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Studies in Atmospheric Electricity.

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With Plates I—IV.

GENERAL DESCRIPTION.

The facts to be discussed below have been obtained chiefly from the "Report on Observations in Terrestrial Magnetism and Atmospheric Electricity made at the Central Meteorological Observatory of Japan for the Year 1897," though some are from the original photographic records preserved in that observatory. The observatory, whose coördinates are $\phi = 35° \, 41'$ N., $\lambda = 139° \, 45'$ E., occupies a portion of the old castle of Yedo, and thus stands pretty well out of the direct effect of the dust and smoke of the city. The collector for atmospheric electricity is a water-dropper whose nozzle is 2 m. from the wall of the building and 1.7 m. above the ground. The photographic record is given by a Kelvin-Mascart's self-recording electrometer. The time refers to the central standard time, *i.e.* the mean time for the meridian 135° E. Other details with regard to the observation and réduction will be found in the first pages of the Report.

Every one looking at the photographs will be struck by the most irregular and capricious manner, in which the potential varies from instant to instant. (See PL. I.) This fact, together with the observations of Lord Kelvin and others that at two stations distant from each other by more than 100 m., no similarity in the variations could be detected, suggests to us that the principal causes of the phenomenon are located not very far from the earth, but perhaps within a few kilometres from, and possibly just near the surface.

On examining the figures given in the Report, we see at once that the cold seasons show a decided tendency to have higher potentials than the warm. While fully recognizing this tendency, we feel some hesitation in accepting these figures as representing the genuine values of the potential at all seasons. Probably defective insulation of the instrument in the warm and wet season has some part in the effect.

Undoubtedly the diurnal variation is much more faithfully represented. Here we see two maxima and two minima, somewhat resembling the variation of the atmospheric pressure, with which the phenomenon has probably a close connection. As to the time of

	Min.	Sunrise	Max. (Volt)	Min. (Volt)	Sunset	Max.
Jan.	3.45 a.	6.50 a.	7.45 a. (171)	2.30 p. (47)	4.50 p.	9.00 p.
Feb.	3.00 a.	6.29 a.	7.45 a. (143)	noon (22)	5.21 p.	10.00 p.
Mar.	4.15 a.	5.52 a.	6.45 a. (104)	3.00 p. (12)	5.47 p.	10.45 p.
April	2.00 a.	5.10 a.	6.15 a. (119)	3.00 p. (5)	6.13 p.	12.00 p.
May	—	4.39 a.	6.15 a. (74)	2.30 p. (4)	6.37 p.	—
June	3.00 a.	4.27 a.	6.00 a. (49)	1.00 p. (3)	6.55 p.	9.00 p.
July	2.00 a.	4.39 a.	6.00 a. (21)	2.15 p. (3)	6.53 p.	9.00 p.
Aug.	2.00 a.	5.01 a.	6.15 a. (14)	2.45 p. (2)	6.27 p.	8.45 p.
Sept.	3.00 a.	5.25 a.	6.45 a. (19)	2.00 p. (2)	5.46 p.	12.00 p.
Oct.	2.00 a.	5.50 a.	7.00 a. (103)	noon (25)	5.05 p.	9.00 p.
Nov.	3.15 a.	6.18 a.	7.30 a. (108)	2.15 p. (38)	4.35 p.	10.00 p.
Dec.	3.45 a.	6.44 a.	8.00 a. (188)	2.45 p. (42)	4.30 p.	10.00 p.

occurrence of the extreme values in each monthly mean, we have the accompanying table.

Thus we see that the morning maximum occurs a little more than one hour after sunrise, throughout all the seasons. The fact that this maximum occurs much more regularly than the other extreme values, is not confined to the monthly means, but also exhibits itself in daily values. For, it generally deviates only an hour or two from one day to another, while the evening maximum, for instance, may occur at 7 p.m., or not be reached even at midnight. This fact is at least one of the causes which make the morning maximum so conspicuous in the diurnal variation curve in each month.

THEORIES.

Before proceeding further to examine the relations of the potential to other meteorological phenomena, it will be well here to recapitulate briefly some of the theories of atmospheric electricity, and to state the author's view in accordance with which be wishes to discuss those relations.

Perhaps the oldest of the theories still held is that of Erman (1803) and Peltier (1836), which supposes the earth to have an inherent negative charge. Among the modern supporters of this theory we find Exner, who, while ascribing the primary cause of atmospheric electricity to the earth's inherent charge, strives to explain its variations as being due to the action of the aqueous vapour, which in evaporating from the earth's surface, carries more or less negative charge with it,[1] the latter supposition being founded on

1) Exner, Sitzungsberichte d. Wiener Akad. d. W. **93.** p. 222. 1886; **96.** p. 419. 1837; **97.** p. 277. 1888.

an experiment of Mascart's, who observed (1878) that the evaporation took place more rapidly from an electrified liquid than from a neutral one.

Edlund's theory[1] of unipolar induction considers the earth as a rotating conducting sheath, within which a magnet is situated. The induction, as he calculates, causes positive electricity to accumulate in the upper atmosphere, which is the origin of atmospheric electricity.

Sohncke[2] ascribed the cause of atmospheric electricity to the friction of ice on water particles, whereby, as was first shown by Faraday[3] and afterwards ascertained by Sohncke,[4] ice becomes positively and water negatively electrified. Thus the layer of air lying above the isothermal of 0° and carrying ice spicules, becomes pesitively electrified by friction with the layer lying below the isothermal and containing water particles, and the negative electricity of the latter partly passes down to the earth through precipitation.

The photoelectric theory, which was first proposed by Arrhenius,[5] and then somewhat modified and fully developed by Elster and Geitel,[6] considers that the negative electricity of the earth's surface is dissipated in the atmosphere by the action of the ultraviolet light from the sun. Some relations are traced between the seasonal and diurnal variations and the intensity of the solar radiation.

The so-called ion-theory of atmospheric electricity was first suggested by J. J. Thomson,[7] during his investigation on the charge

1) Edlund, Actes de l'Academie des Sciences de Suéde, **XVI**. 1878.

2) Sohncke, Der Ursprung der Gewitter-elektricität und der gewöhnlichen Elektricität der Atmosphäre, Jena. 1885.

3) Faraday, Experimental Researches, **II**. p. 106.

4) Sohncke, Wied. Ann. **28**. p. 550. 1886.

5) Arrhenius, Meteorologische Zeitschrift, **5**. p. 297. 1888.

6) Elster und Geitel, Sitzungsberichte d. Wiener Akad. **101**. p. 703, 1892.

7) J. J. Thomson, Phil. Mag. **XLVI**. p. 533. 1898.

of electricity carried by the ions produced by Röntgen rays, in the following terms. "If the negative ions, say, were to differ in their power of condensing water around them from the positive, then we might get a cloud formed round one set of ions and not round the other. The ions in the cloud would fall under gravity, and thus we might have separation of positive and negative ions, and the production of an electric field, the work required for the production of the field being done by gravity." C. T. R. Wilson[1] actually found that it requires a greater expansion to produce a cloud on positive ions than on negative ones, and he considers that if ions ever act as condensation nuclei in the atmosphere, it must be mainly or solely the negative ones which do so, and thus a preponderance of negative electricity will be carried down by precipitation to the earth's surface. Elster and Geitel[2] observed that an isolated charged body gradually loses its electricity when exposed to the atmosphere, the negative electricity being, generally speaking, the more quickly dissipated. They investigated the phenomenon under various circumstances, and came to the conclusion that solar radiation gives a kind of conductivity to the air, by generating in it some minute nuclei capable of carrying electric charges, which they called *ions*. Of these the negative ions move more quickly than the positive, and soon reach conductors such as the earth's surface, and give up their negative charge, while the positive ions remain and accumulate in the atmosphere. Thus the usual electric condition of the atmosphere is set up and maintained. Ebert[3] repeated the experiments in balloons and found that the rate of dissipation is greater in the higher altitudes

1) C.T.R. Wilson, Phil. Trans. 1899, or Nature **LXII**. p. 149. 1900.

2) Elster u. Geitel, Terr. Mag. **IV**. 1899, or Ann. d. Phys. **2**. p. 425. 1900.

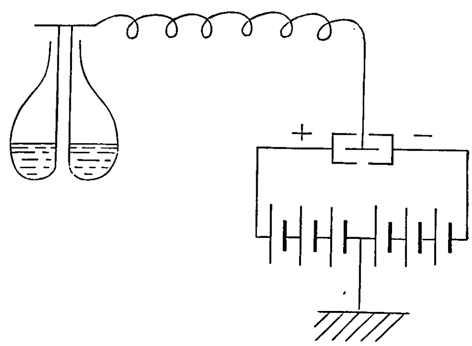
3) Ebert, Sitzungsberichte d. mathem.-phys. Classe d. kgl. bayer. Akad. d. W. **XXX**. p. 511, 1900; **XXXI**. p. 35. 1901.

and also that the rate gradually tends to become independent of the sign of the charge.

Now all of the above mentioned theories are based on experiments, and the actions or processes contained in them may actually take place in the atmosphere. The only question is that of the competence. For my part, I feel convinced that friction is by far the most effective cause of electrification. It is my main object here to see how far we can explain the manifold phenomena in atmospheric electricity by the friction theory alone.

EXPERIMENTS.

First of all, in order to assure myself, how different objects become electrified, I made the following experiments. I took a Kelvin-Mascart's electrometer, whose quadrants were charged by a water battery, the middle point of which was connected with the earth. To the needle was connected one end of a fine wire, the other end of which was put on a Mascart's insulator. The sensibility of the needle was about 0.17 volt per division of the scale.



Experiment I.—The friction of sand particles with leaves, twigs, wood, etc. These objects were placed one by one upon the Mascart's insulator, and from a metallic funnel suspended by silk thread, a stream of fine sand was poured down against them, so as to electrify them by friction. In each case, the electrometer showed a positive electrification. These objects were then disconnected from the wire, and held by a separate stand over the insulator. A stream of sand passing down against them, was received by a plate on the insulator. The electrometer showed negative electrifications. From these experiments we may conclude that the above named objects become positively, and sand negatively electrified by their mutual friction.

Experiment II.—The friction of water particles with leaves, twigs, wood, etc. These objects were placed upon the insulator, and to them was directed a jet of steam from the finely drawn out end of a horizontal glass tube 1.5 m. long, whose other end was bent down into a flask of boiling water. The electrometer showed slight negative electrifications of these objects, except in one case, namely dry ice, which showed itself positively electrified. Though this group of experiments gave results with less degree of certainty than the rest, I contented myself with them ; for exactly the same results had been already obtained by many investigators. For instance, Faraday[1] proved in his famous experiments conducted for the explanation of Armstrong's hydroelectric machine, that water becomes positively electrified by friction with many substances, for instance, ivory, quartz, glass, etc.; but becomes negatively electrified by friction with dry ice. Elster,[2] in investigating the electromotive force excited in a stream of water, showed that the electrification took place solely where the water was in contact with solids such as mica, agate, caoutchouc, wax, glass, porcelain, etc., and where the water mass experienced friction, and that the electrification was such that water acquired positive electricity with regard to these substances. Again Sohncke[3] proved that ice became positively electrified by friction with water, and also that ice was positive against all the substances he tried, e.g. steel, brass, glass, dust in the air, etc.

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1) Faraday, Experimental Researches, **II**. p. 106.
2) Elster, Wied. Ann. **6**. p. 553. 1879.
3) Sohncke, Wied. Ann. **28**. p. 550. 1886.

Experiment III.—The contact of hot and cold air. A piece of lighted candle was placed on the insulator, so as to serve as a collector. When a gas flame was brought near it, the electrometer showed a negative electrification, amounting to 10 divisions or more. When, however, the gas was opened unlighted, no electrification was observed. Not only the gas flame, but the flames of lamp and candle, and even a heated piece of iron, produced the same effect of negative electrification. The same effect, though in much less degree, was obtained when a current of warmed air was sent against the collector. The opposite effect, *i.e.* positive electrification was obtained, when a current of air cooled by a freezing mixture, was blown against the collector. These experiments show that when two masses of air at different temperatures are in contact with each other, the hotter one becomes negatively and the cooler one positively electrified. In order to verify this rather important conclusion, I caused two adjoining rooms to have temperatures of 10° and 20° respectively, and placed the candle flame collector on the insulator just near the connecting door. On slightly opening the door, the flame was at once blown towards the warmer room, and the electrometer showed an increase of potential, which was precisely the result expected.

Now as is well known, such experiments on statical electricity are usually associated with a greater or less degree of capriciousness and uncertainty, and, I confess, my case was no exception. It must be added, however, that the experiments were repeated over and over again, and that nearly all the eye observations of the electrometer were carried out by my two assistants, who had not been informed of what I was expecting to obtain.

EXPLANATIONS OF SEVERAL PHENOMENA.

In explanation of the general distribution of atmospheric electricity, I agree with Sohncke. Only I consider in addition, that the contact of warm and cold air, the intensity of wind, and the amount of dust are circumstances having no in-considerable bearing upon the phenomena, especially upon the seasonal and diurnal variations. Against Sohncke's theory, it has been objected that in winter it is not seldom that the isothermal of 0° does not lie at all within the atmosphere, and the explanation of the high potential at a low temperature much below the freezing point, seems to present an insurmountable obstacle to the acceptance of this theory. Again that, if an inversion of temperature occurs, so that the freezing point is reached at a cetain height from the surface, the potential gradient will become negative, a result utterly contrary to experience.[1]

To the first objection we may reply that probably the isothermal of 0° always exists in the atmosphere, when the weather is calm and the sky is clear. Some instances of temperature measurements in balloons, which point to the above conclusion, may be mentioned.

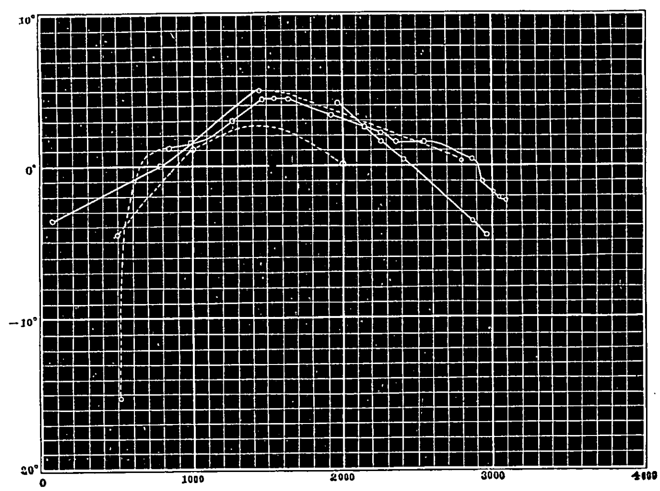
On Nov. 10, 1900, after a few days' continuance of calm and anticyclonic weather, and under a perfectly clear sky, Ebert[2] in Münich measured the following temperatures: 4°.2 at 1975 m. (8.56a.–9.11a.); 2°.7 at 2160 m.; 1°.7 at 2275 m.; 0°.5 at 2420 m.; –3°.8 at 2890 m.; –4°.7 at 2965 m. (10.38a.–10.53a.). On Jan. 17, 1901, under similar conditions, the same observer[3] measured: –15°.2 at the surface (524 m.?); 1°.2 at 842 m.; (9.18a.); 1°.6 at 995 m.; 3°.0 at 1275 m.; 4°.4 at 1470 m. (10.02a.–10. 17a.); 4°.5 at 1550 m.; 4°.3 at 1650 m.; 3°.3 at 1930 m.; 2°.1 at 2285 m.; 1°.7 at 2375 m.; 1°.7 at 2560 m.; 0°.3 at 2880 m.; –1°.0 at 2930 m. (0.11p.–0.17p.);

1) Elster u. Geitel, Zusammenstellung d. Ergebnisse neuerer Arbeiten ü. atmosphärische Elektricität. p. 11. 1897.

2) Ebert, Sitzungsberichte d. mathem.-phys. Classe d. kgl. bayer. Akad. d. W. **XXX**. p. 511. 1900.

3) Ibid. **XXXI**. p. 35. 1901.

–1°.9 at 3005 m.; –2°.2 at 3105 m.; –2°.1 at 3060 m. Again on the occasion of the international balloon ascents on Jan. 10, 1901,[1] a balloon from Vienna recorded the following temperatures: –4°.6 at



500 m.; 1°.2 at 1000 m.; 0°.2 at 2000 m. Another from Berlin recorded: –3°.6 at the starting; 0°.0 at 790 m.; 5°.0 at 1460 m.; 0°.2 at 2825 m.

Of course these will differ somewhat from the minimum temperatures of the day at the respective altitudes. But the difference, I believe, will be at most only a degree or two; for according to Hergesell,[2] the diurnal variations of the temperature at higher altitudes are very small, amounting, for instance, to 3° or 4° at 800 m., when the sky is clear, and much less when it is overcast. Also the days on which the above mentioned ascensions were made may be regarded as typical winter days with high pressure and severe frost on the ground, so that we may believe that the atmospheric conditions then observed are normal, and not exceptional. The meteorological

1) Nature **LXIII**. p. 353. 1901.

2) Hergesell, Petermann's Geographische Mitteilungen Pt. **V**. 1900.

observations on Mount Tsukuba during January and February, 1893,[1] point to similar results. There the inversion of temperature was observed mainly during the night time when the sky was clear, namely, when the temperature at the lower regions was falling very low. Considering all these circumstances, I believe that it is not too much to say that under normal conditions a certain layer of air, say between 800 m. and 2000 m. or 3000 m., has temperature above 0°, even if the temperature near the surface be several degrees below 0°.

The second objection has no significance. For, if the general distribution of atmospheric electricity be already determined by the isothermal of 0° and other circumstances, and if then the earth's surface and layer of air near it be gradually cooled by radiation, so that the temperature sinks below 0° and there is formed a *second* isothermal of 0°, there can be no other result than the augmentation of the potential of the air near the ground.

EFFECT OF WIND.

Strong wind is generally accompanied by a low potential. Especially when the wind is strong enough as to raise dust in the atmosphere, the potential becomes negative even under a perfectly clear sky. (See Fig. 2.) It is worthy of notice that the potential remains positive, however violent the wind may be, provided the ground be wet with the previous precipitation and in consequence the dust does not rise in the atmosphere.

We may explain the phenomena by considering that the friction of dust particles on terrestrial objects gives a negative charge to the former and a positive to the latter, as Experiment I shows.

The following instances are picked out of the Report.

1) Annual Report of the Central Meteorological Observatory of Japan for the Year 1893. Pt. II, p. 62.

Jan.	2.	N.	strong wind,	potential neg. 10a.-11a.
Jan.	16.	N.	strong wind,	potential low but pos. (*snow on 14th rain on 15th.*)
Feb.	2.		gale at M. N.,	potential low but pos. (*rain on 1st, 2nd.*)
Feb.	7.	W.	strong wind,	potential neg. 11a.-3p.
Feb.	11.	N.W.	gale,	potential neg. 10a.-4p.
Mar.	5.	N.	gale 3p.	potential pos. (*rain on 4th, 5th.*)
Mar.	6.	N.	gale -5a.	potential pos. and nearly constant.
Mar.	10.		gale,	potential pos. (*rain on 9th, 10th.*)
Mar.	11.		gale,	potential pos.
Mar.	13.		gale,	potential neg. 9a.-3p.
Mar.	24.		gale,	potential neg. 9a.-5p.
Mar.	31.		gale,	potential pos. -4 at 4p. (*rain on 30th.*)
April	7.	N.	gale,	potential neg. 2p-5p. (*rain on 6th.*)
April	10.		gale,	potential pos. but low towards after-noon. (*heavy rain on 9th.*)
April	11.	N.	strong wind,	potential neg. 1p.-5p.
April	22.		strong wind,	potential neg. 2p.-4p.
April	31.	S.	strong wind,	potential neg. 0p.-5p.
May	2.	S.	strong wind,	potential neg. 9a.-3p.
May	7.	S.	gale,	potential neg. 0p.-
May	15.	S.	strong wind,	potential neg. 8a.-5p.
May	22.	N.W.	gale,	potential neg. 0a.-5p.
May	28.	S.	strong wind,	potential neg. 10a.-5p.
May	29.	S.	strong wind,	potential neg. 11a.-2p.
June	2.		strong wind,	potential neg. 11a.-3p.
June	21.	S.	strong wind,	potential neg. 0p.-6p.
Oct.	30.	N.W.	gale from eve.,	potential neg. 8p.-
Oct.	31.	N.W.	gale,	potential neg. 0a.-4a., 9a.-1p.

Nov. 18. N. gale,	potential positive, but low towards afternoon. (*rain on 17th.*)
Nov. 25. N. gale,	potential low but pos. (*rain on 24th.*)
Dec. 27. N.W. gale,	potential neg. 10a.–4p.
Dec. 29. N. gale,	potential neg. 3p.–4p.

EFFECT OF FOG AND HAZE.

Mornings with fog or haze are generally characterized by a high potential with energetic fluctuations. (See Fig. 3.) Sometimes there are no sensible effect, and this we find mostly in cases when the ground is wet through previous precipitation. (See Fig. 4. and 5.) We may think that when the ground is dry, the particles of water become electrified positively with respect to the earth, while if the ground be wet, no electrification is produced.

A few instances are adduced.

Mornings with fog :—

Jan. 8. potential very high ;	April 6. potential high ;
June 18. potential high ;	June 29. potential high ;
July 25. potential high ;	July 26. potential very high ;
July 27. potential very high ;	Oct. 4. potential normal ;
Oct. 30. potential very high ;	Nov. 20. potential low (*rain on 19th*) ;
Dec. 3. potential high ;	Dec. 9. potential high ;
Dec. 10. potential high.	

Mornings with haze :—

Jan. 23. potential very high ;	Feb. 5. potential very high ;
Feb. 12. potential very high ;	Feb. 13. potential very high ;
April 8. potential high ;	April 23. potential very high ;
Dec. 10. potential high.	

EXCESSIVELY HIGH POTENTIAL.

If we pick out the days on which the potential was excessively high, we see that they are almost always days on which the temperature was excessively low. This result is not difficult to explain, for, as we have seen, the cold air will be positively electrified by contact with the warm air.

Here are a few instances.

Jan.	3.	0a.-12p.	clear	temp. low.
Jan.	8.	0a.-8p.	cloudy	temp. low.
Jan.	10.	4a.-12p.	fair	temp. low.
Jan.	26.	7p.-27. 11a.	cloudy	temp. low.
Jan.	28.	7p.-29. 6a.	cloudy	temp. low.
Feb.	5.	6a.-6. 9a.	clear	temp. low.
Feb.	8.	0a.-12p.	fair	temp. low.
Feb.	9.	0a.-11a, 8p.-11p.	fair	temp. low.
Feb.	13.	0a.-10a.	clear	temp. very low.
Mar.	6.	0p.-	clear	temp. low.
Mar.	14.	6a.-12p.	fair	temp. low.
Mar.	24.	5a.-12p.	clear	temp. low.
Mar.	25.	0a.-6p.	fair	temp. normal.
Mar.	29.	0a.-12p.	fair	temp. low.
Apr.	1.	0a.-1p.	cloudy	temp. normal.
Apr.	8.	0a.-9a.	clear	temp. low.
Apr.	23.	0a.-8a.	clear	temp. low.
May.	23.	0a.-1p.	cloudy	temp. low.
May.	26.	0a.-12p.	clear	temp. low. except 7a.-4p.
Oct.	15.	4a.-12p.	cloudy	temp. normal.
Oct.	20.	0a.-12p.	clear	temp. low.
Oct.	30.	0a.-3p.	fair	temp. normal, dense fog.

Nov.	2.	0a.–12p.	clear	temp. low.
Nov.	3.	0a.–12p.	clear	temp. normal.
Nov.	14.	0a.–12p.	clear	temp. low.
Nov.	30.	0a.–11a.	fair	temp. low.
Dec.	2.	5a.–12p.	fair	temp. low.
Dec.	18.	0a.–10a.	clear	temp. low.
Dec.	19.	0a.–12p.	fair	temp. low.
Dec.	30.	5a.–11a.	clear	temp. low.

EFFECT OF RAIN.

When the rain is moderate and the drops fine, the potential keeps very low positive values with only slight variations. When a down-pour takes place with sufficient violence, the potential becomes at once negative, and exhibits very irregular and energetic variations. As soon as the violence of the rain diminishes, the potential regains its positive value. (See Fig. 6.) These phenomena can all be explained in accordance with Lenard's investigation on the electricity of waterfalls.[1] Lenard proved by a series of the most conclusive experiments, that when a stream of pure water falls upon a metallic or other conductors previously moistened, the water droplets splashing in all directions become positively, and the air near them negatively electrified. There is no difficulty in applying this result to explain the negative potential in the case of a steady down-pour of rain. The summer rain gives sometimes a positive as well as a negative potential with violent variations. This is no doubt due to the proper charge of the rain drops, whose formation is probably something different from that in the case of the usual cyclonic precipitation. Usually a peal or two of thunder will be heard on such an occasion.

1) Lenard, Wied. Ann. 46. 1892.

EFFECT OF SNOW.

In the case of a snowfall, the variation is much more regular, though no less energetic, than in the case of rain. The potential now increases in the positive direction, then decreases to zero and to extreme negative values, and then back again, etc. (See Fig. 7.) Whence may come such a quasiperiodic nature? As a matter of fact, the snowfall is attended with a greater or less periodicity; thus during one interval, there will be a heavy fall of fine snow; during next time the violence decreases and there will fall only scattered flakes. May not this fact have some connection with the above described manner of variation? On Feb. 25, 1901, there was a steady snowfall in the afternoon, and at 2 p.m., I measured the potential of the air outside the laboratory, and found it to be positive. At 4 p.m. the fall began to be scanty, and at 4.20 p.m. the potential was again measured, and was found to have a very great negative value. Since this was the only occasion I experimented on, it is unsafe to draw any conclusion from it, and I hope to make similar observations on the next available occasion.

ABNORMAL INDICATIONS.

There were two remarkable instances (see PL. IV) in which the potential showed abnormally great variations in both directions, positive and negative, while there was no precipitation, no thunder and no lightning. On May 26, a little before 4 p.m. the potential began to decrease suddenly, reaching extreme negative values at and near 4 p.m. Then it began to rise and crossed the zero-line at 4.20 p.m. and then as suddenly increased to reach its extreme positive value a little before 5 p.m. It then began to decrease, became negative again at and near 5.30 p.m., and then increased, and recovered its usual course at 6 p.m.

Now the temperature at those hours was: 22°.7 at 3 p.m.; 21°.9 at 4 p.m.; 18°.7 at 5 p.m.; 17°.7 at 6 p.m. The thermograph preserved in the Central Meteorological Observatory shows a sudden decrease of temperature from 4.00 p.m. to 4.30 p.m. The wind was NNW 4.6 at 4 p.m. and E 6.7 at 5 p.m. Thus we see that at about 4 p.m. a cold current of air suddenly came from the east. The negative potential at first observed was then the effect of the negative electrification of the previously existing warmer air, and the positive potential afterwards observed, of the positive electrification of the coming colder air on mixing with the former.

Again on Dec. 26, the potential began to get very high from 1 p.m. and was quite out of the paper at 1.30 p.m. It began to decrease and crossed the zero line at about 2 p.m., and became negative, and then gradually returned, till at 3 p.m. it had recovered its usual course, though much lower than it had kept before.

The temperature was 5°.0 at noon; 5°.3 at 1 p.m.; 11°.7 at 2 p.m.; 11°.9 at 3 p.m. The thermograph shows a sudden increase of temperature from about 1.45 p.m. to 2.00 p.m. The wind was NNW 2.0 at 1 p.m.; WNW 3.0 at 2 p.m.; SW 7.4 at 3 p.m. Thus we see that at about 1.45 p.m. a warm current of air came from SW. The positive indications at first observed were no doubt the consequence of the positive electrification of the colder air previously existing, and the negative indications afterwards observed, of the negative electrification of the newly arrived warmer air on mixing with the former.

CONCLUSIONS

A summary of the principal conclusions obtained from the above considerations is added here.

1. The negative potential observed during strong wind is entirely due to the negative electrification of the dust raised and carried in the atmosphere, by friction with terrestrial objects.

2. Similarly the high potential observed during fog or haze is due to the positive electrification of the water particles composing it.

3. When a mass of cold air comes in contact with a mass of warm air, the former becomes positively electrified with respect to the latter. This fact is probably one of the causes which determine the normal distribution of the electric field in the atmosphere. Also it may account for the fact that an abnormally high potential is generally accompanied by an abnormally low temperature.

4. The invariably high potentials at or near sunrise are probably due to the fact that the air lying near the surface has then a temperature lower than that of the air above it, and becomes, in consequence, positively electrified.

5. When two masses of air at different temperatures happen to be mixed suddenly, the elecric field is violently disturbed. The disturbances are, however, just such as are in accord with the fact stated in 3.

In conclusion, I wish to express my great indebtedness to Dr. K. Nakamura, director of the Central Meteorological Observatory, by whose kind permission, I have been able to examine several original records preserved in that observatory. The copies of photographs are also reproduced here through the courtesy of that gentleman. My best thanks are due to Professor Tanakadate and to Professor Nagaoka of the Tokyo University, who were kind enough to give me valuable suggestions, and to favour me with access to the literature of the subject.

Physical Laboratory, First High School.

Tokyo.

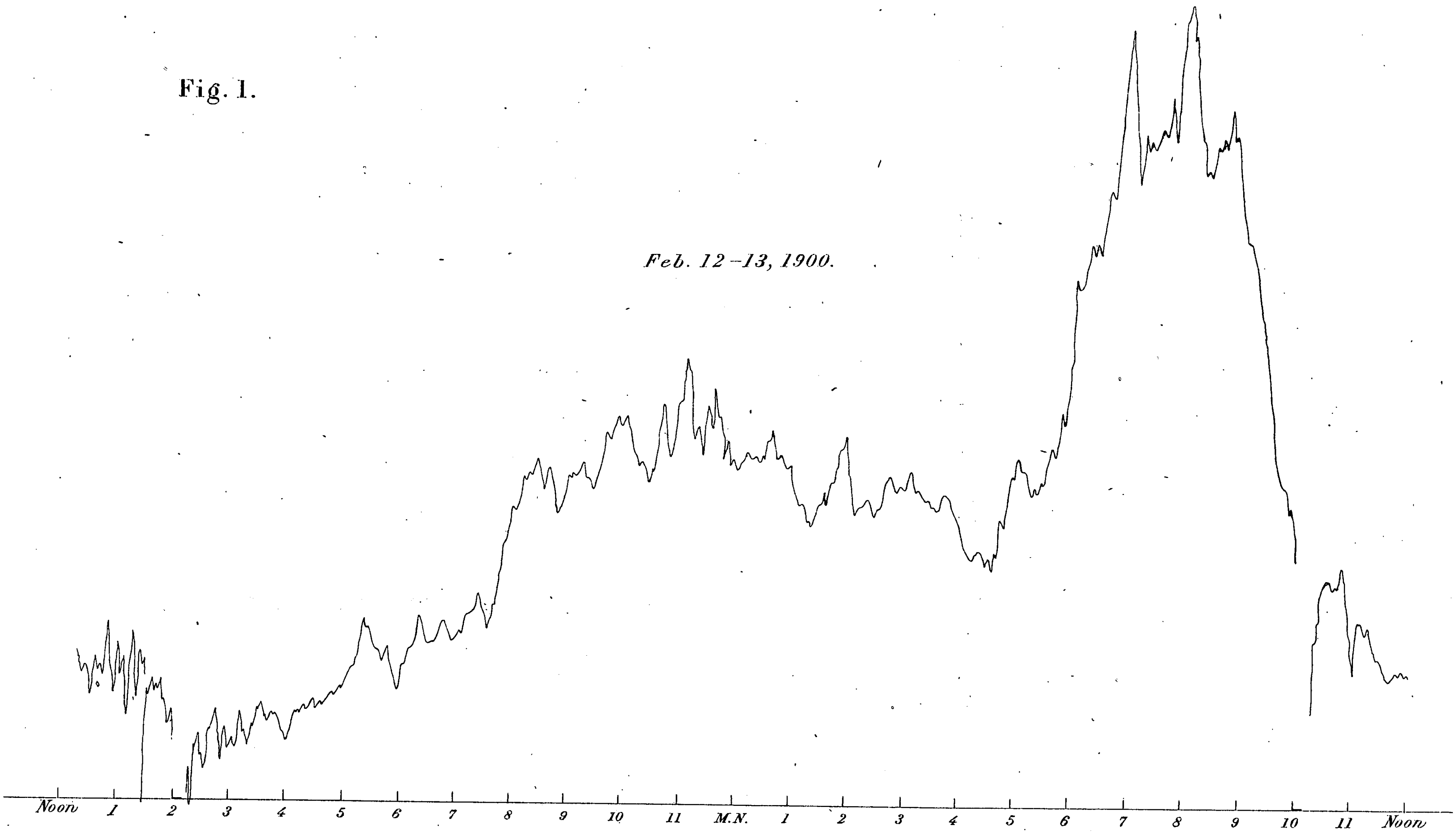
November, 1901.

PLATE I.

Fig. 1 represents a normal type of the potential. The weather was clear, with light to moderate winds.

Fig. 2 represents a case of the potential disturbed by a gale. On Apr. 11, 1901, NNW gale prevailed with the following intensities: 13.2 at 11 a. m., 12.6 at noon, 12.6 at 1 p. m., 11.7 at 2 p. m., 13.0 at 3 p. m., 9.9 at 4 p. m., 11.7 at 5 p. m., 7.6 at 6 p. m., 6.7 at 7 p. m., etc.

Fig. 1.


Feb. 12–13, 1900.
Noon
1
2
3
4
5
6
7
8
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10
11
M.N.
1
2
3
4
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7
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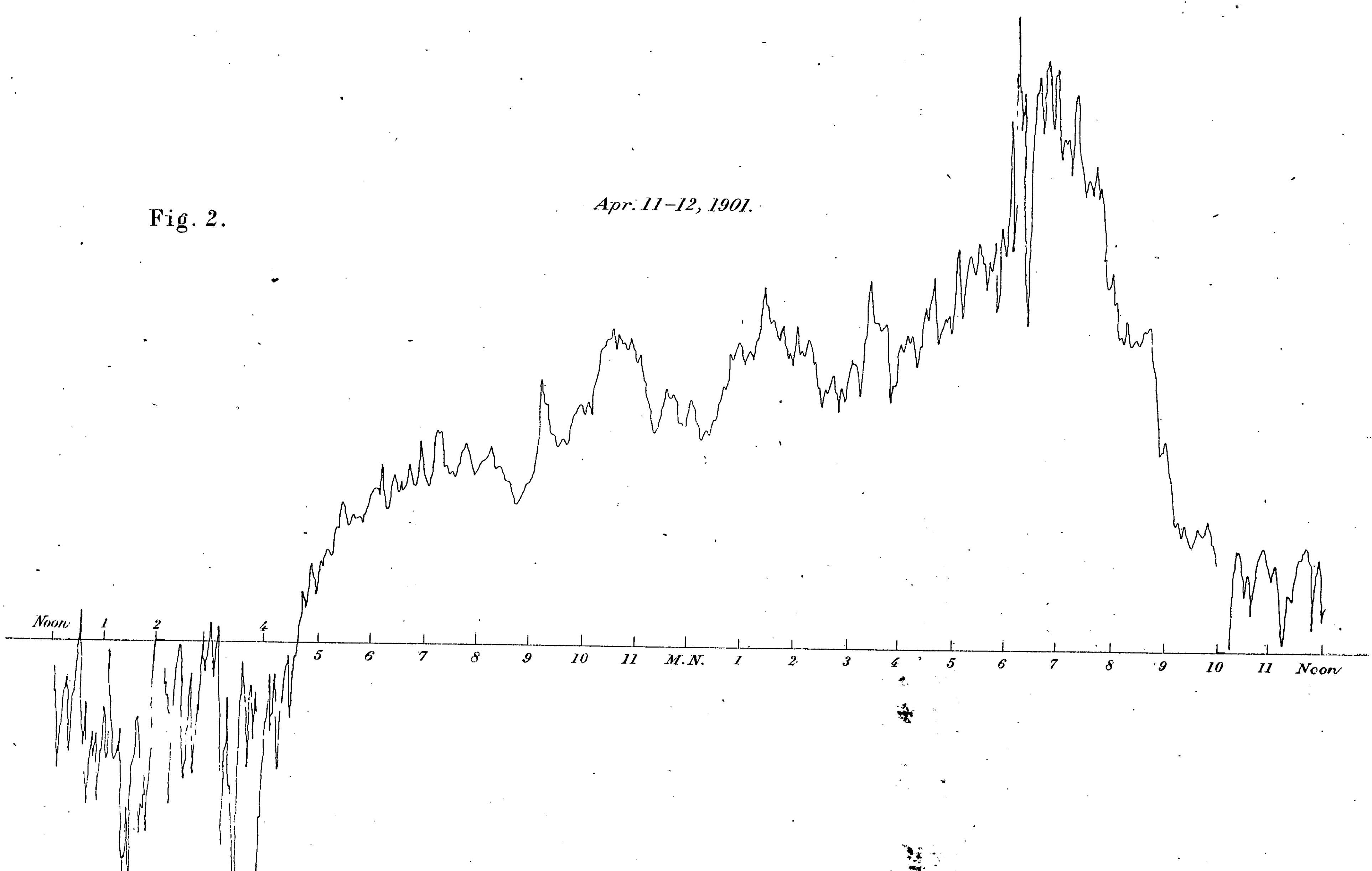
11
Noon

Fig. 2.


Apr. 11–12, 1901.
Noon
1
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4
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9
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11
M.N.
1
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3
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5
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10
11
Noon

PLATE II.

Fig. 3 represents a very high potential on the occasion of a haze. The weather was exceedingly calm with perfectly cloudless sky. There was a thick haze from 8 a. m. to 11 a. m. on the 18th.

Fig. 4 represents a case of the potential undisturbed by a haze. On Oct. 14, 1900, there was a light rain in the afternoon, which ceased at 2.55 p. m. On the morning of the 15th, the weather was clear and calm, and the surface was very wet. There was a thick haze from 7 a. m.

Fig. 5 represents a case of the potential undisturbed by a fog. On Jan. 21, 1901, there was rain in the morning, which became light from 2.10 p. m. and ceased at 3.40 p. m. There were also some showers in the night. On the morning of the 22nd there was a fog.

Fig. 3.

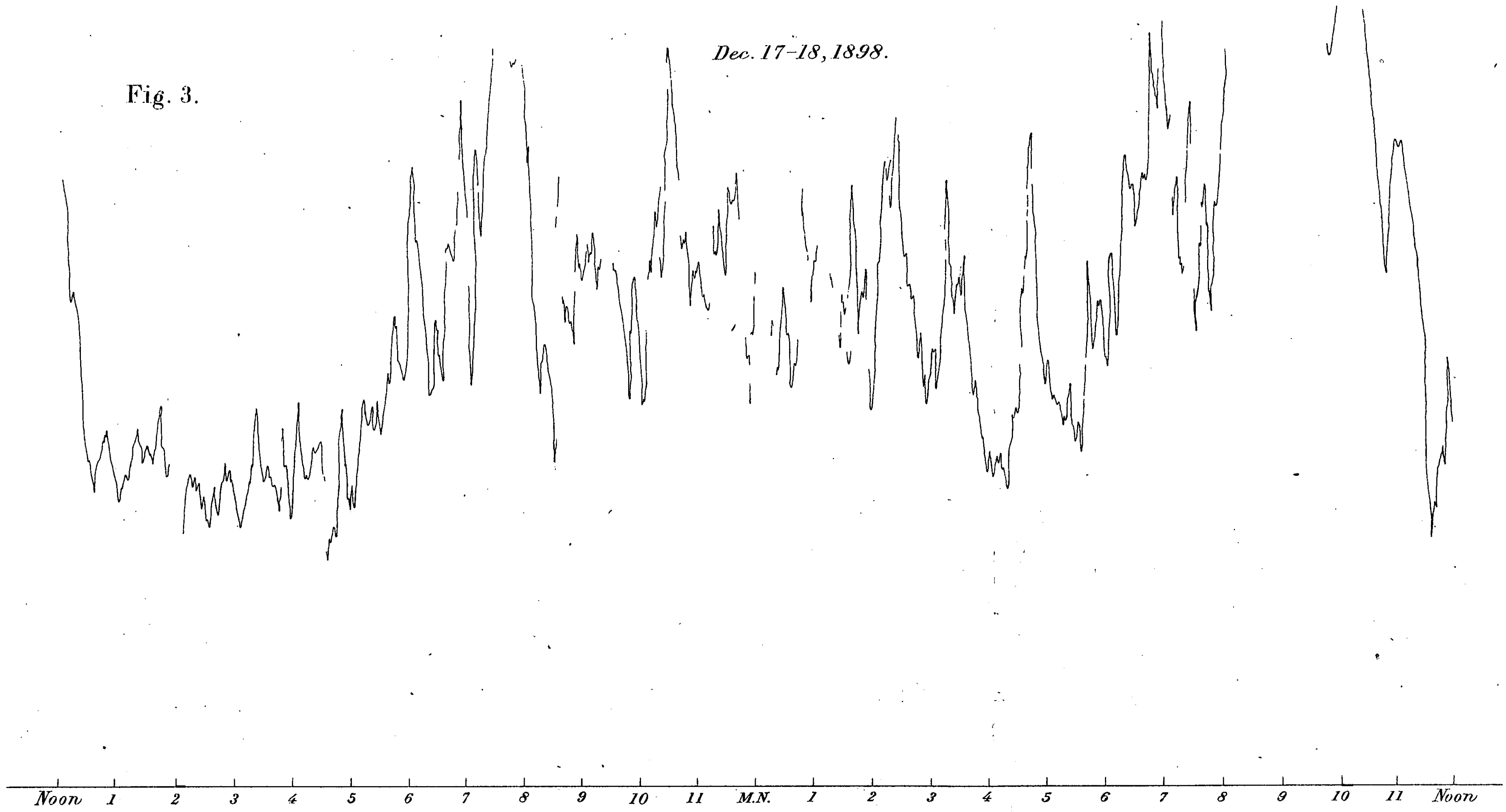

Fig. 4.

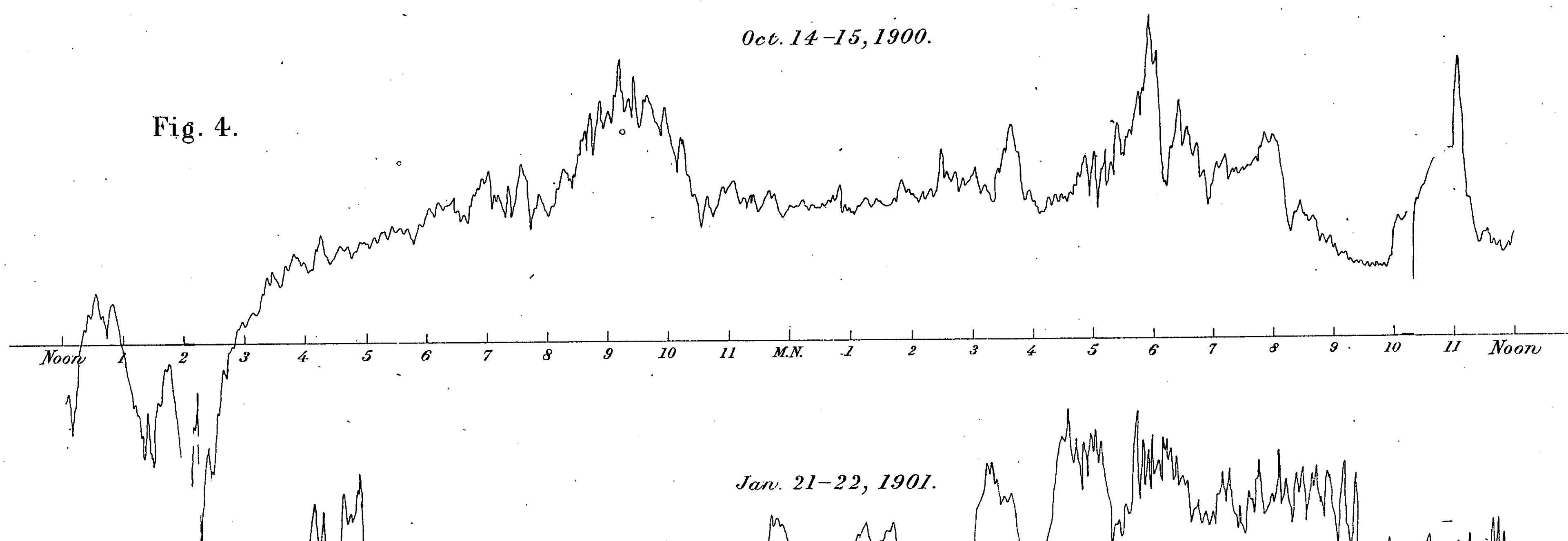

Fig. 5.

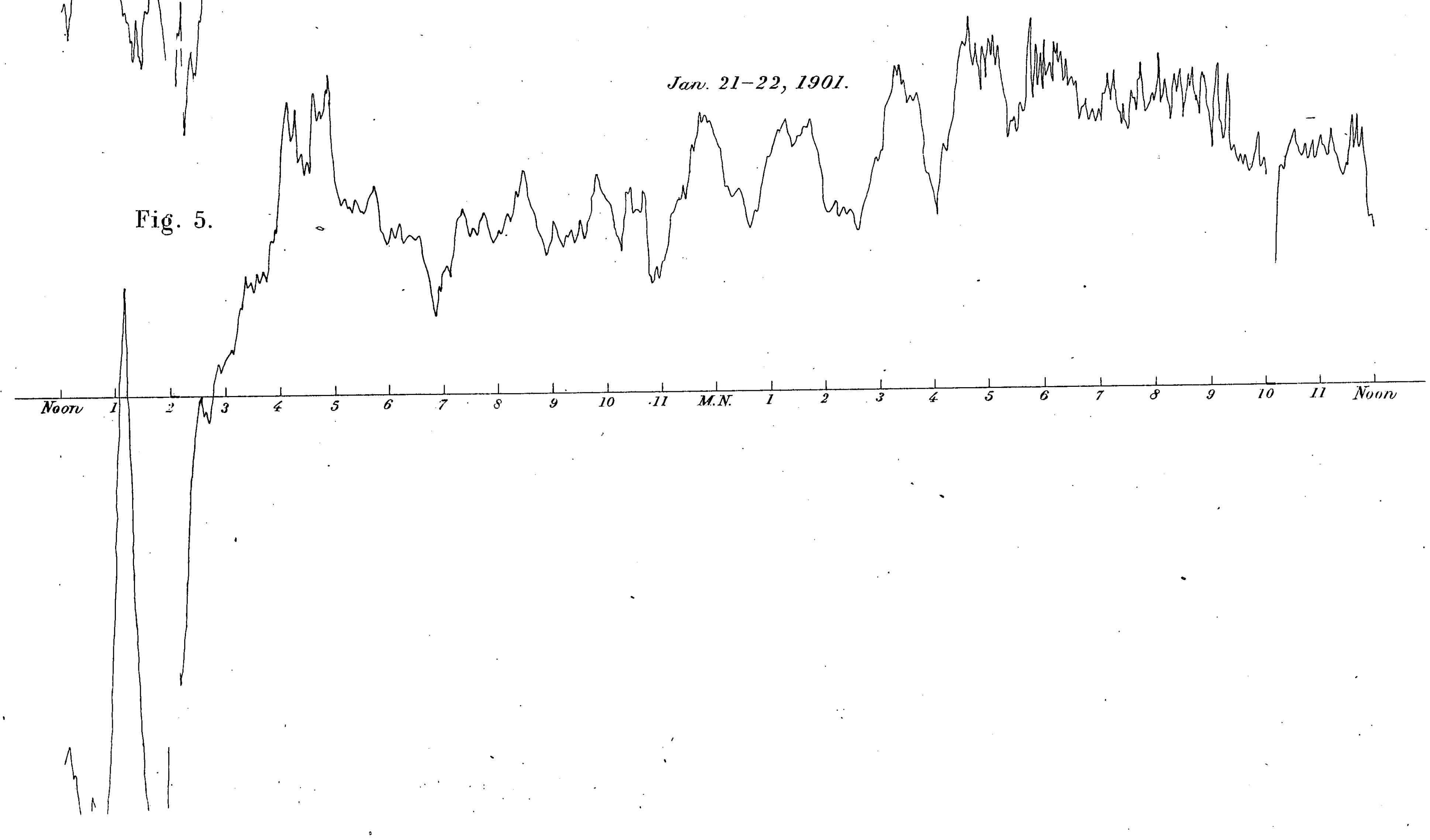

PLATE III.

Fig. 6 represents a case of the potential disturbed by rain. On the night of April 27, 1897, rain began to fall from 9.50 p. m. and continued to the morning of the 28th. There was a heavy fall between 5.10 a. m. and 6 a. m., on the 28th. It ceased completely at 9. 10 a. m.

Fig. 7 is a case of snowfall. On Jan. 21, 1900, snow began to fall at 6.15 a. m., continuing all the day, until at 6.30 p. m., the fall began to decrease and was accompanied by rain. The precipitation ceased completely at 9.55 p. m.

Fig. 6.

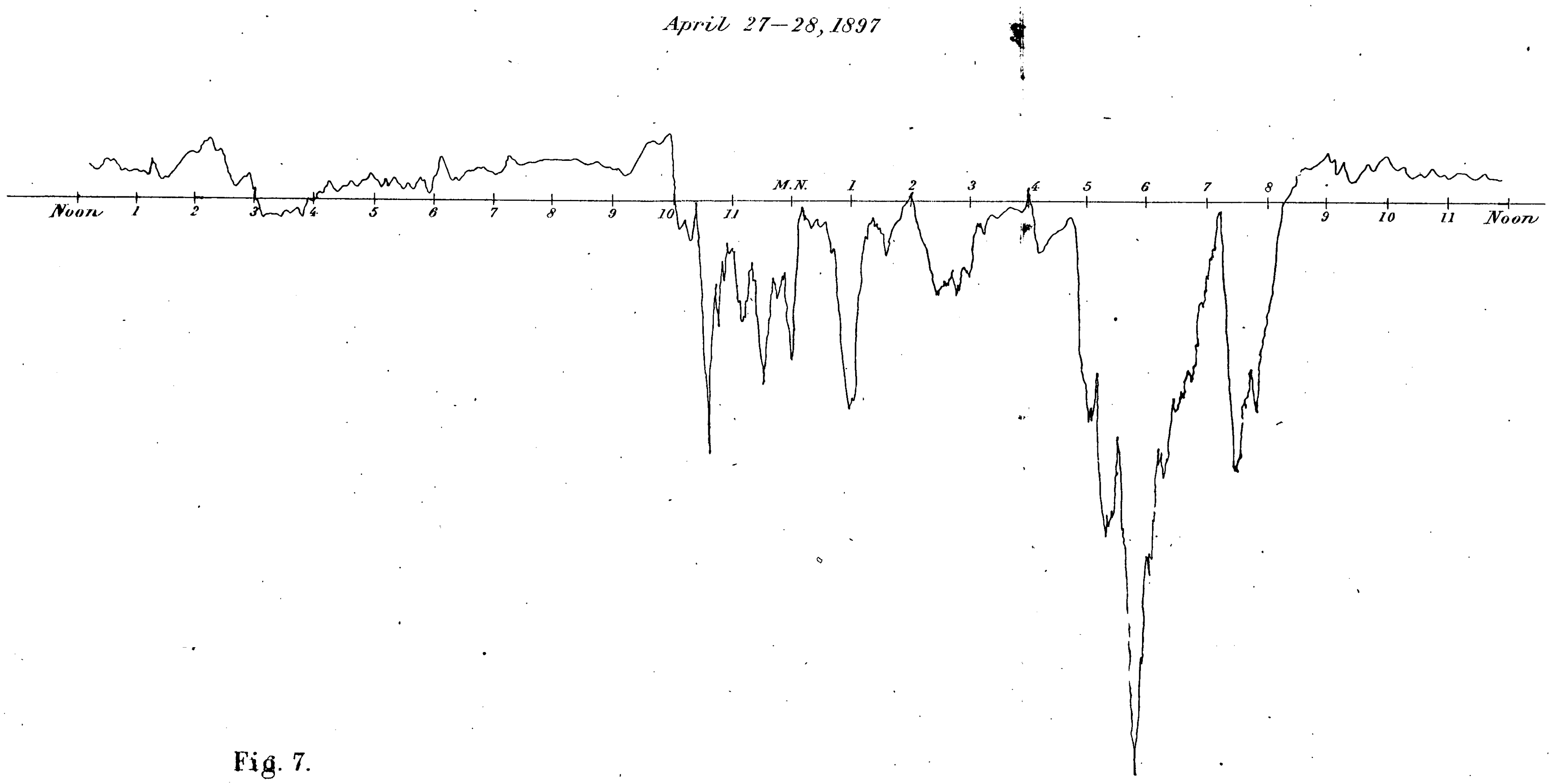
April 27—28, 1897
Noon 1 2 3 4 5 6 7 8 9 10 11 M.N. 1 2 3 4 5 6 7 8 9 10 11 Noon

Fig. 7.

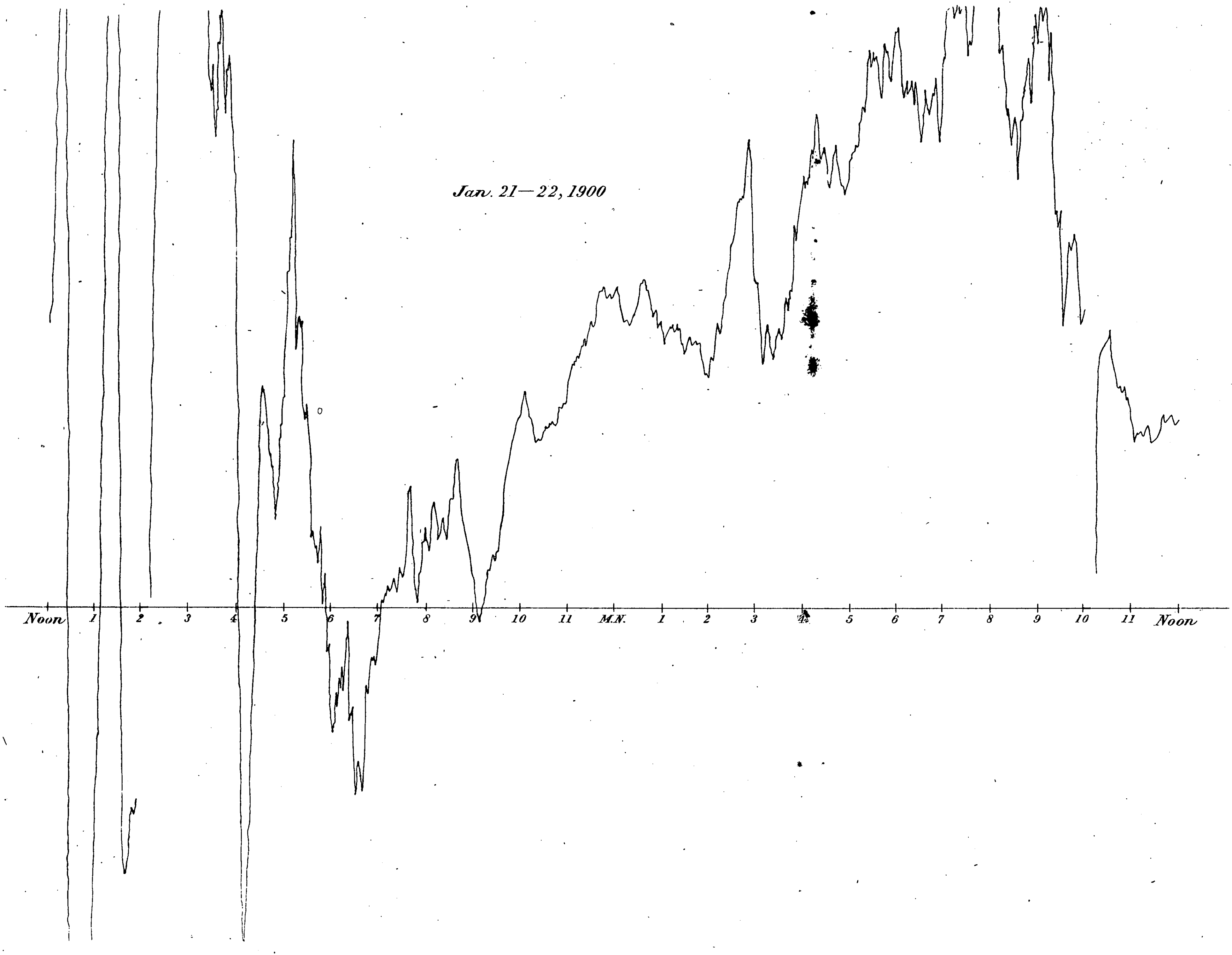
Jan. 21—22, 1900
Noon 1 2 3 4 5 6 7 8 9 10 11 M.N. 1 2 3 4 5 6 7 8 9 10 11 Noon

PLATE IV.

This represents two cases of abnormal variations. The constant determinations are represented in both cases, each corresponding to 100 volts. The dotted lines represent the variation of the temperature.

Fig. 8. *May 26, 1897.*

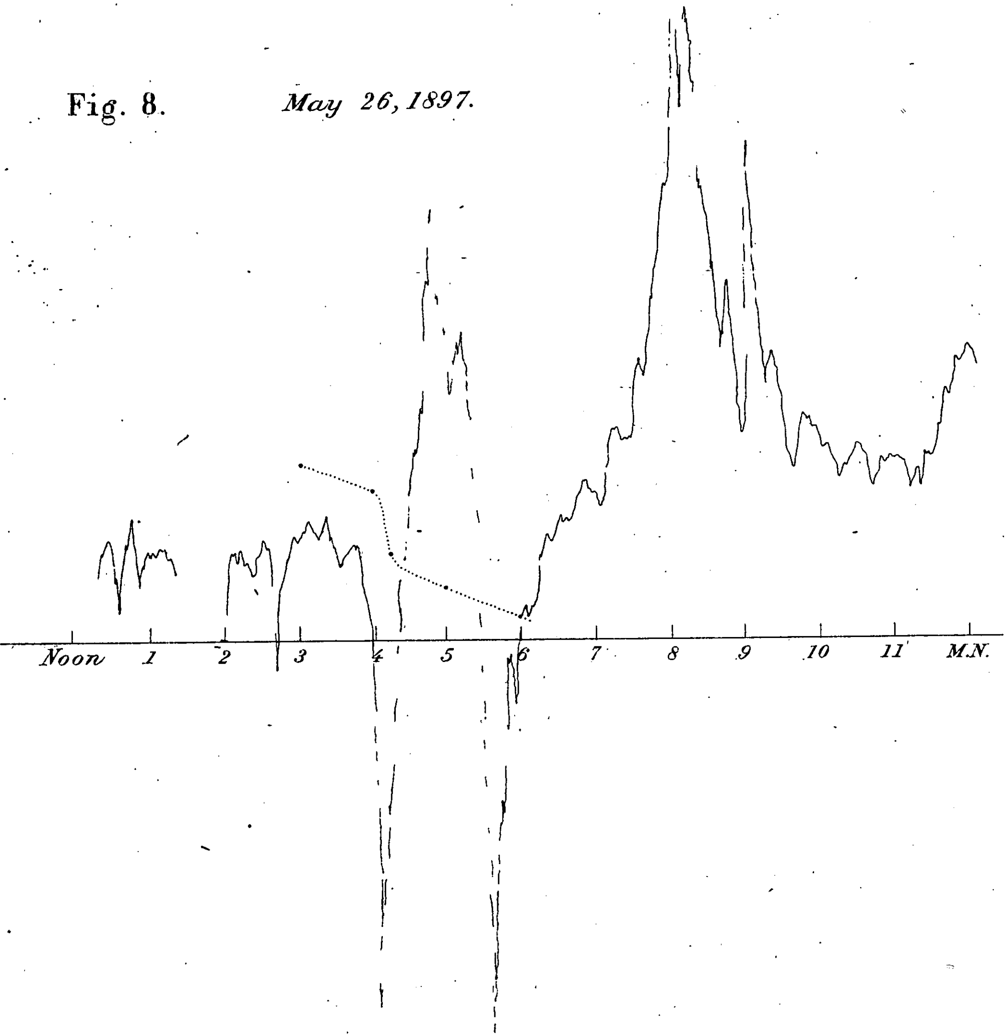

Fig. 9. *Dec. 26; 1897.*