfaces for regions in the vicinity of a long wall or the long side of a narrow building are such that at a point near the wall

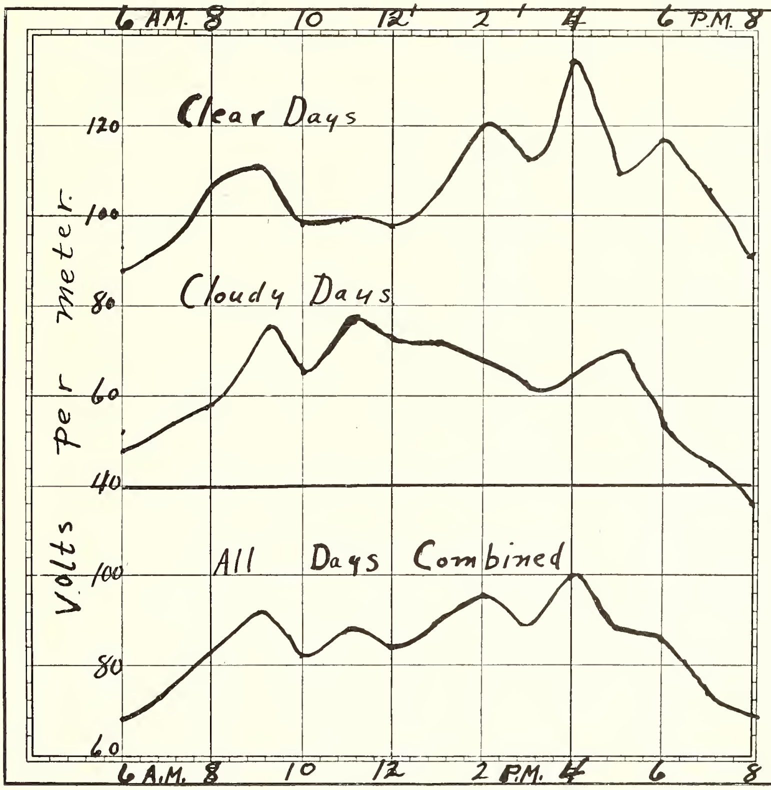

Fig. 2—Potential gradient curves for Boulder, Colorado, July-August, 1927. Diurnal variations.

and at a height .808, the total height of the wall, the values for the horizontal gradient may be substituted for the absolute vertical gradient values at points near the earth's surface and remote from the wall. Thus it was merely necessary to choose a window at approximately this height and keep a record of the distance of the pointed collector from the wall of the building. This distance was kept at three meters for most measurements.

As might be expected, the curves show a decidedly higher set of values for clear days than for cloudy days. The 9 AM maximum point

[1] Proc. Royal Society, vol. 91, p. 440.

shown in both the Paris and Kew curves is evident in the curves for Boulder. The early morning and late evening minimum points are also clearly shown, but as regards the values for the middle of the day the Boulder curves show no similarity to the Kew curve. The curve for clear days shows a very high maximum for mid-afternooon as does the Paris curve. The order of magnitude of the potential-gradient was about the same as those for Kew and Paris on clear days at the same

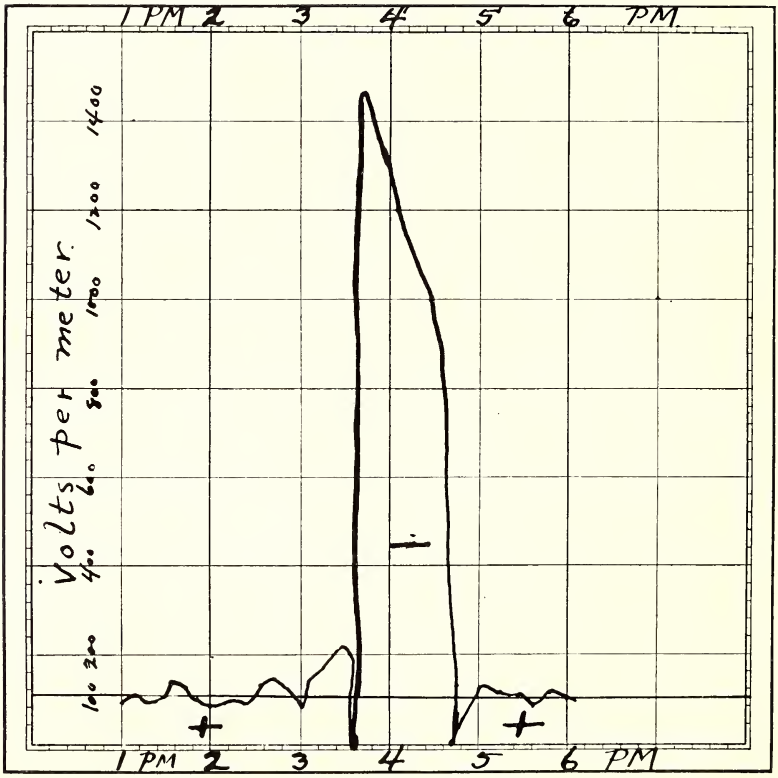

Fig. 3—Variations of the potential-gradient at Boulder, Colorado, during a thunderstorm, August 22, 1927.

period of the year. When all days are considered, however, as is the case at Kew and Paris, the mean values are about ten per cent lower than those at the above named places. The greater ionizing effect of the sun at higher altitudes will account for this, but the effect of the altitude is not as great as might be inferred.

While these readings were being taken an effort was made on three or four occasions to obtain values during a thunderstorm. In one case the effort was attended with remarkable success. The curve shown in figure 3 shows the record for the afternoon of August 22. At one o'clock the sky was absolutely clear and so remained until about 3 PM, when clouds began to appear from the mountains. The potential-gradient, which was of a positive sign, began to rise until about 3:30, when it suddenly dropped to zero at 3:35. Lightning was beginning to flash at intervals but no rain was falling as yet. At this point the potential-gradient changed sign to negative and rose rapidly until 3.47, when it had risen to 1,440 volts per meter. It dropped quite suddenly as the cloud passed and reached zero again at 4:45. Here it again changed sign to positive and rose to normal values. The sky had now cleared perfectly, as is the usual case in mountain storms. During the storm a few drops of water fell but the disturbance was of a very mild character.

This curve shows clearly what generally takes place when a thunder storm passes over. The potential of the atmosphere usually changes sign, as does the earth at this point, and the order of magnitude of the gradient becomes exceedingly high. Quantitative values are very difficult to obtain, however, and very few have been published.

In conclusion it occurs to the writer that since we are concerned nowadays so much with radio transmission and reception, a study of atmospheric electricity, especially with reference to the potential-gradient, might be of much use. It might be added furthermore that recent values for the potential-gradient at Kew show a decided tendency to become much greater since the war and this is attributed by Chree and Watson[2] to atmospheric pollution due to smoke from factories which have sprung up in the vicinity. Some correlation between smoke pollution of the atmosphere and the prevalence of destructive thunderstorms might be shown.

The writer wishes to acknowledge his indebtedness to Professors O. E. Lester, J. W. Broxon and W. B. Pietenpol of the Physics Department of the University of Colorado for their gracious assistance in furnishing the apparatus and for their kindly suggestions during the course of the research.

[2] Proc. Royal Soc. vol. 105—1924, pp. 311-333.