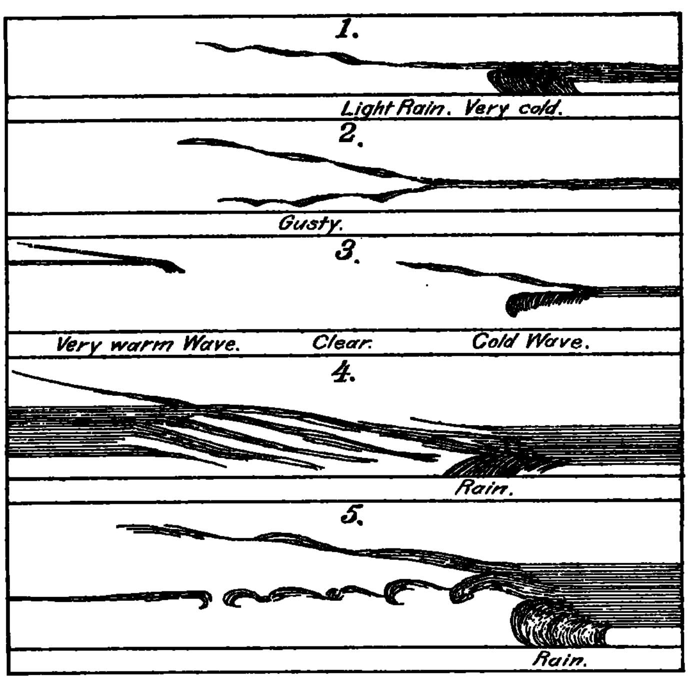
and composite centrifugal forces, which are due to the mobility of the reference axes. Two equal masses animated by different movements are, in the case of rotation, not subject to equal forces. In a convective zone (viz, where motion exists) the level surfaces are not parallel to the surface of quiet water; they are more concave toward the center of the globe. Pressure diminishes slowly from the center of such a zone toward its boundaries.

The surface of separation between two zones is the locus of the mutual intersections of level surfaces having the same numerical designation in the two zones [viz, the place of intersection of the equivalent contour lines in the two zones.—C. A.]. This surface can have any inclination whatever to the horizon; it is parallel to the axis of rotation of the earth if the densities are equal, although the velocities may be different. Two conditions are necessary for stability; one of these I shall call *thermic*, the other *dynamic*. The thermic condition requires that in going from the ground upward in the direction of the pole, but not in the direction of the vertical, one shall meet layers of air of decreasing density; the dynamic condition is that the velocity of the wind toward the east shall decrease as we traverse horizontally over the discontinuous surface (the surface of separation) in the direction of increasing latitude. In a ring of mixture [i.e., the belt along a small circle of latitude between the northern and southern components.—C. A.], where the relative proportion of the two components varies progressively, the dynamic condition is that the velocity of the wind toward the east shall increase less rapidly as we go from south to north than in a homogeneous ring in convective equilibrium.



The left hand side of this diagram is the polar side: Cold above, wind from the east.

The right hand side is the equatorial side: Warm above, wind from the west.

As to the position of the mixture, higher or lower in the atmosphere, this also depends upon two conditions, one thermic and the other dynamic. In the case of mixtures of two zones of dry air, the dynamic condition has a preponderating influence, since the specific volume of the mixture is then equal to the average of the specific volumes of the components; but this is not the case when there is any condensation, and especially when there is any evaporation, to even a limited amount. From this there results, at different altitudes, on the surface of separation of two unequally cloudy zones certain tendencies, sometimes concordant, but unequal, sometimes opposed to each other, to which I have devoted a somewhat minute discussion. The preceding figure represents an outline section of the five most important cases and explains itself.

During the many years that I have studied the sky, I have very frequently observed, in all their purity, the more typical forms of clouds in continuous zones occupying the whole sky. It was the almost complete absence of these forms from the International Cloud Atlas and the evident insufficiency of the descriptions in that atlas which, by exciting my curiosity, led me to undertake to study their theory. Hereafter, excepting any errors that I may have made in this study, the signification of any given aspect of the sky will be associated with a perfectly definite atmospheric condition as to the direction and force of the wind, the inequalities of distant temperatures, the relative altitudes and thicknesses of distant clouds, and the consecutive modifications of these conditions. We have no longer to do with personal and local experience, but with an analytical description of a small number of characteristics, easy to comprehend and applicable at every locality throughout the globe.

My very extensive memoir is at present in press and will appear in "Annales" of the Central Meteorological Bureau of France, 1898. The object of this short note is to point out to physicists the fact that the questions of general meteorology belong to their domain and merit their attention, and that however difficult they may appear they are not unsolvable.

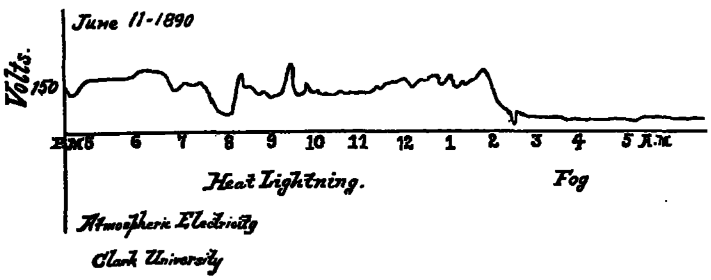
The types shown in the five sections of the accompanying diagram differ only as to the thickness and the elevation of the cloudy layers. In the neighborhood of the ground the variation of temperature with latitude is inverse to that which obtains in the upper levels; the ring of mixture extends around the earth on parallels of latitude nearly uniformly at the same level as that of the two zones throughout their whole extent; generally it rises to the upper part of the atmosphere on its polar side, and on its equatorial side descends to the lower atmosphere near the ground.

The more complicated types in which the variation of temperature with latitude has the same sign above and below, but the opposite sign at a medium altitude, are also described in the complete memoir; these give rise to thunderstorms.

CLIMATE AS A CONTROLLING FACTOR IN LONG-DISTANCE TRANSMISSION OF ELECTRICAL ENERGY.

By Alexander G. McAdie (dated August 27, 1897).

Those of us who have done any experimental work in atmospheric electricity, at a very early period in our experiments, learned the necessity of an almost perfect system of insulation, in dealing with the very high potentials likely to be encountered. In fact, with all our care, there is always a lingering suspicion in examining photographic records, that the running down of the voltage in foggy and damp weather was, in large measure, the consequence of the defective insulation due to a deposit of the moisture. The careful worker will always rigorously and frequently test his insulators. In the material, glass with sulphuric acid, and in the shape of the insulator, we strive to prevent any creeping or leaking of the charge. The Mascart table and suspension insulators which are now to be found in most physical laboratories are excellent and embody the principles upon which the future high-test insulators must be constructed. Since they were designed, however, both mica and quartz have come into commercial use, and it might be interesting to compare insulators made of these materials with the standard Mascart patterns. But even with a good insulator we must watch constantly the hygrometric condition of the air, for the insulation which is excellent in the afternoon may weaken materially during the night. I found it advisable at Clark University, some years ago, to keep an extra set of dry, clean Mascart table insulators always in readiness. Almost every morning, after tests, the insulators were exchanged with those under the collector which stood in a wooden shelter, projecting from a second-story window and exposed to the weather. Indeed, a very good hygroscope might be devised upon this variation of insulation with humidity. The accompanying diagram shows the potential curve obtained with a photographic Mascart electrometer and outfit. It is interesting to note the fall in



the potential with the occurrence of fog. This may have been a natural fall, for in the diurnal curve a minimum occurs about the time of sunrise; or it may have been, and in all probability was, brought about by the decreasing insulation. There are, however, different kinds of fog; so also, do we find different values of the potential at times of fog, and to some degree the electrometer takes note of the difference. Generally with fog, haze, and smoke there is a rapid fall from high positive to low positive or negative values. Dust whirls, because of frictional effects, give marked disturbances. But fogs, after fine drizzling rain, as a rule, give high positive values. On October 4, 1886, at the top of the Washington Monument during a light and seemingly dry fog, I obtained potentials of over 700 volts, and had no difficulty in drawing small sparks. Simultaneous observations were made at a station 450 feet lower, and potentials of 140 volts, on the average, were obtained. These were high values for this elevation and exposure. On the day following, about the same in general character except for the fog, the potential values were but one-half the former *at both stations.*

The great problem then in atmospheric electricity has been to preserve a high insulation in the apparatus. There is another question, viz, the breaking down of the air itself. For example, after the passage of an electric current, as in the case of a flash of lightning, the particular path is defective thereafter and allows easy escape of high surface charges. Then again, as Hallwachs, Elster, and Geitel, and others have shown, a negatively charged surface will discharge into air under the influence of ultraviolet light. What is of significance to the meteorologist, in these investigations, is the apparent relation, as Schuster points out,[1] "between the ultraviolet radiations and the amount of aqueous vapor present in the air."

Much could be said concerning these potential falls and the accompanying phenomena; but the object of the present paper is rather to trace the dependence of the industrial applications of electricity upon atmospheric conditions. More particularly the point is that electrical development is reaching a limit because of unsuitable insulation. In other words, so rapid has been the advance in the use of high potentials that the electrical engineer to-day is very nearly in the position of the experimenter in atmospheric electricity. He has to deal with potentials of enormously high voltage, and realizes that the successful transmission of the same will be determined largely by the insulation, and this in turn is determined by the weather.

[1] Lecture before Royal Institute, February 22, 1895.

Electrical journals are largely filled at present with accounts of the transmission of electrical energy from mountain streams to towns and cities many miles distant. For example, a power company with a plant in the mountains, contracts to deliver at a city 25 miles away, a three-phase alternating current of 2,500 volts pressure. Through the agency of step-up transformers the potential is sent up to 11,000 volts and transmitted thus, mile after mile in the open country. Reaching the city, it is transformed down, first to 2,000 or 2,500 and then again to 100 or less. In reading the description of such a system, one is attracted first by the step-up transformers. These cast iron, oil-filled, water-jacketed boxes are more or less at the mercy of the weather. Secondly, the large copper wires carrying the high potentials, must be very well insulated. As we read of triple-petticoated insulators, we recall the earlier struggles of the investigator of atmospheric electricity.

In further applications of high potential electricity then, there will be limitations because of atmospheric conditions. Will the meteorologist, with his knowledge of the physics of the air, come to the rescue and point out the proper directions for experiment with the aim of overcoming present difficulties?

That the views set forth above are not exaggerated, the following editorial from the Journal of Electricity of May, 1897, will prove:

* * * Science has well in hand the control of lightning, of static effects, and of the mechanical features that give permanence, safety, and reliability to overhead transmission lines, nor is difficulty experienced in the handling of line voltages at present used, but the barrier—thus far insuperable—to the employment of higher potentials is, as stated, embodied in the insulator alone.

Climate exerts a potent influence on the reliability of insulators, and so great is this influence that to it rather than to the insulator itself may be attributed the existing limitations to the commercial use of higher voltages. In addition to being a practically perfect nonconductor, the insulator should be wind, rain, snow, sleet, dust, and insect proof. Its reliability as a sure preventive against all possible sources of trouble should be absolute, for if susceptible to breakdowns, its weakness necessitates the duplication of the transmission lines that no interruption to service may occur in making repairs. The saving in copper which will result from the invention of a perfect insulator would be twofold in that it would enable the use of higher voltages and require only a single transmission line. Truly may it be said that unlimited reward awaits the inventor of a perfect high-tension insulator.

ATMOSPHERIC ELECTRICITY: ITS ORIGIN, VARIATIONS, AND PERTURBATIONS.

By Prof. Marcel Brillouin, of the École Normale Supérieure of Paris.

[Translated from the Revue Générale des Sciences pures et Appliquées, August 30, 1897; and from Ciel et Terre, October 1, 1897.]

The origin of atmospheric electricity still remains quite unknown; the suggested theories all rest upon properties that are hypothetical or even contradictory to experience. It has long seemed to me that the action of the ultraviolet radiations from electrified bodies furnishes an entirely satisfactory explanation, assuming only that ice acts in the same way as metals; as to this latter assumption I was able to satisfy myself during this past winter.

The following lines give a brief synopsis of this physical theory of the electric phenomena of the atmosphere:

1.—In 1887 Herz discovered that the electric discharge occurs more easily under the action of ultraviolet light than in the dark. In 1888 Wiedemann and Ebert showed that this action takes place at the "cathode" or negative electrode; that its effect is a maximum when the air is under a pressure of about 300 millimeters of mercury; according to Arrhenius the maximum occurs when the air is under a pressure of 6 millimeters, but according to Stoletow, at a pressure that varies very nearly in proportion to the intensity of the electric field.