PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Atmospheric Electricity in High Latitudes

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III. *Atmospheric Electricity in High Latitudes.*

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INVESTIGATION into the problems of atmospheric electricity may be divided into two periods. The first period was devoted almost entirely to measurements of the normal potential gradient in the lower region of the earth's atmosphere, with the aim of finding its daily and yearly variations, its geographical distribution and its dependence on meteorological condition. To this period belongs the fine work of Lord KELVIN and Professor EXNER.*

The second period commenced in 1899, when the interest in the problems of atmospheric electricity was at rather a low ebb, owing to the small real progress made during the latter few years. In that year the discovery that atmospheric air is always more or less ionized—made at about the same time by ELSTER and GEITEL† in Germany and C. T. R. WILSON‡ in England—had a completely revolutionizing influence on the theories held to account for the earth's normal field. This discovery has brought about a great revival of interest and opened a totally new field for investigation.

As long as air could be considered a perfect non-conductor EXNER'S theory that the charge on the earth is a residual charge held a very strong position; but with a conducting atmosphere it is untenable. An ionized atmosphere means a continual passage of electricity from the charged surface into the highest regions of the atmosphere, where only any residual charge could be held. The new discovery having proved conclusively that the charge on the earth is being continuously dissipated into the ionized air above, it became of prime importance to determine the rate at which the electricity is dissipated and the conditions under which the loss takes place.

The first serious attempt to do this was made by ELSTER and GEITEL.§ They designed an instrument consisting of a charged cylinder exposed to the air—

* For a good *résumé* of this period see EXNER, 'Terr. Mag.,' vol. 5, p. 167, 1900.

† 'Phys. Zeit.,' 1, p. 245, 1899; 'Phys. Zeit.,' 2, p. 116, 1900.

‡ 'Roy. Soc. Proc.,' 68, p. 151, 1901.

§ 'Phys. Zeit.,' 1, p. 11, 1899; 'Terr. Mag. and Atm. Elect.,' 4, p. 213, 1899; 'DRUDE'S Ann.,' **2**, p. 425, 1900.

protected from extraneous electrical fields—and so connected to an electroscope that the rate at which it lost its charge could be measured. By making certain assumptions it can be shown that the charge lost in a small interval of time from any charged body exposed to the air is always a definite fraction of the charge on the body. Thus, when ELSTER and GEITEL had found the charge lost by their cylinder in a minute, they were able to express the loss as a percentage of the charge on the cylinder, and then, by applying this percentage to the charge on the earth, were able to find the quantity of electricity being dissipated from every square metre of surface each minute.

Besides knowing the amount of electricity dissipated from the surface—which depends upon many factors—it became also of great importance to know to what extent the air is ionized at any moment. For this purpose EBERT* designed an instrument which gives the amount of ionization independently of everything else. A known quantity of air is drawn through a cylinder condenser, the inner cylinder of which is connected to an electroscope. As the air passes between the cylinders the charged inner one attracts to it all the ions of the opposite sign. These ions neutralize an equal amount of electricity, and so the charge lost by the inner cylinder is a measure of the number of ions contained in the known quantity of air which has been drawn through the instrument. In this way it is possible to find how many electrostatic units of each kind of electricity are free in a cubic metre of air.

These two instruments are very powerful weapons for attacking the new problems of atmospheric electricity, and have been used as such to a large extent on the Continent. Systematic observations of the dissipation were undertaken by ELSTER and GEITEL, and quite a number of other physicists have devoted themselves to finding the relations existing between meteorological conditions, ionization, the rate of dissipation and the potential gradient. As a result of this work the electrical conditions of the atmosphere are already fairly well known for lands lying within the temperate zone. With the idea of extending this knowledge to places within the Arctic Circle I was granted permission by the Commissioners of the 1851 Exhibition Scholarship to undertake a year's work on atmospheric electricity in Lapland.

The work which I proposed to do was the following :—

1. By means of a Benndorf self-registering electrometer to obtain daily curves of the potential gradient and from these to calculate the yearly and daily variation.
2. To make systematic observations of the dissipation by means of ELSTER and GEITEL'S instrument.
3. To make corresponding measurements of the ionization with EBERT'S apparatus.

* Short description, 'Phys. Zeit.,' 2, p. 662, 1901; fuller description, 'Aëronautische Mittheilungen,' p. 1, 1902.

4. To measure the amount of radio-active emanation in the atmosphere.
5. To investigate as far as possible the influence of the Aurora on the electrical conditions of the atmosphere.

In my choice of a station I decided to get as far north as possible without being actually on the sea coast, and found that the Lapp village of Karasjok (69° 17′ N., 25° 35′ E., 129 metres above sea-level) was very well suited for my purpose.

Meteorological Conditions.

Before going on to a discussion of the electrical results obtained, it will be as well to give a short account of the meteorological conditions experienced during the year's work. From its high latitude the north of Norway should be a very cold district; but the presence of the open ocean on the north and west greatly modifies the temperature. The effect of the water is of course very much more marked on the sea coast than inland. As one recedes from the coast the mean temperature for the winter six months falls very rapidly, it being $-2°\cdot3$ C. at Gjesvœr, near the North Cape, and $-11°\cdot7$ at Karasjok. If there were no interchange of air between the ocean and the interior of the land the latter would of course have a very low temperature. This became very noticeable during periods of calm weather, for the temperature would then run down to very low values, reaching on several occasions $-40°$ C., while, on the contrary, whenever the wind rose the temperature rose also.

When there was no wind, a cap of very cold air would form over the land, causing a nearly permanent temperature inversion. Although I could not observe this inversion instrumentally—neither kites nor balloons forming part of my equipment—there could be little doubt as to its reality. On September 30th, with an air-temperature of $-6°$ C., a bright rainbow was observed. Then again, on descending the high banks of the river, one felt at once the cold air collected in the river basin, and the Lapps stated that it was seldom as cold on the hills as in the valleys. Then, again, the fact that a wind was always accompanied by mild weather also points to the cold of still weather being confined to a layer of air of no considerable depth lying over the surface. This condition of things almost entirely prevented the formation of ascending currents of air, so causing very small values of the amount of precipitation and almost entirely preventing the formation of low clouds during the winter. It also had a very marked effect on the electrical condition of the atmosphere, to which reference will be made later.

During the summer the weather conditions were very similar to those of England, with the exception that the precipitation was very much less and thunderstorms were scarce. On three days only was thunder heard and lightning was not seen once.

From November 26 to January 18 the sun did not rise above the horizon; nevertheless, even in the darkest days there were two or three hours of twilight during which the sky was too bright for the stars to be seen. The period during which the sun did not go below the horizon extended from May 20 to July 22.

*Methods of Work.**

Potential Gradient.—BENNDORF'S self-registering electrometer, with radium collector attached, was set in action on September 28, 1903, and produced a nearly continuous record of the potential gradient until October 1, 1904. Each day the curve for the previous day was measured and the mean potential gradient for each hour obtained. This was done by first drawing a curve as smoothly as possible through the registered curve, then five equidistant ordinates in each hour were measured, and the mean of these five taken to represent the mean potential gradient during the hour. In discussing the potential gradient for any place it is usual to use only observations made during fine weather, neglecting all those which have been affected by any atmospheric disturbance. This plan I also followed during the summer months (April to end of September), for then the curves drawn by the instrument were exceedingly regular unless there was actually precipitation taking place in the neighbourhood. But during the winter the curves were so irregular, even on the finest days, that it was quite impossible to decide whether a particular curve ought to be neglected or not, so I used, during the winter, all the curves quite independently of the weather This caused irregularities in the final curves, but has not, I think, affected the conclusion to be drawn from them.

Dissipation.—The value of the dissipation, as measured by ELSTER and GEITEL'S instrument, depends to a very great extent on the manner in which the instrument is exposed to the wind. This is as it should be, for the actual dissipation from the earth's surface (which the instrument is designed to measure) depends largely on the wind strength. In order that the instrument should measure the amount of dissipation taking place from the earth's surface, it should be exposed to the same wind condition as the general surface. This fact has not been fully realized by most observers. It has been quite a common practice to shelter the instrument from the wind, either by erecting screens or by observing close to a building, and in several cases the instrument has been placed within a room close to an open window. Observations taken under such conditions are of very little value: they are certainly of no use in comparing the dissipation of one place with that of another, and at the best can only be used to compare variations from time to time at the same place. In order that the dissipation at one place may be compared with that of another, the instruments used should in both cases be exposed to the full force of the wind, for wind strength is just as much a factor in determining the dissipation as is the ionization. For this reason my instrument was only used in a freely exposed situation, where it was in no way sheltered from the wind. This method also has its drawbacks, for with anything like a high wind the leaves of the electroscope were so blown about that they continually discharged the instrument by coming in contact with the case. Hence measurements could not be made in very high winds, and so the mean values of the dissipation

* For fuller particulars of methods of work and arrangement of apparatus see Appendix.

found are slightly less than they would have been if observation could have been made in all winds; but the final results are very little affected. Observations also could not be made during rain, owing to trouble with the insulation. Except when it was impossible to observe, owing to these two causes, measurements of the dissipation were made three times each day, between 7.30 and 9.30 in the morning, between 12 and 2 midday, and between 6 and 8 in the evening.

In expressing the dissipation, ELSTER and GEITEL'S example has been followed, *i.e.*, the dissipation is expressed as the percentage of charge lost by a charged body in a minute. Thus $a_+ = 1 \cdot 00$ per cent. means that 1 per cent. of the positive charge on any body will be dissipated in a minute; similarly, a_- expresses the dissipation of a negative charge. The ratio a_-/a_+ is written q. There are two methods of obtaining the mean value of this ratio, either $\frac{1}{n}\Sigma\left(\frac{a_-}{a_+}\right)$ or $\frac{\Sigma a_-}{\Sigma a_+}$; in most cases these two are very nearly equal. In this paper q is always obtained by the latter method.

Ionization.—EBERT'S instrument for measuring the ionization was used at the same time as the dissipation instrument. It was often possible, however, to use the Ebert apparatus on days when the wind made it impossible to use the dissipation apparatus; but, on the other hand, the insulation of the Ebert instrument would often fail, owing to high humidity of the atmosphere, when satisfactory measurements of the dissipation could be obtained. EBERT'S instrument also could not be used when the temperature fell below $-20°$ C., for then the oil in the air turbine froze and prevented the clock-work running freely. EBERT'S method of expressing the ionization has been followed; the positive ionization is expressed as the number of electrostatic units of free positive ions in a cubic metre of air; similarly for negative ionization. The symbols used to denote positive and negative ionization are I_+ and I_- respectively. The ratio of positive ionization to negative, *i.e.*, I_+/I_-, is written r, and the mean is obtained by the process $\Sigma I_+/\Sigma I_-$.

RESULTS OF THE OBSERVATIONS.

Yearly Variations.

Potential Gradient.—Table I. gives the monthly values of the potential gradient.

TABLE I.—Potential Gradient.

Winter.	Volts/metre.	Summer.	Volts/metre.
October	121	April	131
November	167	May	103
December	175	June	90
January	199	July	98
February	209	August	93
March	191	September	93

The yearly course of the potential gradient is shown in Curve I., fig. 1, on which each point gives the mean potential gradient for a week, the means for the months (as in Table I.) being shown by points enclosed within circles. It will at once be seen how irregular the potential gradient is during the winter when taken for such short time intervals as a week; on the contrary the monthly means fall very nearly on a regular curve. It must be remembered that, as stated above, these values during the winter are obtained from both fine and disturbed days. If only fine days had been used not only would the curve have been more regular, but also the mean potential gradient would have been greater. The trend of the curve may be summed up as a regular rise in the potential gradient from October to the middle of February, followed by a more rapid fall until the end of May, after which the potential gradient remains nearly constant during the summer months.

Dissipation.—The mean values of the dissipation for each month are shown in the following table. In order to find the effect of the seasons, and whether the total absence of the sun for nearly three months during the winter and its presence for an equal length of time during the summer influences the electrical conditions of the atmosphere, the observations have been grouped into periods of three months, the winter three months containing the period of no sun and the summer three months that of permanent sun.

TABLE II.—Dissipation.

Months.	a_+.	a_-.	q.	$a_\pm$.	Seasons.	a_+.	a_-.	q.	$a_\pm$.
November	3·20	3·43	1·07	3·32	Winter	2·44	2·76	1·13	2·61
December	2·13	2·53	1·19	2·33					
January	1·98	2·33	1·18	2·17					
February	1·37	1·47	1·08	1·42	Spring	2·65	3·20	1·20	2·92
March	2·79	3·74	1·34	3·27					
April	3·78	4·38	1·16	4·07					
May	4·41	4·76	1·08	4·58	Summer	4·63	5·14	1·11	4·88
June	4·24	4·68	1·10	4·45					
July	5·25	5·97	1·13	5·61					
August	4·32	4·94	1·14	4·63	Autumn	3·60	4·16	1·15	3·88
September	4·28	4·89	1·14	4·58					
October	2·21	2·65	1·20	2·43					
					Whole year	3·33	3·82	1·15	3·57

On Curve II. these values of the dissipation ($a_\pm$) have been plotted, also the weekly values. If no observations were made for a week a gap has been left in the curve. From the curve it will be seen that the yearly course of the dissipation is strikingly similar to that of the potential gradient when inverted, the one falling and

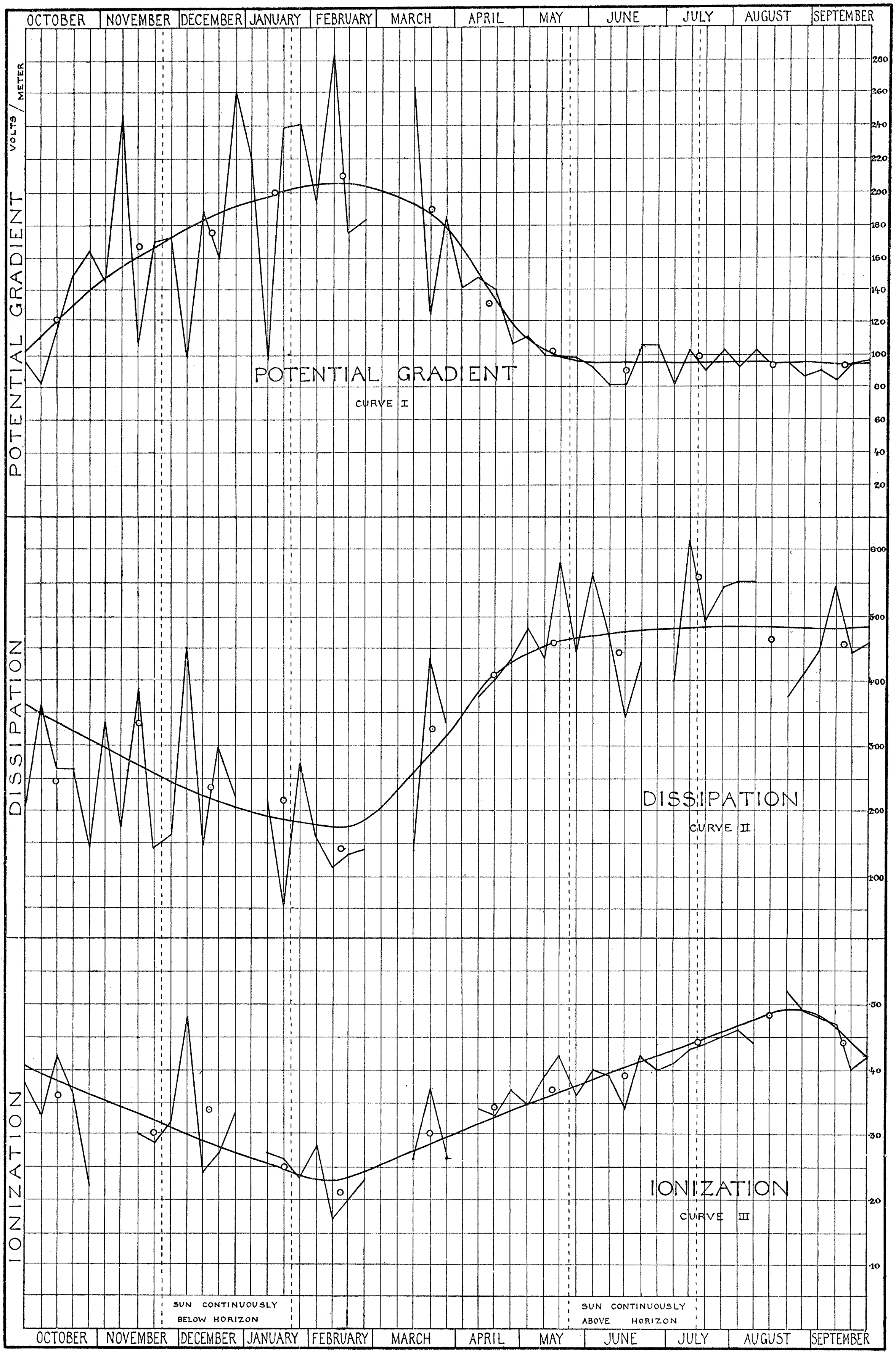

Fig. 1.

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rising at exactly the same time as the other rises and falls, and both remaining constant during the summer. These curves suggest that there is some relation between the two phenomena; this relation will be discussed later in the paper.

The ratio of the negative dissipation to the positive (q) does not appear from these results to have a regular yearly course, but when they are considered in connection with the ionization it will be seen that it is very likely there is a yearly variation with a maximum in the winter and a minimum in the summer.

Ionization.—Table III. gives the monthly mean values of the ionization.

TABLE III.—Ionization.

Months.	I_-.	I_+.	r.	$I_\pm$.	Seasons.	I_-.	I_+.	r.	$I_\pm$.
November	·25	·35	1·40	·30					
December	·28	·39	1·39	·33	Winter	·26	·33	1·28	·29
January	·25	·26	1·04	·25					
February	·20	·24	1·20	·21					
March	·28	·32	1·14	·30	Spring	·26	·31	1·19	·28
April	·31	·38	1·22	·34					
May	·35	·40	1·18	·37					
June	·37	·41	1·09	·39	Summer	·38	·42	1·11	·40
July	·42	·46	1·10	·44					
August	·45	·51	1·13	·48					
September	·42	·46	1·08	·44	Autumn	·40	·46	1·15	·43
October	·34	·40	1·18	·36					
					Whole year	·33	·38	1·17	·36

These results, together with the weekly means, have been plotted in Curve III. Here we have quite a different curve from either of the two previous ones. Instead of the rapid fall and rise in the winter followed by a constant period during the summer we have a six months' linear fall from August to February followed by a similar six months' linear rise from February to August.

That there should be such a great difference between the curves for the dissipation and the ionization was not to be expected, and at first one would be inclined to doubt the correctness of one or other of them. But this can be tested by the following considerations. The dissipation depends practically only on two factors: ionization and wind strength. If the effect of the latter could be eliminated, the course of the dissipation should then be the same as that of the ionization. In order to see if this were so, I took all my measurements of the dissipation and separated them according to the strength of the wind as estimated at the time of observation, then, using only one definite wind strength, took the means for each month and plotted them. The result is shown in fig. 2. Each curve represents one wind strength, and it will at once be seen that all four curves are practically parallel* and are similar in shape to that of the ionization. This shows at once that both the curves of the dissipation and ionization are correct, and that there is a real difference in the yearly course of the two, and also that there is a closer relation between potential gradient and dissipation than between potential gradient and ionization.

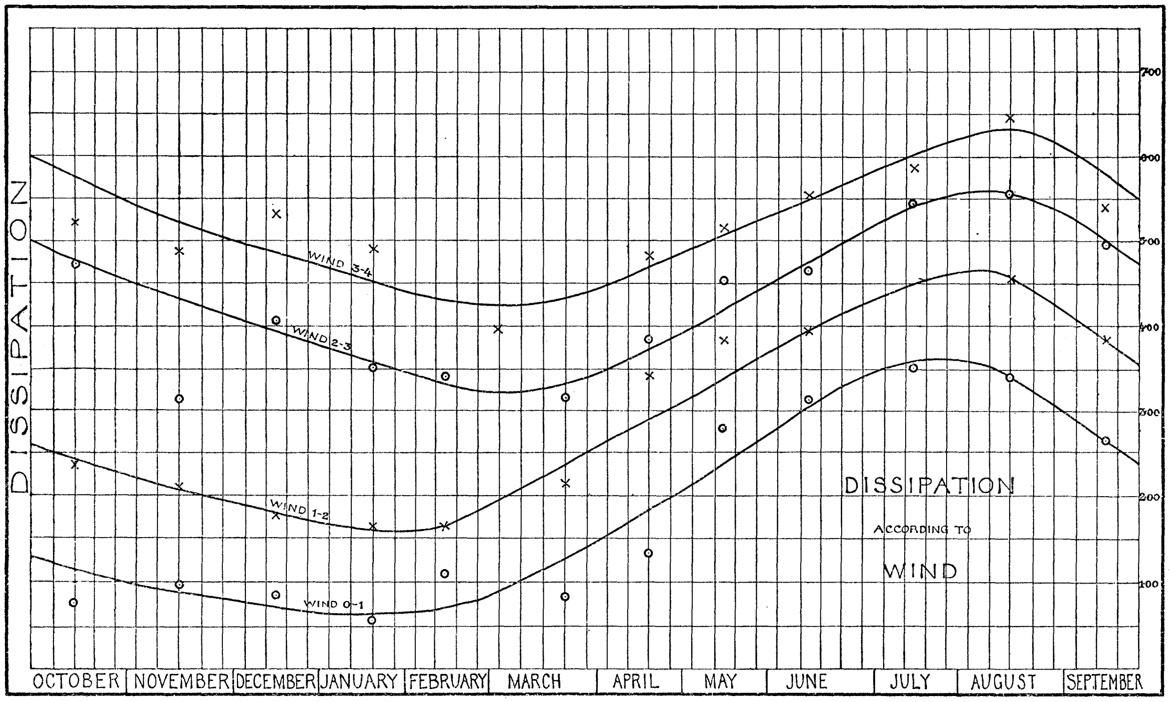

Fig. 2.

The value of the ratio I_+/I_- shows a very distinct yearly period with a maximum in the winter and a minimum during the summer. Later it will be seen that very probably this ratio depends largely on the potential gradient, so that its yearly period might be expected on account of the yearly variations in the potential gradient.

Daily Variations.

Potential Gradient.—The daily course of the potential gradient varies greatly according to the season of the year. For this reason five curves of the daily course

* The lowness of the two curves for wind strengths 0–1 and 1–2 during the first part of the winter is due to the fact that, owing to the darkness at both the morning and evening observations then, it was impossible to see if the smoke of the village was drifting towards my place of observation or not. Nor was I quite aware then of the fact, which I found later, that with no wind the smoke of the village extended in an almost invisible haze over the whole valley, out of which it could not get. This smoke effect, of course, only acted when there was insufficient wind to drive the smoke away, and its effect is not at all visible on the two curves with wind strength greater than two, *i.e.*, a steady breeze.

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are given: one each for the winter, spring, summer, and autumn three months and another for the year taken as a whole (fig. 3). It will at once be seen that the two

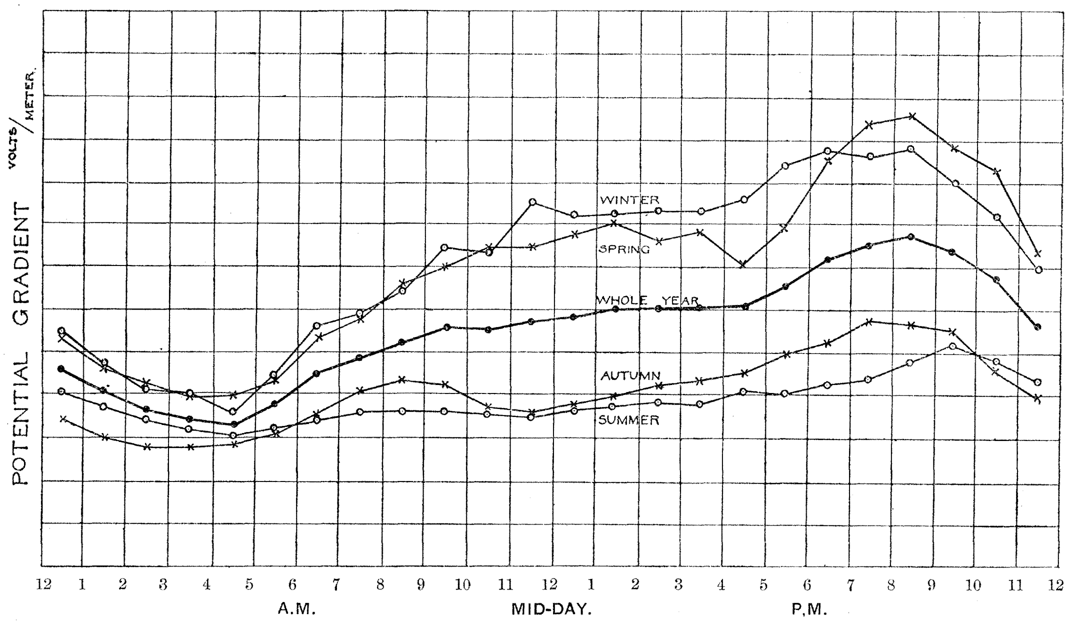

Fig. 3.

curves for the winter and spring lie entirely above the curve for the year and those for the autumn and summer entirely below.

The equations to the five curves are* :—

Winter three months, $P = 180+64\sin(\theta+189)+26\sin(2\theta+155)+\ 4\sin(3\theta+200)$,

Spring ,, ,, $P = 177+57\sin(\theta+176)+37\sin(2\theta+151)+13\sin(3\theta+195)$,

Summer ,, ,, $P = \ 97+16\sin(\theta+141)+\ 9\sin(2\theta+144)+\ 4\sin(3\theta+126)$,

Autumn ,, ,, $P = 103+23\sin(\theta+170)+19\sin(2\theta+184)+\ 2\sin(3\theta+131)$,

Whole year . . . . $P = 139+39\sin(\theta+177)+23\sin(2\theta+158)+\ 5\sin(3\theta+178)$.

From these equations we see that there are two periods which must be taken into account; the amplitude of the third period falls without the limits of the accuracy of the instrument. Of these, the greater is a whole-day period and the lesser a half-day period. We also see that the phase of the main period undergoes a regular shift from a maximum in the winter to a minimum in the summer, which means that the evening maximum is earlier in the winter than the summer, thus following the sun. The phase of the second period does not vary regularly, and on account of its

* These equations are worked out to *mean local time*, taking 12 o'clock midnight as the zero and 15° to represent an hour. All other time used in this paper is mid-European, which is 42 minutes *behind* mean local time.

smallness during the summer and autumn its position is not then well fixed. The ratio of the amplitude of the second period to the first is: winter ·40, spring ·65, summer ·56, autumn ·83, whole year ·59. This shows no regular variation; the large value for the autumn is due to the strengthening of the second period by the formation of mists over the river about the times of sunrise and sunset, which mists always give rise to high potential gradients.

The hourly values of the potential gradient corresponding to the five curves are given in the following table:—

TABLE IV.—Daily Course of the Potential Gradient.

		12 to 1.	1–2.	2–3.	3–4.	4–5.	5–6.	6–7.	7–8.	8–9.	9–10.	10–11.	11–12.
Winter	A.M.	138	119	103	100	90	111	141	148	162	187	184	214
	P.M.	210	212	214	208	216	236	245	242	247	226	206	174
Spring	A.M.	134	122	107	99	99	109	135	146	164	175	187	187
	P.M.	193	201	190	196	177	198	238	262	266	247	233	185
Summer	A.M.	101	93	86	81	77	81	86	90	90	90	89	87
	P.M.	91	94	97	96	103	101	107	110	121	131	122	108
Autumn	A.M.	87	75	70	70	72	78	90	102	108	106	93	90
	P.M.	94	99	105	108	114	125	132	144	143	138	115	99
Whole year	A.M.	115	102	92	87	84	95	113	121	131	140	138	144
	P.M.	147	151	151	152	153	165	180	189	194	185	169	142

Dissipation.—As I had no self-registering instrument to record the dissipation and ionization, it is impossible to work out the daily course of these two as has been done for the potential gradient. Nevertheless, some idea of the course can be obtained by comparing the results according to the different times of observing. In Table V. the mean results from the morning, midday and evening observations are shown for each three months and then for the whole year.

TABLE V.—Dissipation.

	Morning (8 to 9 A.M.).			Midday (12 to 1 P.M.).			Evening (6 to 7 P.M.).		
	a_+.	a_-.	q.	a_+.	a_-.	q.	a_+.	a_-.	q.
Winter. Three months, November, December, January	2·11	2·71	1·02	2·02	2·47	1·23	1·92	2·37	1·23
Spring. Three months, February, March, April	3·00	3·58	1·19	2·84	3·29	1·16	2·08	2·55	1·23
Summer. Three months, May, June, July	4·54	4·97	1·10	4·96	5·31	1·07	4·45	5·07	1·14
Autumn. Three months, August, September, October	3·51	4·04	1·15	4·34	4·85	1·12	2·92	3·57	1·22
Whole year.	3·43	3·83	1·12	3·54	3·98	1·12	2·84	3·39	1·20

During the winter and spring the morning observations show a slightly higher dissipation than the midday, while, on the contrary, during the summer and autumn the midday values are the higher. For the whole year the dissipation is slightly higher at midday than earlier in the morning, while the evening observations show the lowest dissipation of the three. The value of the ratio q for nine months shows a daily period, being lower at midday than at either the morning or evening observations. The difficulties of observing during the winter three months make the value of the ratio found then very doubtful.

The evening fall in the dissipation no doubt stands in some relation to the evening maximum of the potential gradient, while it is almost certain that the high evening value of q is directly caused by the high value of the potential gradient at that time.

Ionization.—The results of the ionization observations are shown in Table VI. in the same way as those of the dissipation were in Table V.

TABLE VI.—Ionization.

	Morning (8 to 9 A.M.).			Midday (12 to 1 P.M.).			Evening (6 to 7 P.M.)		
	I_-.	I_+.	*r*.	I_-.	I_+.	*r*.	I_-.	I_+.	*r*.
Winter. Three months, November, December, January	·27	·32	1·20	·26	·35	1·35	·24	·32	1·35
Spring. Three months, February, March, April	·27	·34	1·26	·28	·31	1·11	·23	·30	1·30
Summer. Three months, May, June, July	·39	·42	1·08	·36	·43	1·20	·36	·41	1·14
Autumn. Three months, August, September, October	·42	·46	1·11	·41	·46	1·13	·36	·44	1·23
Whole year.	·34	·39	1·15	·33	·39	1·18	·30	·37	1·23

The daily period of the ionization is not so pronounced as that of the dissipation, but the ionization is slightly lower in the evening than in the morning or at midday during the whole year. There is practically no difference between the midday and morning ionizations. The daily period of the ratio q is a steady rise from the morning to the evening; in this respect the ionization does not correspond with the dissipation.

Interrelation of the Ionization, Dissipation and Potential Gradient.

Potential Gradient and Dissipation.—The relation between potential gradient and dissipation has been very closely studied by GOCKEL* and ZÖLSS.† The latter shows that the potential gradient varies very considerably with the dissipation, high potential gradient being accompanied by low values of the dissipation, and *vice versa;* and both show very clearly that the ratio of negative dissipation to positive dissipation rises considerably as the potential gradient rises. Table VII. shows the

* 'Phys. Zeit.,' 4, p. 871, 1903.

† 'Phys. Zeit.,' 5, p. 106, 1904.

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results of my observations of the dissipation tabulated according to the potential gradient.

TABLE VII.—Potential Gradient and Dissipation.

Potential gradient.	Winter.			Summer.			Year.		
	a_+.	a_-.	q.	a_+.	a_-.	q.	a_+.	a_-.	q.
volts/metre.									
50 to 100	3·94 (57)*	4·14 (60)	1·05	4·50 (93)	5·02 (93)	1·11	4·29 (150)	4·67 (153)	1·09
100 „ 150	2·34 (63)	2·77 (64)	1·18	4·18 (81)	4·83 (8)	1·16	3·38 (144)	3·93 (145)	1·16
150 „ 200	1·75 (25)	2·43 (24)	1·39	2·50 (1)	3·47 (1)	1·38	1·85 (25)	2·58 (24)	1·40
200 „ 300	1·32 (41)	1·54 (41)	1·17	1·82 (5)	1·92 (5)	1·05	1·37 (46)	1·58 (46)	1·16
300 „ 400	·60 (12)	·85 (13)	1·42	—	—	—	·60 (12)	·85 (13)	1·42
>400	·51 (19)	·64 (20)	1·25	—	—	—	·51 (19)	·64 (20)	1·25

It will be seen that here also there is the same marked relation between the potential gradient and the dissipation; but the relation between the potential gradient and the value of the ratio q does not appear so clearly. Nevertheless, the table does not disprove that the ratio rises with the potential gradient, there is rather some support given. In the first place there is a distinct rise in the ratio over the range from 50 to 200 volts/metre, and the highest value found falls between 300 and 400 volts/metre. When the whole year is taken into account there are only two out of the six divisions which do not conform to the rule.

Potential Gradient and Ionization.—So far no results have been published showing the relation between potential gradient and ionization, so that the results given in the following table cannot be compared with previous work.

TABLE VIII.—Potential Gradient and Ionization.

Potential gradient.	Winter.			Summer.			Year.		
	I_-.	I_+.	r.	I_-.	I_+.	r.	I_-.	I_+.	r.
volts/metre.									
50 to 100	·35 (53)	·42 (52)	1·20	·42 (84)	·44 (84)	1·07	·39 (137)	·43 (136)	1·11
100 „ 150	·29 (52)	·34 (53)	1·15	·35 (48)	·42 (48)	1·18	·32 (100)	·37 (101)	1·15
150 „ 200	·28 (34)	·33 (30)	1·26	·27 (4)	·37 (4)	1·41	·28 (38)	·36 (34)	1·28
200 „ 300	·19 (25)	·24 (21)	1·26	·17 (5)	·30 (5)	1·74	·19 (30)	·26 (26)	1·42
300 „ 400	·15 (7)	·15 (7)	1·00	—	—	—	·15 (7)	·15 (7)	1·00
400 „ 500	·12 (5)	·14 (5)	1·22	—	—	—	·12 (5)	·14 (5)	1·22
>500	·12 (6)	·10 (3)	—	—	—	—	·12 (6)	·10 (3)	—

The first striking fact which this table shows is the great dependence of the potential gradient on the ionization; this we might have expected from the dissipation results already considered.

* These small numbers in brackets give the number of observations from which the mean is drawn.

High values of the ionization accompany low values of the potential gradient and *vice versa*.

Here we find that the ratio between positive and negative ionization (r) does increase with the potential gradient over the range from 50 to 300 volts/metre. That there is not the same agreement higher is to be expected from the fact that for values of the potential gradient over 300 volts/metre the ionization is so small as to be only just within the power of the instrument to measure, and so one cannot expect the *ratio* of the observations to be given with any degree of accuracy; also the number of observations with the potential gradient over 300 volts/metre is so small that better results could hardly be expected.

We may, then, take it that the ionization and dissipation have a great determining influence on the potential gradient, and that high values of the potential gradient are, on the whole, accompanied by high values of the ratio r and q.

Ionization and Dissipation.—It has already been stated that the values of the dissipation, as given by ELSTER and GEITEL'S instrument, depend mainly on the two factors ionization and wind strength. It would be of considerable interest to find how the dissipation varies with either of these factors, the other remaining constant.

When the greater part of my observations of the dissipation were made, EBERT'S instrument was also in use, and gave the true value of the ionization at the time when each observation of the dissipation was taken. In order to find how the dissipation varies with variations of the ionization, the wind strength being constant, I separated out all the results of the dissipation obtained with a given wind strength, then divided these again according to the values of the ionization observed at the same time. The results are given in Table IX., and have been plotted in fig. 4.

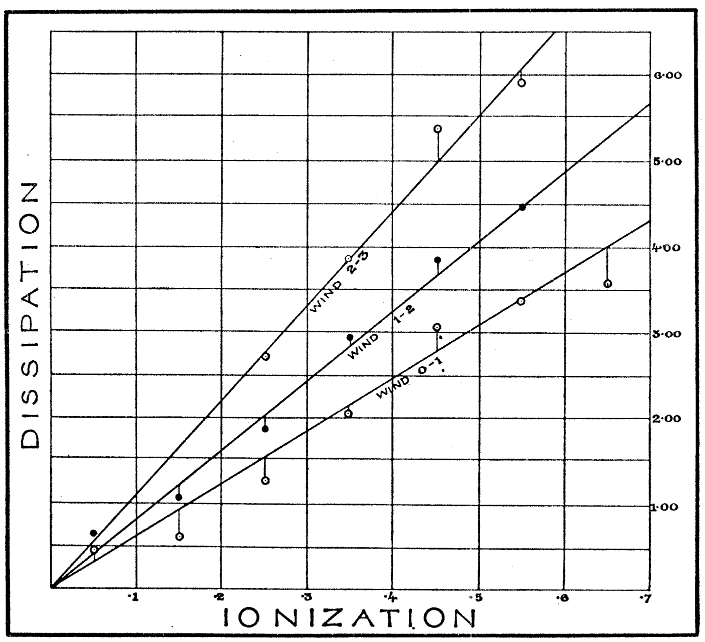

Fig. 4.

TABLE IX.—Ionization and Dissipation according to Wind.

Ionization.	Dissipation.		
	Wind 0–1.	Wind 1–2.	Wind 2–3.
·0–·1	·45 (12)	·65 (6)	—
·1–·2	·60 (56)	1·08 (10)	—
·2–·3	1·26 (38)	1·85 (20)	2·70 (16)
·3–·4	2·04 (28)	2·92 (17)	3·88 (47)
·4–·5	3·03 (44)	3·83 (33)	5·33 (54)
·5–·6	3·36 (24)	4·48 (6)	5·90 (14)
·6–·7	3·56 (4)	—	—

We see that, allowing a large margin for the uncertainties of such an investigation, the dissipation may be regarded as a linear function of the ionization for any given wind strength. It must be remembered that this agreement is only true when dealing with a large number of observations; for the mobility of the ions affects the dissipation considerably. It would be interesting to compare individual observations of the ionization and the dissipation when the wind strength was accurately known. In that case the effect of the mobility of the ions would be very apparent. My observations do not allow of this being done, as the wind strengths were only roughly judged by the "feel" of the wind, and no doubt varied very much more amongst themselves than the mobility did. For the same reason it is of no use finding from my observations how the dissipation varied with the wind strength, the ionization being constant; for my classification of the wind strengths, although based on the Beaufort scale, would almost certainly differ from a similar classification made by another observer.

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Dissipation and Wind.—After what has been already said about the method of estimating the wind strength, the following table cannot be regarded as final; but as it shows the influence of the wind as found from all the observations it is printed here. It is of considerable interest to notice that the ratio q falls as the wind strength increases.

TABLE X.—Dissipation and Wind.

Wind. Beaufort Scale, 0–12.	Winter.			Summer.			Year.		
	a_+.	a_-.	q.	a_+.	a_-.	q.	a_+.	a_-.	q.
0–1	·85 (106)	1·04 (108)	1·22	2·68 (50)	3·16 (50)	1·18	1·44 (156)	1·71 (158)	1·19
1–2	1·84 (45)	2·21 (46)	1·20	3·71 (23)	4·30 (23)	1·16	2·48 (68)	2·91 (69)	1·17
2–3	3·64 (30)	3·99 (27)	1·09	4·62 (52)	5·20 (50)	1·13	4·26 (82)	4·78 (77)	1·12
3–4	4·45 (21)	4·85 (25)	1·09	5·11 (44)	5·58 (43)	1·09	4·90 (65)	5·40 (68)	1·10
>4	5·80 (20)	5·96 (23)	1·03	6·05 (36)	6·78 (33)	1·12	5·97 (56)	6·44 (56)	1·08

Dissipation and Relative Humidity.—GOCKEL* has gone very fully into the relation between dissipation and relative humidity, and his results, which have in the main been confirmed by ZÖLSS,† show that the dissipation decreases with a rise in the relative humidity, and as the dissipation of the positive electricity decreases more rapidly than that of the negative, the ratio q increases as the relative humidity rises.

TABLE XI.—Dissipation and Relative Humidity.

Relative Humidity.	Winter.			Summer.			Year.		
	a_+.	a_-.	q.	a_+.	a_-.	q.	a_+.	a_-.	q.
per cent. 30 to 40	—	—	—	4·61 (16)	4·97 (16)	1·08	4·61 (16)	4·97 (16)	1·08
40 „ 50	—	—	—	4·71 (63)	5·23 (63)	1·11	4·71 (63)	5·23 (63)	1·11
50 „ 60	—	—	—	4·68 (52)	5·49 (52)	1·17	4·68 (52)	5·49 (52)	1·17
60 „ 70	3·03 (22)	3·55 (22)	1·17	3·88 (37)	4·53 (37)	1·17	3·56 (59)	4·16 (59)	1·17
70 „ 80	2·61 (42)	3·01 (42)	1·16	2·90 (29)	3·37 (29)	1·16	2·73 (71)	3·16 (71)	1·16
>80	1·37 (51)	1·71 (51)	1·25	—	—	—	1·37 (51)	1·71 (51)	1·25

Table XI. shows that for relative humidities greater than 50 per cent. my results agree with GOCKEL'S, the decrease in the dissipation as the relative humidity rises being very marked, and the value of q also increases as the relative humidity increases. But it should be remarked that the fall in the dissipation as the relative humidity rises is not entirely due to the relative humidity, for the conditions in Karasjok were such that nearly all values of the relative humidity higher than 80 per cent. were accompanied by a calm atmosphere, and in the main low values of the relative humidity were accompanied by high wind.

Dissipation and Temperature.—ZÖLSS (*loc. cit.*) has shown that the dissipation in the free air increases with the temperature, and he found that the variation was linear

* 'Phys. Zeit.,' 4, p. 871, 1903.

† 'Phys. Zeit.,' 5, p. 108, 1904.

over the range he investigated. Later GOCKEL returns to this point,* and throws out the suggestion that the increase in the dissipation is due to the increase which the ozone in the atmosphere undergoes as the temperature rises. In Karasjok the temperature fell so low during the winter that I was able to observe the influence of temperature on the dissipation at very much lower temperatures than had ever been done before, obtaining sixty observations with the temperature between − 40° and − 20° C. Table XII. shows the results, which, in the main, confirm ZÖLSS's

TABLE XII.—Dissipation and Temperature.

Temperature.	Winter.			Summer.			Year.		
	a_+.	a_-.	q.	a_+.	a_-.	q.	a_+	a_-.	q.
° C.									
< -20	·76 (28)	·91 (31)	1·19	—	—	—	·76 (28)	·91 (31)	1·19
− 20 to − 15	·99 (34)	1·22 (34)	1·24	—	—	—	·99 (34)	1·22 (34)	1·24
− 15 „ − 10	1·51 (39)	1·73 (39)	1·15	—	—	—	1·51 (39)	1·73 (39)	1·15
− 10 „ − 5	2·45 (44)	2·82 (44)	1·16	—	—	—	2·45 (44)	2·82 (44)	1·16
− 5 „ 0	3·17 (63)	3·75 (64)	1·18	3·99 (10)	4·71 (10)	1·18	3·28 (73)	3·90 (74)	1·19
0 „ 5	4·34 (18)	4·66 (20)	1·07	3·71 (37)	3·73 (37)	1·01	3·92 (55)	4·06 (57)	1·03
5 „ 10	—	—	—	4·41 (80)	4·99 (80)	1·13	4·41 (80)	4·99 (80)	1·13
10 „ 15	—	—	—	4·68 (66)	5·23 (66)	1·12	4·68 (66)	5·23 (66)	1·12

observations. The temperature has a great effect on the dissipation, for it rises from ·83 with temperatures between − 40° and − 20° C. to 4·95 with temperatures between 10° and 15° C., and when the results for the whole year are considered the relation is practically linear. But here again attention must be called to the fact that the very low temperatures were always accompanied by calm weather; and that there was very much more wind during the summer when the high temperatures were obtained than during the winter with its low temperatures. It is interesting to note that temperature has no apparent effect on the ratio q.

Ionization and Relative Humidity.—It will be seen from Table XIII. that when the whole year is taken into account the effect of the relative humidity on the ionization is very similar to its effect on the dissipation. That is, the amount of ionization decreases with an increase in the relative humidity, while the ratio r increases. But it is very interesting to note that when the winter and summer results are taken separately this effect is hardly apparent at all. No definite effect of the relative humidity on the positive ionization can be detected during either the winter or summer six months. While the negative ionization is slightly affected during the winter, no effect can be seen during the summer. Nevertheless, during both winter and summer the value of the ratio r increases regularly with the relative humidity.

* 'Phys. Zeit.,' 5, p. 257, 1904.

TABLE XIII.—Ionization and Relative Humidity.

Relative humidity.	Winter.			Summer.			Year.		
	I−.	I+.	r.	I−.	I+.	r.	I−.	I+.	r.
per cent.									
30 to 40	—	—	—	·45 (6)	·45 (6)	1·04	·45 (6)	·45 (6)	1·04
40 ,, 50	—	—	—	·38 (44)	·41 (44)	1·10	·38 (44)	·41 (44)	1·10
50 ,, 60	·32 (15)	·35 (15)	1·09	·37 (52)	·42 (52)	1·14	·36 (67)	·40 (67)	1·13
60 ,, 70	·28 (24)	·32 (24)	1·15	·39 (34)	·45 (34)	1·15	·34 (58)	·40 (58)	1·15
70 ,, 80	·28 (32)	·33 (32)	1·16	·46 (8)	·55 (8)	1·20	·32 (40)	·37 (40)	1·18
>80	·23 (17)	·32 (17)	1·39	—	—	—	·23 (17)	·32 (17)	1·39

Ionization and Temperature.—From Table XIV. it will be seen that temperature has a great effect on the ionization—the ionization at temperatures lower than −20° C. being only a little greater than a third of those with temperatures between 10° and 15° C. No effect of temperature on the ratio r is apparent.

TABLE XIV.—Ionization and Temperature.

Temperature.	Winter.			Summer.			Year.		
	I−.	I+.	r.	I−.	I+.	r.	I−.	I+.	r.
° C.									
< −20	·16 (10)	·18 (9)	1·12	—	—	—	·16 (10)	·18 (9)	1·12
−20 to −15	·18 (26)	·22 (24)	1·23	—	—	—	·18 (26)	·22 (24)	1·23
−15 ,, −10	·22 (27)	·26 (26)	1·18	—	—	—	·22 (27)	·26 (26)	1·18
−10 ,, − 5	·30 (41)	·36 (38)	1·20	—	—	—	·30 (41)	·36 (38)	1·20
− 5 ,, 0	·32 (56)	·39 (53)	1·27	·31 (21)	·37 (21)	1·19	·31 (77)	·39 (74)	1·24
0 ,, 5	·36 (31)	·42 (29)	1·16	·36 (40)	·39 (40)	1·07	·35 (71)	·40 (69)	1·12
5 ,, 10	—	—	—	·40 (66)	·45 (66)	1·13	·40 (66)	·45 (66)	1·13
10 ,, 15	—	—	—	·43 (28)	·45 (28)	1·06	·43 (28)	·45 (28)	1·06

In discussing the effect of temperature on dissipation it was stated that the absence of wind at low temperatures might account for the decreased dissipation; but we now see that the smallness of the dissipation is more likely caused by the low ionization at low temperatures.

Potential Gradient and Temperature.—It has already been shown that the potential gradient varies very greatly with the ionization and dissipation. As we have also seen that the ionization and dissipation depend greatly on the temperature, we should expect the temperature to have an effect on the potential gradient. That such is the case can be seen from Table XV. The potential gradient is high with low temperatures and low with high temperatures. This fact has often been noticed and recorded before.

TABLE XV.—Potential Gradient and Temperature.

Temperature.	Potential gradient, volts/metre.		
	Winter.	Summer.	Year.
° C.			
− 40 to − 30	256 (29)	—	256 (29)
− 30 „ − 20	259 (55)	—	259 (55)
− 20 „ − 10	235 (117)	—	235 (117)
− 10 „ 0	158 (178)	126 (40)	152 (218)
0 „ 10	108 (45)	105 (174)	106 (219)
10 „ 20	—	98 (79)	98 (97)

The Aurora and the Electrical Conditions of the Atmosphere.

During the whole of my stay in Karasjok I could not detect the slightest effect of the aurora on any of the electrical conditions of the atmosphere, and most careful watching of the needle of the self-registering electrometer did not show any relation between potential gradient and the aurora. On first starting my observations I thought I found, as many other observers have done, an unsteadiness of the potential gradient during an aurora display, but longer experience showed that this unsteadiness had nothing to do with the aurora. In order for an aurora to be visible it must be a clear night, and a clear night is generally accompanied by low temperature and a high potential gradient. The high potential on clear cold nights was always unsteady and varied quite irrespective of the presence or absence of an aurora. When an aurora was visible naturally it often appeared as if a change in the aurora was coincident with a change in the potential gradient, but the attempt to connect changes in the potential gradient with changes in the aurora over any length of time always failed. Other observers have recorded negative potential gradient during an aurora display; but during the whole winter my self-registering electrometer did not once record any such reversal.

CONCLUSIONS TO BE DRAWN FROM THE WORK.

The first and most important conclusion is that the difference in the electrical conditions of the atmosphere between mid-Europe and this northerly station can all be accounted for by the difference in the meteorological condition at the two places.

Dissipation.—For reasons which have been set out above, the actual numbers obtained for the dissipation cannot be compared directly with those of other observers, but one is quite safe in saying that they are of the same order as those obtained further south under the same meteorological conditions. They certainly do not show that great increase in dissipation and unipolarity which has been ascribed to places of high latitude by some writers, who base their general conclusions on a few observations made by ELSTER.*

Ionization.—At the time of writing no similar series of observations made with EBERT'S apparatus have been published, so it is impossible to compare the ionization in high latitudes with those in lower. But judging from my own experience, as with the dissipation there is no change in the ionization which cannot be explained by the meteorological conditions. There is certainly no abnormal ionization nor abnormal unipolarity, both the ratios q and r being in excellent agreement with those found in Germany.

The yearly course of the ionization is of great interest and of much importance. What causes the yearly variation is not at first obvious. The ionization of the air at any moment is determined by two factors: firstly, the rate at which ions are produced in the air, and secondly, by the rate at which they re-combine.† The yearly variation of the ionization must be caused by variation in either one or both of these factors. We do not yet know what the ionizing influences at work in the air are; but possible ones are radio-emanation, the sun's light, and temperature. But none of these undergo a yearly change corresponding to that of the ionization. It will be shown later that the yearly course of the radio-active emanation in the air is exactly opposite to that of the ionization. The sun's light and the temperature both have a yearly course in some agreement with that of the ionization, but the maxima and minima do not agree: the maximum and minimum of the ionization fall two months behind those of the sun's light and one month behind those of the temperature. We should then rather expect to find a cause for the variation by assuming a constant ionizing factor and looking for a change in the conditions which affect the re-combination of the ions. One of the first things which ELSTER and GEITEL found when working at the ionization of the air was that the dissipation depends to a great extent on the clearness of the air. This factor in itself is capable of accounting for the yearly course of the ionization at Karasjok.

All who have travelled in Arctic regions know the peculiar haze which fills the air when the temperature falls very low and gives the "cold" aspect to Arctic scenes. Such a haze, which is not a mist or fog, was frequent during the winter at Karasjok. On the other hand, at the end of the summer the air reached a degree of transparency which I have never seen equalled in any other place. On going into the open air one was often struck with the great transparency of the atmosphere, giving sometimes the impression that the air between one and distant objects had been entirely removed. That it is the transparency of the air rather than the temperature which determines the ionization could often be seen from individual observation. On June 16 the temperature rose to the abnormal value of 24·7° C., the air being exceedingly hazy and oppressive; the ionization was only ·18, the mean

* 'Phys. Zeit.,' 2, p. 113, 1900.

† SCHUSTER, 'Proc. Man. Lit. and Phil. Soc.,' vol. 48, Part II., p. 1, 1904.

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for the month of June being ·39. On September 19 the temperature rose to 16·4° C., after having been below 5° for the previous few days; the air again was very hazy and sultry and the ionization went down to ·24, the mean for the month being ·44. On the contrary, a clear day in the winter would be accompanied by comparatively high value of the ionization: February 22 ionization ·40, mean for month, ·21. Much to my regret I cannot support this conclusion by actual figures, as Karasjok was so enclosed by low hills that it was impossible to obtain even a rough arbitrary scale of the clearness of the air by the visibility of distant objects. But there can be no doubt that the maximum of the transparency of the atmosphere corresponded with the maximum of the ionization.

Potential Gradient.—The yearly course of the potential gradient in Karasjok conforms to the general rule for the northern hemisphere formulated by HANN* in the following words: "The maximum of the potential gradient occurs in December, January or February; it falls rapidly in the spring; remains nearly at the same level during the summer and then rapidly rises again in October and November."

The fact that the potential gradient runs so exactly opposite to the dissipation makes it appear as though there were a constant charge of negative electricity being continually given to the surface of the earth during the whole year, and that the amount at any moment on the surface itself (measured, of course, by the potential gradient) is determined by the rate at which the charge is being dissipated. How this charge is supplied to the earth still remains, in spite of many theories, one of the unsolved problems of atmospheric electricity.

Two types of daily variation of the potential gradient are known.† The first is a double period, having a minimum between 3 and 5 A.M. and a second about midday, the corresponding maxima falling at about 8 A.M. and 8 P.M. Good examples ot this are Batavia and Paris. The other type consists of a single maximum and minimum, the former falling in the evening and the latter between 3 and 5 A.M. To this type belong the records made at high altitudes and at some places during the winter.

The daily course of the potential gradient for the whole year at Karasjok belongs to the latter class, there being only one maximum and one minimum. Taking the four seasons each by itself, we see that the winter and spring curves are of the same type, while that for the summer shows a slight tendency to form a minimum at midday, and the autumn curve has a distinct double period. As stated above, the morning and evening maxima of the autumn curve were considerably strengthened by the mists which formed over the river. The nearest place to Karasjok at which measurements have been made of the potential gradient is Sodankyla‡ in Finland, and the curves for the two places are in surprising agreement.

* 'Lehrbuch der Meteorologie,' p. 715.

† HANN, 'Lehrbuch der Meteorologie,' p. 716.

‡ 'Expédition polaire, 1882–83.'

It would appear from these results as though the double daily period were confined to places having a large daily temperature variation. The daily variation of the temperature was much the greatest in Karasjok during the autumn three months: the sun not rising during the winter three months, not setting during the summer three months, and the snows still being on the ground during the spring, all tended to keep the daily temperature variations low during these seasons. In all places having a double daily period of the potential gradient the midday minimum is always greater during the summer than during the winter, which supports the same conclusion.

Atmospheric Radio-Activity.

In 1901 Elster and Geitel* made the very important discovery that the atmosphere always contains more or less radio-active emanation. Since the discovery several workers have repeated the observations and confirmed the results. During the whole of 1902 Elster and Geitel† made daily observations of the radio-activity, and found that the amount of emanation in the atmosphere depends largely on some meteorological conditions, such as the rising or falling of the barometer and temperature; and, as a result of their work, made the suggestion that the emanation in the air is supplied entirely by the radium or radio-active emanation contained in the soil.

The method used by Elster and Geitel to detect and measure the emanation in the air, which has been adopted by other observers, consisted of stretching a wire about 10 metres long between insulators in the open air. This wire was then charged to a negative potential of between 2000 and 2500 volts. After the wire had been exposed to the air at this potential for two hours, it was removed and wrapped round a net cylinder fitting inside the "protection cylinder" attached to their dissipation apparatus (specially closed at the bottom as well as the top for this measurement), and the rate at which the electroscope discharged was determined. When one metre of the wire discharged the electroscope one volt in one hour the atmospheric activity was said to be unity and written A = 1.

Using Elster and Geitel's method, I made observations of the atmospheric radio-activity in Karasjok. I first started by making odd observations every now and again, but found that the values obtained were so much higher than anything which had up to that time been recorded that I determined to make a thorough investigation of the matter. In December, 1903, I started a series of observations, observing three times each day. As each observation occupied over two hours, it was impossible to take them so frequently without interfering with my other work, therefore I decided to take three observations each day for a month, then wait a month, then

* 'Phys. Zeit.,' 2, p. 590, 1901.

† 'Phys. Zeit.,' 4, p. 526, 1903.

repeat them the following month, and so on. This was done for the whole year with the exception of the summer months, when observations were made alternate weeks instead of alternate months. Besides the three observations during the day, for one week out of every four I continued the observations during the night, observing between the hours of 3 and 5 A.M.

In order not to interfere with my other observations, the observations of the radio-activity had to fit in between them, and the following times were chosen as being the most convenient: Night observation from 3 to 5 A.M.; morning observation from 10 to 12 A.M.; afternoon observation from 3 to 5 P.M.; and evening observation from 8.30 to 10.30 P.M. In this way it proved possible to get a good idea of the yearly and daily course of the radio-activity. From the 420 separate observations the effect of the different meteorological conditions have been obtained.

As the value of the radio-activity varied very greatly from month to month, in all the following tables each month is treated by itself, and then the whole year treated in a separate column.

TABLE XVI.—Radio-activity.

	Mean values.				Mean values.	Maximum values.			
	Early morning, 3–5 A.M.	Morning, 10–12 A.M.	After-noon, 3–5 P.M.	Evening, 8.30–10.30 P.M.		Early morning.	Morning.	After-noon.	Evening.
*November and December	209 (6)	87 (24)	88 (24)	131 (22)	129	396	204	384	432
February .	221 (6)	72 (23)	113 (24)	101 (24)	127	366	234	342	228
April . . .	87 (6)	41 (23)	37 (23)	55 (22)	55	210	120	90	120
May and June	79 (6)	35 (20)	32 (20)	43 (20)	47	204	102	78	108
July and August	175 (6)	35 (20)	32 (20)	76 (20)	80	270	72	93	198
September .	201 (6)	81 (18)	70 (18)	142 (18)	123	390	156	122	264
Year . . .	162 (36)	58 (128)	62 (129)	92 (126)	93	396	234	384	432

* For the observations of this month set out in full detail see 'Roy. Soc. Proc.,' vol. 73, p. 209, 1904.

Table XVI. gives the mean and maximum values of the activity for each month. From it the yearly course is seen to consist of two periods. During the first, extending from the beginning of September to the end of February, the radio-activity is constant and very high. During the other months the activity is much lower (less than half) and not quite so constant. The maximum falls in midwinter and the minimum in midsummer. A distinct daily period is also shown: the maximum falling in the early hours of the morning and the minimum about midday.

Table XVII. shows the effect of temperature on the radio-activity. It is interesting to notice that from the results for the whole year the temperature appears to have a very marked effect on the radio-activity; but when each month is taken by itself, the effect is not apparent at all. It would appear from this that temperature only plays a secondary part in determining the amount of activity in the air.

TABLE XVII.—Radio-activity and Temperature.

Temperature.	November and December.	February.	April.	May and June.	July and August.	September.	Year.
° C.							
< − 30	127 (12)	98 (11)	—	—	—	—	113 (23)
− 30 to − 20	166 (10)	126 (34)	—	—	—	—	135 (44)
− 20 „ − 10	80 (17)	96 (20)	—	—	—	—	88 (37)
− 10 „ 0	82 (25)	66 (12)	51 (27)	—	—	271 (4)	78 (68)
0 „ 10	110 (8)	—	47 (46)	33 (41)	62 (33)	100 (44)	63 (172)
10 „ 20	—	—	—	56 (19)	56 (30)	83 (12)	61 (61)
> 20	—	—	—	39 (6)	65 (3)	—	48 (9)

The relative humidity appears to have a very large effect on the radio-activity, for not only can its influence be seen when the year is taken as a whole, but it is very apparent in each separate month with the exception of February.

TABLE XVIII.—Radio-activity and Relative Humidity.

Relative humidity.	November and December.	February.	April.	May and June.	July and August.	September.	Year.
Per cent.							
< 50	—	—	24 (7)	30 (27)	38 (22)	53 (6)	34 (62)
50 to 60	—	27 (2)	32 (11)	45 (10)	31 (8)	70 (15)	46 (46)
60 „ 70	—	54 (11)	39 (13)	43 (12)	32 (9)	86 (10)	50 (55)
70 „ 80	—	124 (47)	48 (23)	43 (8)	51 (15)	97 (9)	88 (102)
80 „ 90	—	90 (14)	63 (11)	75 (6)	143 (9)	156 (11)	106 (51)
> 90	—	60 (1)	85 (8)	40 (2)	170 (3)	196 (8)	132 (22)

The wind strength has a most direct influence, which can not only be seen in the year and separate months, but can also be detected in nearly all the individual observations.

TABLE XIX.—Radio-activity and Wind Strength.

Wind (Beaufort Scale).	November and December.	February.	April.	May and June.	July and August.	September.	Year.
0–2	116 (49)	110 (68)	65 (32)	57 (29)	81 (37)	126 (41)	98 (257)
3–4	79 (13)	66 (7)	36 (22)	33 (20)	35 (22)	67 (13)	47 (97)
5–6	63 (6)	54 (2)	34 (16)	27 (11)	39 (2)	60 (4)	40 (41)
>6	32 (3)	—	21 (3)	10 (6)	20 (6)	114 (3)	33 (21)

The radio-activity is greater with a falling than with a rising barometer. The results show this every month without exception.

TABLE XX.—Radio-activity and Barometer.

Barometer.	November and December.	February.	April.	May and June.	July and August.	September.	Year.
Rising	95 (44)	97 (34)	38 (29)	25 (25)	50 (42)	107 (27)	71 (201)
Falling. . . .	115 (23)	119 (34)	53 (40)	53 (40)	77 (23)	110 (28)	85 (190)

But this does not necessarily mean that the radio-activity is greater with a low than with a high barometer. Table XXI. shows that such is not the case. Out of the six separate periods only two, April and May and June, show a regular increase in the radio-activity as the height of the barometer decreases. In the other months, and for the year considered as a whole, no relation appears between the radio-activity and the height of the barometer.

TABLE XXI.—Radio-activity and Height of the Barometer.

Barometer.	November and December.	February.	April.	May and June.	July and August.	September.	Year.
millims.							
>760	—	73 (14)	30 (2)	—	—	158 (5)	89 (21)
760 to 750	137 (20)	104 (13)	39 (13)	29 (25)	74 (9)	102 (33)	81 (126)
750 „ 740	85 (23)	93 (29)	42 (37)	44 (32)	53 (35)	104 (28)	65 (174)
740 „ 730	109 (18)	146 (20)	65 (23)	57 (9)	50 (9)	—	93 (79)
730 „ 720	66 (10)	102 (1)	—	—	—	—	70 (11)

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An uncertain result is obtained when the observations are divided according to the amount of cloud. For the whole year and for two of the separate months the clouds appear to have a direct influence on the radio-activity, but during the other four months there does not appear to be any relation between the two.

TABLE XXII.—Radio-activity and Clouds.

Clouds.	November and December.	February.	April.	May and June.	July and August.	September.	Year.
0–3	130 (18)	120 (33)	34 (9)	30 (8)	117 (8)	172 (7)	114 (68)
4–7	107 (26)	124 (17)	61 (15)	49 (13)	102 (16)	96 (20)	93 (107)
8–10	76 (27)	96 (27)	46 (50)	39 (45)	42 (47)	102 (33)	62 (229)

The direction of the wind appears to have an influence on the radio-activity, for the latter is at a maximum with a south wind and a minimum with a north wind. It is very questionable if this is a real effect or only a re-statement of the relation between radio-activity and a rising or falling barometer, for every case of a north wind was accompanied by a rising barometer and nearly every case of a south wind by a falling barometer. That it is not the other way about is seen from the fact that observations taken with no wind show an unmistakable relation between the radio-activity and a rising or falling barometer.

TABLE XXIII.—Radio-activity and Wind Direction.

Wind strength.	N.	S.	E.	W.
Greater than 3 on the Beaufort scale . . .	25 (48)	53 (57)	28 (49)	47 (44)

No relation between the radio-activity and potential gradient can be detected either in the separate months or the whole year.

TABLE XXIV.—Radio-activity and Potential Gradient.

Potential Gradient.	November and December.	February.	April.	May and June.	July and August.	September.	Year.
Negative potential	33 (6)	—	41 (4)	24 (1)	42 (2)	137 (2)	49 (15)
0 to 100 volts/metre	106 (16)	148 (16)	51 (22)	24 (42)	59 (35)	100 (40)	77 (171)
100 „ 200 „	143 (25)	119 (29)	51 (37)	34 (21)	61 (28)	134 (15)	86 (155)
200 „ 300 „	90 (10)	90 (10)	32 (4)	—	—	—	81 (24)
300 „ 400 „	71 (10)	64 (6)	51 (2)	—	—	—	66 (18)
>400 „	83 (3)	61 (16)	31 (5)	—	—	—	58 (24)

I found it impossible to make observations of the ionization and dissipation at the same time as those of the radio-activity. This is much to be regretted, as it is very important to decide if the emanation in the atmosphere is the cause of the permanent ionization. That the ionization does not depend on the amount of emanation alone is quite clear from the yearly variations of the two, for the ionization is at a minimum during the winter, exactly the season when the activity is at its maximum. But that does not prove that the ionization is not due to the emanation; we can only say that if it is, then the increase in the production of ions owing to the excess of emanation is overbalanced by the increased rate of recombination due to the winter conditions.

That all the relations shown by the above analysis should be as they are gives an exceedingly strong support to ELSTER and GEITEL's theory of the origin of the atmospheric radio-active emanation. According to their theory, the air which is mixed up with the soil of the ground becomes highly charged with radium emanation.* When the barometer falls, this air passes out of the ground into the atmosphere, bringing with it its charge of emanation.

All the facts of the above analysis receive a very simple explanation by this theory if one extends it to include the fact that, as the emanation is a gas contained in the soil, it must constantly diffuse into the atmosphere above quite independently of the state of the barometer. Assuming this constant diffusion, we at once see that *everything which tends to reduce the atmospheric circulation, i.e., to keep the air stagnant, tends also to increase the quantity of emanation in the lower layers of the atmosphere.*

Looking now at each of the tables in order, we see that the temperature does not have a direct, but an indirect influence on the radio-activity. This is explained by the fact that the low temperature of the winter produces a nearly permanent temperature inversion, as mentioned above, which entirely prevents ascending currents of air. Thus the emanation on leaving the ground in cold weather cannot rise, but collects in the lower atmosphere, causing the high winter values of the radio-activity.

The reason why the radio-activity is high with high relative humidity is easily found when one considers that each evening, as the temperature rapidly falls, two things happen: first there is a rapid rise in the relative humidity and secondly ascending currents of air are cut off. The latter fact gives rise to the high radio-activity. Also a mist or fog is always a sign of stagnant air.

A high wind is naturally accompanied by low activity, for it acts as a stirrer, and rapidly mixes the escaped emanation with a large volume of air.

ELSTER and GEITEL's theory explains the relation found between radio-activity and a rising and falling barometer. If air stream out of the ground when the barometer falls, it must charge the atmosphere with its emanation.

* 'Phys. Zeit.,' 5, p. 11, 1904; 'Terr. Mag.,' vol. 9, p. 49, 1904.

The effect of the clouds is not easy to understand, and as the results do not show a pronounced dependence of the radio-activity on the clouds, perhaps it is not real, unless it is that clouds are usually associated with ascending currents of air. Other observers* have found a relation between radio-activity and clouds, but until more observations are made the question must be left unsettled.

Thus we see that the whole effect of the meteorological conditions on the radio-activity depends on whether those conditions tend to mix the emanation rapidly with a large volume of air, or to keep it near to the ground from which it is always escaping.

The same principles lead us to an explanation of the daily and yearly course of the radio-activity. During the daytime ascending currents are formed, while as the evening approaches these stop and the air lies cold and stagnant during the night. Thus we see why the minimum should be in the daytime and the maximum during the night.

The yearly period has a similar explanation. During the winter in Karasjok, when the snow is permanently on the ground, temperature inversion accompanied by stagnant air is the rule rather than the exception. On the contrary, during the summer when there is nearly permanent sunshine, ascending currents will be formed at all times of the day and night. This accounts for the winter maximum and the summer minimum of the radio-activity.

One strange fact is that the activity should be so high during the winter when the whole country is covered with snow. This at first led me,† with other observers,‡ to doubt ELSTER and GEITEL'S theory, but the reason is not hard to find if it is remembered that the snow must form a very large reservoir to hold the emanation as it is escaping from the soil. It would be interesting to see if air, drawn from the snow in the way ELSTER and GEITEL drew it from the ground, would be charged with emanation. I wished to test this, but had no instruments with me which could be used for the experiment.

One would also expect high values of the radio-activity in Karasjok during the winter from another consideration. Karasjok is situated on the river, and just as the water from all the surrounding land flows down to the river, so when the temperature falls very low the cold air will also find its way into the river valley. This cold air flowing over the ground will sweep the emanation along with it, and so the valley will become filled with air highly charged with emanation.

In order to find if the minerals of Karasjok are particularly rich in radio-active constituents I sent samples of sand and rock to the Hon. R. J. STRUTT, who very kindly undertook to test them, and to whom my best thanks are due for the trouble he took in his investigation of them. In none of the specimens was he "able to

* GOCKEL, 'Phys. Zeit.'; ZÖLSS, 'Phys. Zeit.'

† 'Roy. Soc. Proc.,' vol. 73, p. 209, 1904.

‡ 'Phys. Zeit.,' 5, p. 591; 1904.

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detect the emanation with certainty, and none yielded more than a $\frac{1}{100,000}$ part of what the same quantity of pitchblende would give on heating." Thus the soil conditions of Karasjok do not appear to be abnormal, so that the high radio-activity found there during the winter must be due to the meteorological conditions being so favourable to the collection of the emanation in the lower atmosphere.

In order to compare the value of the radio-activity at Karasjok with that of other places, the only observations which can be used are ELSTER and GEITEL'S,* in Wolfenbüttel (mid-Germany), and GOCKEL'S,† in Freiburg (Switzerland); no other observer has extended his observations over a sufficiently long period to give good mean values. Neither ELSTER and GEITEL nor GOCKEL observed between 8 P.M. and 8 A.M., and as the values I found between those hours were very much the largest it is not right to compare my means with their means, so in what follows I use only the values which were obtained during the morning and afternoon observations in Karasjok.

The means for the whole year are Wolfenbüttel 18·6, Freiburg 84 and Karasjok 60. Thus Freiburg is the highest and Wolfenbüttel the lowest. The absolute maxima (between 8 A.M. and 8 P.M.) are Wolfenbüttel 64, Freiburg 420, Karasjok 384, *i.e.*, the same order as before.

It is a strange fact that the yearly period should be so marked in Karasjok, while no yearly period can be detected in either Wolfenbüttel or Freiburg. As stated above, neither ELSTER and GEITEL nor GOCKEL have observed after 8 P.M., so it is impossible to compare the daily periods. It would be exceedingly interesting to know if there is a large daily variation in mid-Europe, for if there is not, then the mean *winter* value of the radio-activity in Karasjok will be very high compared with mid-Europe, the mean for the winter, when night as well as day observations are taken into account, being 126 at Karasjok.

GOCKEL'S maximum observation of 420 was quite an exception, but even that was exceeded by my absolute maximum of 432 (observed between 8 and 10 P.M. on December 17). With this one exception the values found by GOCKEL did not exceed 170, while I found 200 quite a medium value during the winter in Karasjok. It would appear, from the results which have already been published, that high values of the radio-activity are much more common in Karasjok than in any place yet investigated.

ELSTER and GEITEL measured the radio-activity at Juist, an island in the North Sea, and found it only 6, while in the Bavarian Alps they found the high value of 137. From this, and their observations in Wolfenbüttel, they concluded that the radio-activity increased from the sea inland. In order to find if the same conditions held in the north, I stayed in Hammerfest on my way home, and made daily observa-

* 'Phys. Zeit.,' 4, p. 526, 1903.
† 'Phys. Zeit.,' 5, p. 591, 1904.

tions of the radio-activity there for four weeks (October 17 to November 12), in exactly the same way as I had done in Karasjok.

The result was in entire agreement with ELSTER and GEITEL'S observations. The mean for the month was only 58, which must be compared with the Karasjok winter value of 126, the numbers for the different times of observing being—

TABLE XXV.—Radio-activity in Hammerfest.

	Early morning, 3–5 A.M.	Morning, 10–12 A.M.	Afternoon, 3–5 P.M.	Evening, 8.30–10.30 P.M.	Mean.
Mean	97 (6)	33 (24)	50 (24)	52 (24)	58
Maximum . . .	204	156	252	150	—

But what is much more interesting and important is the great variation of the radio-activity with the wind direction. When it is remembered that Hammerfest is free to the open ocean on the north and west, while to the south lies the whole stretch of Norway and Sweden, the following table tells its own story :—

TABLE XXVI.—Radio-activity and Wind Direction in Hammerfest.

	North.	South.	West.
Mean	8 (10)	72 (30)	4 (10)
Maximum	20	250	10

It must be admitted that these results lend great support to ELSTER and GEITEL'S hypothesis.

OBSERVATIONS OF THE AURORA.

It was not my intention on going north to make a particular study of the aurora, but I naturally followed it with as much attention as possible. The necessity of making my regular observations during the daytime, beginning at 7.30 A.M., made it impossible to stay up to watch the aurora late into the night. Each evening I noted down the chief variations in the aurora's form and brilliancy, but did not go into minor details. I intend here to shortly record a few of the things which struck me, and which are rather of a general than particular interest.

During the year of my stay there were not many exceptionally fine auroras, and coloured auroras were very rare. From the one or two I did see the colours appeared to be of two distinct kinds (by colours in this connection I mean colours other than the greenish-white light of the ordinary aurora). There is first the mass of coloured light which retains its form and colour for a comparatively long time, and colours which flash out and disappear immediately. A very interesting fact struck me with regard to the latter class of colour. It is generally known that an aurora arch is often composed of a series of spear-like shafts of light arranged perpendicularly to the direction of the arch, and which appear to be in constant motion. A number of these spears will suddenly become brilliant and the lower ends shoot out of the arch into the black sky below. The brilliancy will then run along the arch like a wave of light, lighting up all the spears as it goes along. I noticed that the "front" of such a wave of brilliancy and the points of the spears *when shooting out* were bright red, but as soon as the motion stopped the colour disappeared, while the more violent the motion the purer and brighter the red. It appeared as if some physical process accompanied the passage of the aurora beam through the air and gave out a red light. For example, if the air had to be ionized before the discharge could pass through, then the process of ionization produced red light. If the motion was particularly violent, the production of red light would be followed by a production of brilliant green light, so that if a bright wave passed along an arch two waves of colour would appear to travel along, first a wave of red light, closely followed by a green wave, the two travelling so closely together as to appear one wave having a two-coloured crest. Similarly spears shooting out with a great velocity would appear to have red and green tips.

The question of the relation of clouds to auroras has been very often raised. Three of my observations bear on this point.

On the evening of October 11, 1903, after a fairly active display, the aurora disappeared; but its place was taken by a system of narrow bands of cirrus clouds stretching right across the sky, which, being illuminated by the bright moon, had all the appearances of the aurora. That they did not form part of the aurora could only be decided at first owing to no line appearing in the spectroscope when pointed at them; but later there could be no doubt, as they partly obscured the moon.

On October 26 a very similar phenomenon again appeared; that which at first was taken to be aurora later turned out to be cloud.

On December 13 the most brilliant aurora display of my stay took place. The whole display reached a climax at 9.45, when a most brilliantly coloured corona shot out from the zenith. While this final brilliant display was taking place the sky suddenly became thinly overcast, and the aurora was only visible later as bright patches through the clouds.

It has long been a matter of controversy as to whether the aurora ever extends into the lower regions of the atmosphere. Several observers positively affirm that they have seen it quite close to the ground. This may be due to an optical illusion; one evening I was, for a considerable time, in doubt as to whether the aurora was really under the clouds or not. All over the sky were detached clouds, the clouds and spaces between them being of about the same size and shape. Right across the sky a long narrow aurora beam stretched, showing bright and dark patches owing to the clouds. It looked exactly as if the aurora beam ran along under the clouds, brightly illuminating the patches of cloud which it met. In reality the bright patches were the openings and not the clouds. It took me a long time to make quite certain of this, and it was only by at last seeing a star in the middle of a bright patch that I could be quite certain.

LEMSTRÖM strongly supported the idea that the aurora often penetrates down to the earth's surface, and described how on one occasion the aurora line appeared in a spectroscope pointed at a black cloth only one or two metres away. I was able to repeat this observation on several occasions, and found that the line which then appeared in the spectroscope was not due to an aurora discharge in the air between the spectroscope and the black cloth, but was due to reflected light, which it was impossible to prevent entering the spectroscope, as the whole landscape was lit up with the monochromatic light of the aurora.

All the time I observed the aurora I could not detect the slightest noise accompanying the discharge.

I cannot close this account of my work in Lapland without expressing my deepest thanks to each and every one of the small Norwegian colony in Karasjok—in particular to my host and hostess, Handlesmand and Fru NIELSEN; and to Lensmand and Fru HEGGE—all of whom did their very best to make my stay amongst them a source of the greatest pleasure and real enjoyment.

APPENDIX.

Potential Gradient.—The potential gradient was measured, as stated in the paper, by means of a Benndorf self-registering electrometer. The electrometer is of the quadrant type, the quadrants being kept at a constant voltage by means of small cells, and the needle itself connected to the collector. To the bifilar suspension of the needle a long aluminium arm is attached, which swings freely above a strip of paper drawn along by clockwork. Every two minutes an electrical contact is made which causes a bar to descend and to press the end of the aluminium arm down upon the paper, where a dot is left showing the position of the arm and so the potential gradient. The zero of the instrument was so arranged that on the normal side a potential gradient of 800 volts/metre could be registered. On the negative side only 100 volts/metre could be registered; but as all the days on which negative potential gradient occurred were disturbed days, and the results on such days not used, the range was quite great enough.

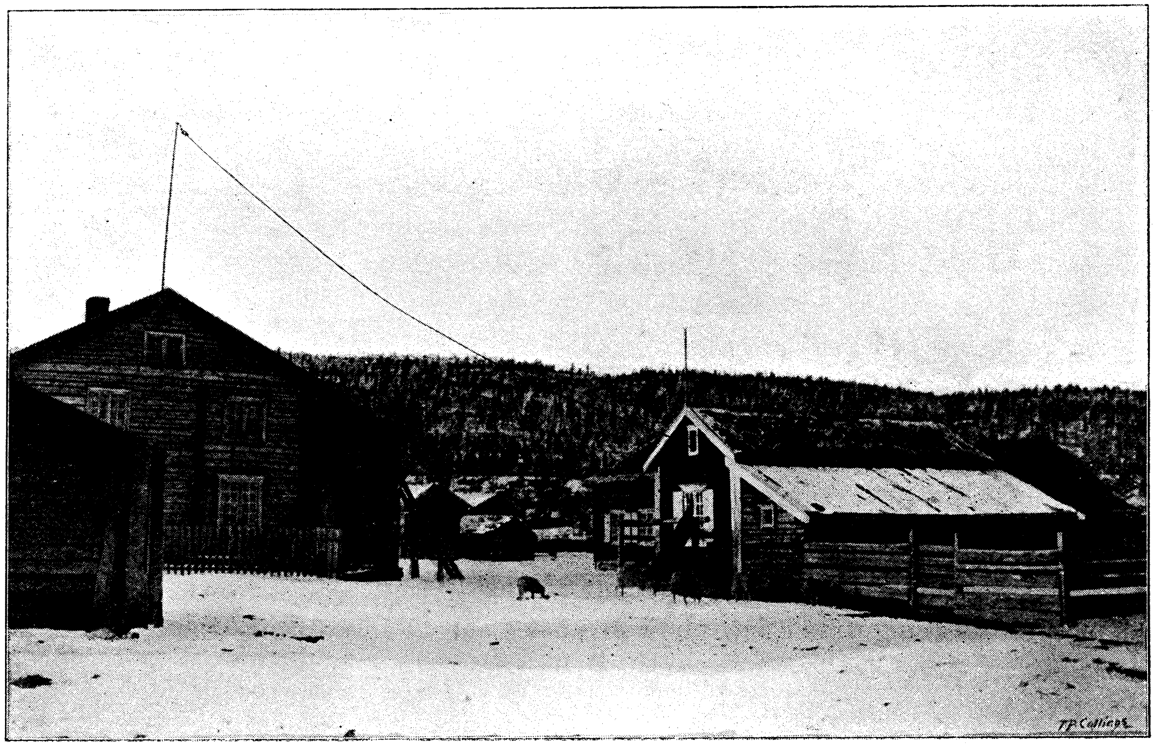
The collector was arranged in the following way:—My bed-sitting room in which

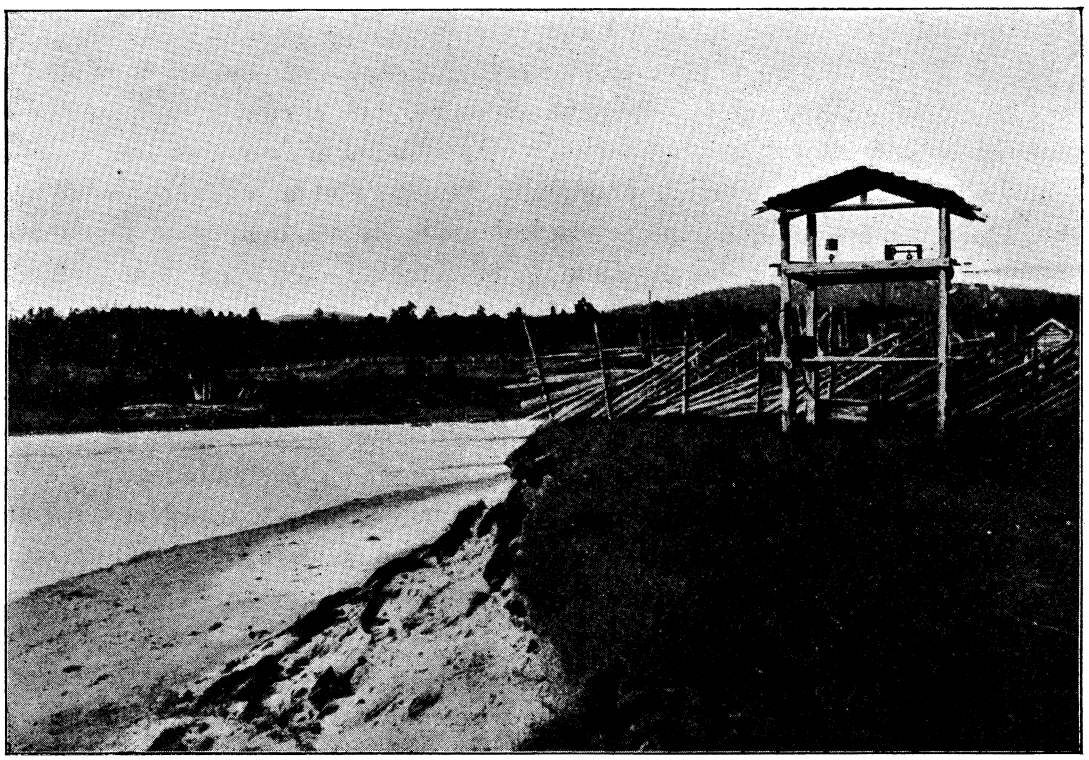
I had my instrument was a little hut near to my host's large "handlesmand's" house. On the end of the large house was a flag staff, to the top of which I attached an insulator and from it took a wire through a window into my room. About a third of the way up the wire I attached two milligrams of radium bromide which acted as a collector. On the accompanying photograph, the insulator, wire and the position of the radium collector are shown. The height of the collector above the ground was $5\frac{1}{2}$ metres. This arrangement acted extremely well and, as far as I could judge, gave as good results as could be wished.

The potential gradient was reduced to that over a level surface by making simultaneous observations with a flame collector and leaf electroscope above the most level piece of ground I could find. The country was so rough that a good and accurate determination could not be made, but the error is certainly not 20 per cent. During the year this reduction was several times repeated, no change being found. Great attention was also paid to the insulations, which were never found defective. As the collector was situated between two houses over a much frequented road, no accumulation of snow took place under it, so corrections due to the height of the snow were not necessary.

Dissipation and Ionization.—In order to observe the ionization and dissipation without being disturbed by the smoke of the village, two platforms (as shown in the photograph) were built at different parts of the village, but as both were to the north of a large part of the village, I could not observe when a south wind was blowing; with all other winds one of the platforms was on the windward side of the houses. The platforms were about a metre above the ground and the instruments on a shelf about a metre and half over the platform; above all was a roof to protect the instruments from rain and snow. By this arrangement the instruments were exposed to the full force of the wind. In order to read the dissipation electroscope in a high wind, a small screen was held to protect the instrument *just at the moment of observation.*

The usual method of observing the dissipation or ionization is to charge the electroscope, take a reading, then return in 15 minutes and take another reading. This method is open to great objections: first it is quite easy to make a false reading, and secondly in open-air work the leaves are not steady enough to allow of one reading being accurate. The method I adopted was to charge the two instruments, then take a reading of the dissipation instrument, half a minute later a reading of the ionization instrument, then at the minute take another reading of the dissipation instrument, at the next half minute a second reading of the ionization instrument, and so on for 5 minutes, when of course I had five readings on each instrument. Ten minutes later I started reading again, and at minute intervals read each of the instruments five times, then from a table found the value corresponding to each of the readings, took the mean of the first five, then that of the second five, and used these means as single values separated by an interval of 15 minutes. In this way





errors of reading were avoided and errors due to the unsteadiness of the leaves greatly diminished.

After having by this method obtained a measurement, using, say, a positive charge, the observation was repeated using a negative charge, and finally another observation with a positive charge. The mean of the two positive values, together with the negative value, were used as the result of the whole observation. This method I found to be absolutely necessary if reliable values of the ratios q and r were to be obtained, for both dissipation and ionization undergo great changes in the course of the time taken to make an observation. A whole observation when taken in this way occupied an hour and a quarter.

Long experience taught me to know when I could expect difficulties with the insulations. On such days, instead of the method sketched above, an observation was taken with one charge, and after that the insulation tested for 15 minutes, then an observation with the other charge, followed by a final insulation test for the same length of time, the whole observation taking about an hour and a half.

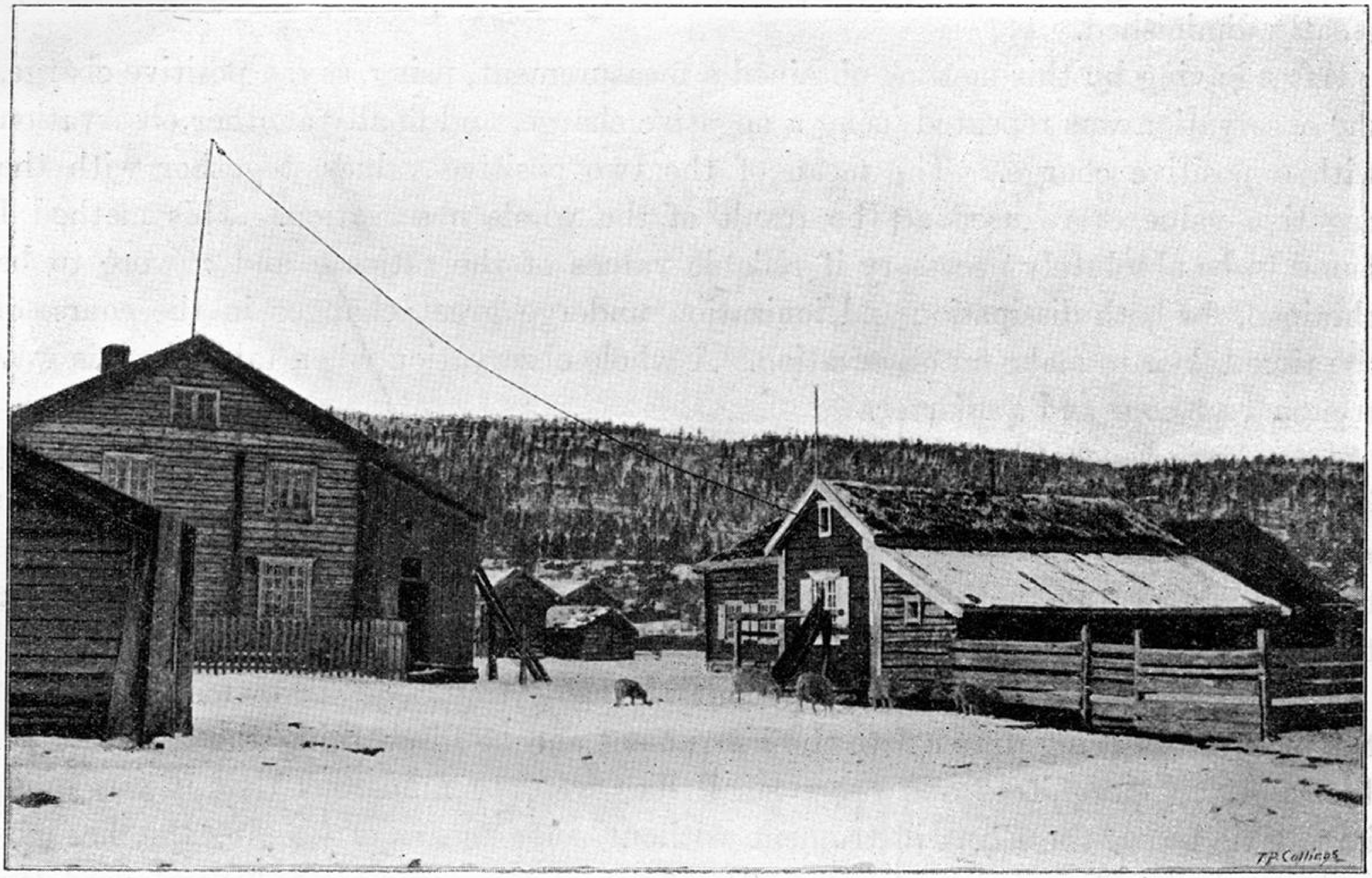
During the summer I had great difficulty in using the Ebert instrument owing to the mosquitoes being drawn into the instrument and so discharging the electroscope. In June the mosquitoes and other small flies were so numerous that it was quite impossible to use the Ebert instrument without some means of keeping the flies out, so I attached a funnel-shaped net to the front of the aspirator tube and used the instrument so protected. I expected that this net would cause some reduction in the value of the ionization as measured by the instrument, so as soon as the mosquitoes were sufficiently reduced in number to allow of observations being made with the unprotected tube I made a series of observations to find the effect of the net. Much to my regret and disappointment I found that the effect of the net varied very much according to the wind strength. In perfectly still air the net reduced the ionization by nearly a quarter, while with a stiff breeze it had no effect. This made individual observation practically useless, and in all the above tables connecting ionization and the meteorological elements all the observations taken when the net was in use—from June 9 to August 12—have been neglected. As the result of a long investigation I concluded that 10 per cent. added to the results in the bulk would just about correct for the effect of the net. Results so corrected are used in the curves and tables showing the yearly course of the ionization.

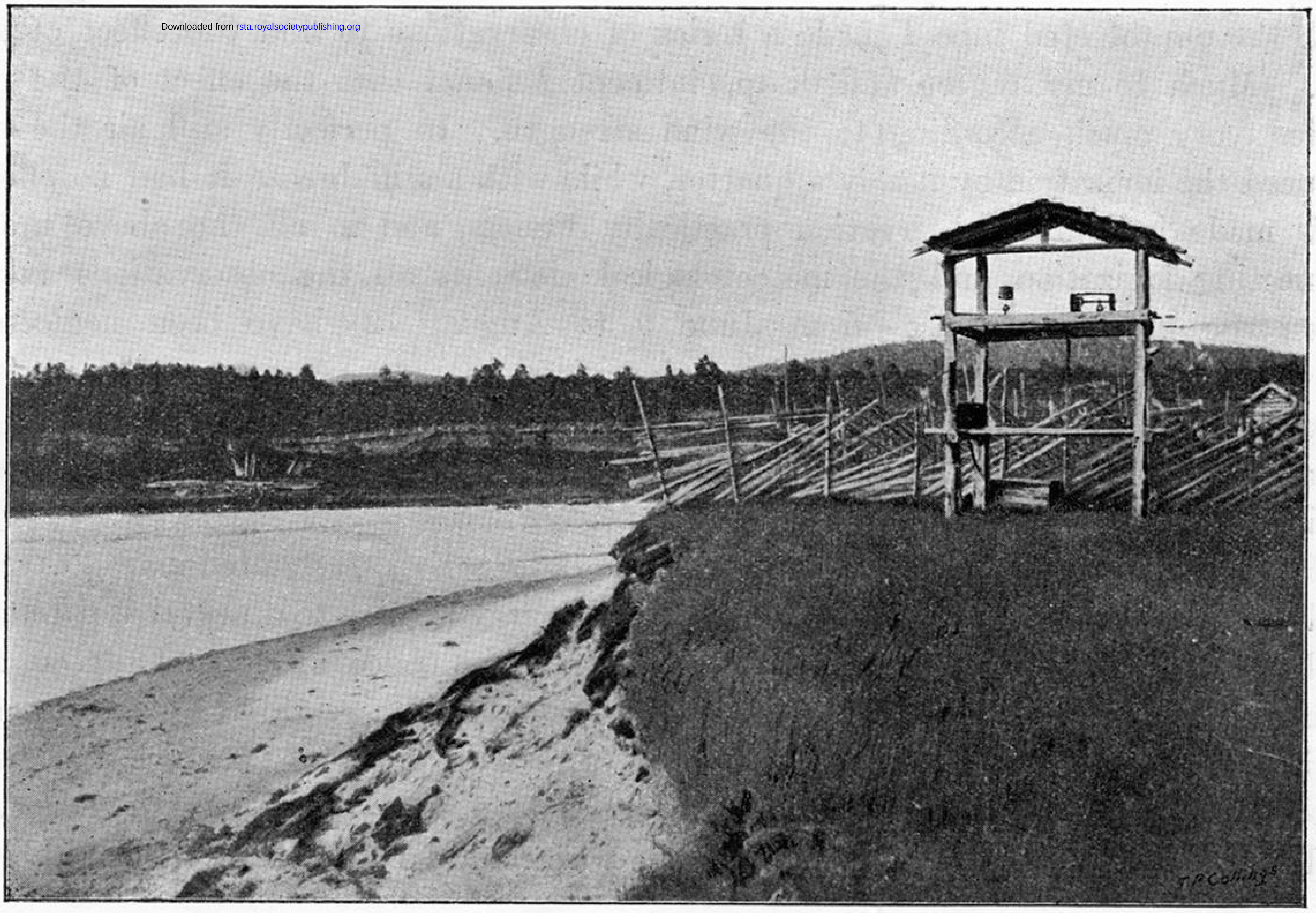
Radio-activity.—In my measurements of the radio-activity, as stated above, ELSTER and GEITEL's method was used. In order to charge the wire to a negative potential of between 2000 and 2500 volts, I used a small influence machine, built on the principle of a Kelvin replenisher and driven by a falling weight. By means of a variable high resistance, consisting of a strip of ebonite, one side of which had been rubbed with a black-lead pencil and so mounted in a tube that an earth-connected pad could move along it, the potential of the wire could be very easily regulated.

The instrument worked splendidly, and I had very little trouble with it. Its only drawback was that it could not be left to itself for more than 20 minutes, for then the weight required winding up again, and sometimes the voltage would vary if not attended to.

For my insulators I used amber enclosed in a metal case, so designed that air had a long way to travel from the outside before it could reach the amber. The insulators acted very well even in rain and fog. It was seldom that I had any difficulty with them, and I was never compelled to give up an observation on account of insulation troubles.

Meteorological Measurements.—Karasjok is a second-order station of the Norwegian Meteorological Service, and I was granted full use of the observations made there. I depended solely on these observations for the height of the barometer. For temperature and relative humidity I used an instrument (the polymeter) made by LAMBRECHT, Göttingen. The hygrometer consists of a bundle of human hairs mounted in such a way that a pointer is made to move over a very open scale showing directly the relative humidity. About once a month the zero was tested by painting the hairs with water in the way usual with such instruments. Treated in this way the instrument proved quite reliable. A mercury thermometer was attached to the metal frame of the hygrometer. The instrument was hung outside the window of a porch, the door of which always stood open. In this way the thermometer was not influenced by the radiation from a warm room, and, as the window looked north, the sun did not shine on it during the day time. The metal back of the instrument prevented the thermometer reading too low on a clear evening. I had no instrument for measuring the wind strength and had to estimate it as well as possible from the "feel." As the wind strength is only used qualitatively, the absolute values are of little importance.





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