

RESULTS OF MAGNETIC AND ELECTRIC OBSERVATIONS MADE DURING THE SOLAR ECLIPSE OF JUNE 8, 1918.—*Concluded.*

By L. A. BAUER, H. W. FISK, AND S. J. MAUCHLY.

PART III.—ATMOSPHERIC-ELECTRIC OBSERVATIONS.—*Concluded.*

ATMOSPHERIC-ELECTRIC OBSERVATIONS AT LAKIN, KANSAS.—*Concluded.*

*Ionic Content.*

98. Observations for the determination of the positive-ion content ( $n_+$ ) of the atmosphere were made with an apparatus similar to that in use on the Carnegie.<sup>1</sup> This apparatus employs a single fiber electroscope of the Einthoven type for noting the

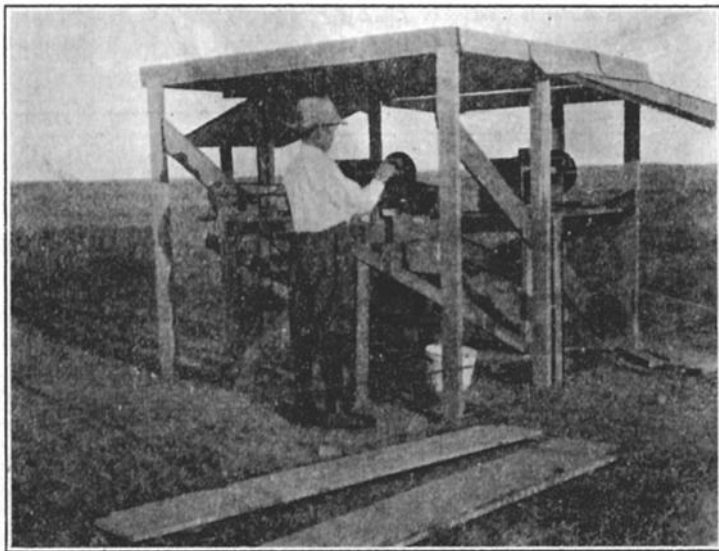


FIG. 23.—Conductivity Apparatus and Shelter at Lakin.

rate of alteration of the potential of the central cylinder during an experiment, and differs from the well-known Ebert ion-counter in causing the ions from the air to be driven to the central system by the action of a suitable charge placed on the insulated outer cylinder. As used at Lakin the electroscope sensitivity was usually from 15 to 20 divisions per volt and the potential of the outer cylinder was maintained at +110 volts. The diameters of the inner and outer cylinders were about 5mm. and 30 mm. respectively,

<sup>1</sup> See W. F. G. Swann, *Terr. Mag.*, Vol. 19, pp. 171-176, 1914.

and the length of each was about 40 cm. The electrical capacity of the entire apparatus was 50.3 cm. As used at Lakin it was always possible to obtain deflections of 10 to 20 scale-divisions in 1 to 2 minutes.

99. The air-flow constant of the clock-driven aspirator is known for sea level, but the normal barometric height at Lakin is between 65 and 70 cm. Owing, however, to the fact that the winds were very variable and nearly always strong enough to cause noticeable fluctuations, sometimes as great as 5 per cent in the time required for the fan to make a given number of revolutions (as indicated by the interval between bell signals), it was not deemed worth while to make a new determination of the air-flow constant under pressure conditions similar to those at Lakin. At Washington, the average rate of air-flow for this apparatus is about 1.3 liters per second, and this value was used for the *approximate* determination of  $n_+$  from the observations made at Lakin,

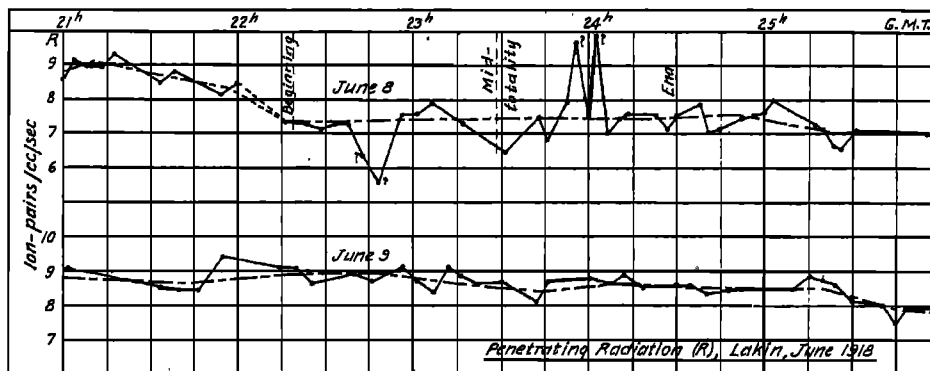


FIG. 24.—Variation of Approximate Ionic-Content at Lakin for Solar Eclipse, June 8, 1918, and Mean Curve.

although it no doubt is too small, and consequently the computed results for  $n_+$  are *too large*. It may be noted in passing that under the conditions described all ions having a velocity greater than about 0.07 cm. per second in unit field will be accounted for in the measurements.

100. Control observations were made on the afternoons of June 5, 6, 9, and 12. A curve embodying the means of the results of these observations is shown in Fig. 24. The curve of June 8 for  $n_+$ , shown in Fig. 24, shows a gradual increase in the ionic content during the first half of the eclipse similar to what was regularly observed shortly before sunset at this station. From 23<sup>h</sup> 07<sup>m</sup>

The cuts for Fig. 24 and Fig. 25 should be interchanged.

to 23<sup>h</sup> 49<sup>m</sup> (G. M. T.) no reliable observations for ionic content were obtained, owing to the development of leak and temperature troubles with the ion-counter electroscope. At the time this trouble developed it was decided to concentrate on the observations for penetrating radiation which were being made by the same observer. As soon as sufficient time could be spared from these latter observations to remedy the difficulty, the ionic-content observations were resumed and continued throughout the afternoon. The curve shows that from about 23<sup>h</sup> 50<sup>m</sup> to the end of the eclipse there was a rather large and rapid diminution in  $n_+$  which was later followed by the normal evening increase mentioned above.

*Penetrating Radiation.*

101. For the measurement of the penetrating radiation the rate of ionization within a cylindrical copper vessel of 21.3 liters capacity was determined by observations on a single-fiber electroscope after the vessel had been thoroughly cleaned and sealed. The arrangement employed was similar to that used aboard the *Carnegie* and described on page 389, Vol. III, *Researches of the Department of Terrestrial Magnetism*. The time occupied by a single experiment was of the order of 3 to 5 minutes and frequent determinations of sensitivity were made in order to avoid instrumental errors due to the large variations in temperature associated with the progress of the eclipse, as also during the 24 hours of the diurnal-variation experiments to be described later. Leak effects were entirely avoided, as indicated in the reference given above, by choosing the scale limits between which the fiber traveled to correspond to potentials of opposite sign which differed by several tenths of a volt and which were symmetrical about the position occupied by the fiber when it was connected to earth. Repeated observations during the regular course of the work showed that the lengths of time spent by the fiber in traversing the two halves of its course did not differ by an observable amount.

102. It was not possible to set up the penetrating-radiation apparatus until the afternoon of June 7 when several test observations were made. The observations were continued throughout the afternoon of June 8 and are represented graphically in the upper part of Fig. 25. After observing for several hours it was found desirable at 22<sup>h</sup> 12<sup>m</sup> (G. M. T.) to readjust several parts of the apparatus. Inasmuch as there had been no opportunity prior to this time to determine the constants of the apparatus,

the values obtained before the readjustment are not strictly comparable with those obtained thereafter and on succeeding days. They do, however, serve to show whatever variation the ionization in the chamber was undergoing prior to the time of adjustment.

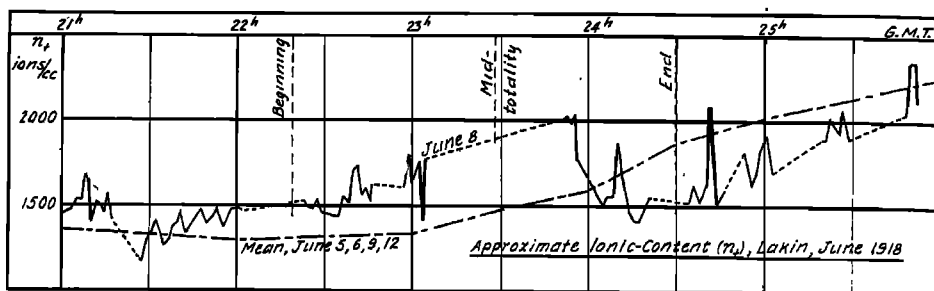


FIG. 25.—Variation of Penetrating Radiation at Lakin for Solar Eclipse, June 8, 1918, and for June 9, 1918.

103. Table 33 shows the individual results of the penetrating-radiation observations together with mean values obtained by grouping the results of approximately 30-minute intervals. In forming these means, 4 values, designated by asterisks (\*), have not been included since it appears probable, from the observational data, that errors of time-reading or of recording may be responsible for their characteristics. The mean values from Table 33 are shown graphically by the broken line in Fig. 25 in connection with the detailed curve for June 8. On the afternoon of June 9 observations were carried out similar to those on June 8 with no appreciable difference except that the average rate of ionizations was found to be about 10 per cent greater than on the preceding day. These results have not been tabulated but they are shown graphically in the lower part of Fig. 25, together with a curve for the 30-minute means, formed as for June 8. When the material for June 8 and 9 is viewed as a whole there seems to be no evidence to indicate that the rate of ionization in the apparatus underwent any appreciable change during the progress of the eclipse. Or, in other words, such part, if any, of the penetrating radiation which was due to the Sun did not form a large enough proportion of the total effect due to all causes, that any change caused by its temporary removal could be observed with certainty by the method employed. This is in accord with the findings of de Broglie<sup>2</sup> who made similar observations at Paris during the solar eclipse of April 17, 1912.

<sup>2</sup>de Broglie, *Comptes Rendus*, June 10, 1912, p. 1652.

*Tabulation of Results for June 8, 1918.*

104. Values of potential gradient, of positive conductivity ( $\lambda_+$ ) and of negative conductivity ( $\lambda_-$ ), and rate of ionization ( $R$ ) within a closed vessel, all as observed at Lakin on June 8, 1918, are given in Tables 31, 32, and 33.

TABLE 31.—*Potential-gradient values ( $X$ ) observed at Lakin, Kansas, June 8, 1918.*

G.M.T.			G.M.T.			G.M.T.			G.M.T.		
h	m	v/m	h	m	v/m	h	m	v/m	h	m	v/m
20	00	84.6	21	32	82.8	23	00	58.2	24	34	53.9
20	02	72.0	21	34	66.7	23	02	67.2	24	36	59.5
20	04	63.2	21	36	55.6	23	04	67.4	24	38	52.7
20	06	72.0	21	38	61.8	23	06	55.0	24	40	53.9
20	08	89.4	21	40	61.3	23	08	53.4	24	44	46.4
20	10	66.2	21	42	55.6	23	10	64.3	24	46	49.7
20	12	72.0	21	44	55.6	23	14	52.8	24	48	58.6
20	14	82.8	21	46	62.4	23	16	54.0	24	50	54.5
20	16	58.2	21	48	75.6	23	18	64.7	24	52	55.8
20	19	59.2	21	50	74.4	23	20	72.2	24	55	54.0
20	22	74.5	21	52	70.9	23	22	59.6	24	56	50.9
20	24	61.2	21	54	58.2	23	24	57.0	24	58	52.7
20	26	94.2	21	56	70.2	23	27.5	55.8	01	00	50.4
20	28	65.4	21	58	62.5	23	29	50.8	01	02	50.2
20	30	55.8	22	00	69.4	23	30.5	49.8	01	04	54.0
20	33	75.6	22	02	73.2	23	33	49.4	01	07	52.1
20	38	77.8	22	04	82.8	23	34	46.6	01	12	47.9
20	40	74.4	22	06	61.2	23	36	48.6	01	14	45.5
20	42	66.6	22	08	76.2	23	38	48.5	01	16	44.3
20	44	76.1	22	10	58.2	23	42	48.5	01	18	52.3
20	46	62.4	22	13	70.8	23	44	48.5	01	20	48.5
20	48	64.3	22	16	69.6	23	46.5	49.6	01	22	48.0
20	50	58.2	22	18	61.1	23	50	52.8	01	24	44.3
20	52	72.0	22	20	61.2	23	52	50.8	01	26	43.7
20	54	58.8	22	22	65.6	23	53	51.6	01	28	40.1
20	56	61.8	22	24	64.2	23	54	53.4	01	30	40.1
20	58	62.5	22	26	53.0	23	55	53.4	01	32	44.3
21	00	59.4	22	28	55.7	23	59	51.7	01	35	42.5
21	02	54.0	22	30	58.1	24	00.5	48.6	01	36	43.2
21	04	56.0	22	32	62.6	24	03	49.9	01	38	46.0
21	06	60.6	22	34	58.2	24	04.5	55.8	01	40	41.3
21	08	73.8	22	36	57.0	24	06	50.6	01	42	41.9
21	10	60.0	22	38	54.0	24	08	51.5	01	44	41.3
21	12	61.7	22	40	78.7	24	10	67.7	01	46	41.5
21	14	57.0	22	42	72.0	24	12	56.6	01	48	38.4
21	16	82.1	22	44	52.8	24	14	50.6	01	50	41.5
21	18	54.0	22	46	56.0	24	17	56.3	01	52	40.7
21	21	61.2	22	48	72.7	24	19	49.3	01	54	41.0
21	22	55.2	22	50	55.0	24	22	59.3	01	56	41.3
21	25	76.8	22	52	68.2	24	25	51.8	01	58	41.5
21	26	77.8	22	54	83.6	24	27	62.9	02	00	40.7
21	28	55.7	22	56	59.2	24	30	52.7	02	02	41.3
21	30	68.2	22	58	63.4	24	32	58.1			

TABLE 32.—Values of positive conductivity ( $\lambda_+$ ) and of negative conductivity ( $\lambda_-$ ) observed at Lakin, Kansas, June 8, 1918.

G.M.T.			G.M.T.			G.M.T.			G.M.T.		
E.S.U. $\times 10^{-4}$			E.S.U. $\times 10^{-4}$			E.S.U. $\times 10^{-4}$			E.S.U. $\times 10^{-4}$		
$\lambda_+$	$\lambda_-$		$\lambda_+$	$\lambda_-$		$\lambda_+$	$\lambda_-$		$\lambda_+$	$\lambda_-$	
h	m		h	m		h	m		h	m	
20	14.4	3.45	21	49.0	3.52	23	14.7	4.25	24	30.2	3.52
	15.4	2.67		50.2	3.52		15.7	3.52		31.4	3.86
	16.7	3.15		51.2	3.34		17.0	4.02		32.4	3.58
	17.7	3.28		52.4	4.08		18.0	3.15		33.7	4.41
	19.0	3.45		53.4	3.52		19.2	3.72		34.7	3.52
	20.0	3.07		54.7	3.79		20.2	3.15		36.0	4.25
	21.2	3.38		55.7	3.34		21.4	3.65		37.0	3.81
	22.2	3.28		57.0	3.72		22.4	3.66		38.2	4.73
	23.4	3.38		58.0	3.15		23.7	4.73		39.2	3.52
	24.4	3.15		59.2	3.52		24.7	4.19		40.4	4.61
	25.7	3.38	22	00.2	3.34		26.0	5.22		41.4	3.52
	26.7	3.22		13.2	3.83		27.0	4.11		50.2	3.99
	37.2	3.92		14.2	3.01		28.2	5.18		51.2	3.58
	38.2	3.01		15.4	4.08		29.2	4.70		52.4	4.70
	39.4	3.45		16.4	3.15		30.4	4.77		53.4	3.58
	40.4	2.88		17.7	3.68		31.4	4.34		54.7	5.34
	41.7	3.45		18.7	3.22		32.7	4.22		55.7	4.40
	42.7	3.07		20.0	3.72		33.7	4.05		57.0	5.22
	44.0	3.49		21.0	3.34		35.0	4.68		58.0	3.98
	45.0	3.31		22.2	3.72		36.0	4.11		59.2	4.61
	46.2	3.38		23.2	3.28		37.2	4.65	25	00.2	3.81
	47.3	3.25		24.4	3.49		38.2	4.26		01.4	4.86
	49.0	3.62		25.4	3.28		39.4	5.06		02.4	3.81
	49.7	3.22		33.2	3.72		40.4	4.62		16.4	4.49
21	03.7	3.22		34.2	3.28		41.7	5.34		17.4	3.66
	04.7	3.39		35.4	3.79		42.7	4.85		18.7	4.81
	06.0	4.13		36.4	3.22		44.0	5.02		19.7	3.81
	07.0	3.42		37.7	3.79		45.0	3.81		21.0	4.54
	08.2	4.13		38.8	3.34		46.2	4.97		22.0	3.34
	09.2	3.31		40.0	3.95		47.2	4.48		23.2	4.54
	10.4	3.56		41.2	3.28		48.4	4.97		24.2	3.34
	11.4	3.15		42.2	3.95		49.4	4.19		25.4	4.54
	12.7	3.61		43.4	2.94		50.7	5.41		26.4	3.52
	13.7	3.01		44.4	3.95		51.7	4.34		27.7	4.54
	15.0	3.99		45.7	3.34		53.0	5.41		28.7	3.90
	16.0	3.22		52.2	3.72	24	04.2	4.02		47.0	4.93
	26.4	3.28		55.2	3.34		07.2	3.15		48.0	4.40
	27.5	2.61		54.4	3.72		08.0	3.95		49.2	4.45
	28.7	3.31		57.4	3.42		09.4	3.81		50.2	4.48
	29.7	2.67		58.0	4.18		10.2	4.38		51.7	5.18
	31.0	3.49		59.7	3.58		11.7	3.73		52.4	4.56
	32.0	3.15	23	00.2	3.72		12.4	4.02		54.0	5.41
	33.2	3.49		02.0	3.76		14.0	3.46		54.7	4.77
	34.2	3.01		02.4	4.18		14.7	3.95		56.2	5.18
	35.4	3.38		04.6	?		16.2	3.22		57.0	4.62
	36.4	3.07		10.2	4.29		17.0	3.95		58.4	5.18
	37.7	3.72		11.2	3.52		18.4	3.07		59.2	4.40
	38.7	2.67		12.4	4.34		19.2	3.83			
	48.0	3.28		13.4	3.42		29.2	3.86			

TABLE 33.—Rate of ionization (*R*) in ion-pairs per cubic centimeter per second within a closed vessel as observed at Lakin, Kansas, June 8, 1918.

G.M.T.	<i>R</i>	Mean Time of Group	No. of Obs.	<i>R</i>	G.M.T.	<i>R</i>	Mean Time of Group	No. of Obs.	<i>R</i>
h m		h m			h m		h m		
19 40	8.4	19 48	3	8.4	42	7.5	23 50	4	7.5
45	8.3				45	6.8			
58	8.5				52	8.0			
20 23	7.5	20 27	2	8.1	55	9.7*			
31	8.7				24 00	7.6	24 18	6	7.4
44	8.3				2	9.9*			
49	8.8	20 51	4	8.5	06	7.0			
54	8.5				10	7.5			
59	8.5				13	7.6	24 51	7	7.6
21 03	9.2	21 10	4	9.1	23	7.6			
08	8.9				27	7.2			
13	8.9				30	7.6	25 24	5	7.0
17	9.3	21 46	4	8.5	38	7.9			
33	8.5				41	7.1			
38	8.8				46	7.2	25 59	2	7.0
54	8.2	22 27	5	7.3	53	7.5			
22 00	8.5				57	7.6			
16	7.4				25 00	7.7			
23	7.3	23 10	5	7.4	03	8.0	26 01		
28	7.2				17	7.3			
33	7.3				20	7.2			
38	7.3	23 10	5	7.4	24	6.7			
43	6.4*				26	6.6			
48	6.8*				31	7.2			
56	7.6	23 10	5	7.4	56	7.0			
23 01	7.6				26 01	6.9			
06	7.9								
17	7.3								
31	6.5								

\* These values not included in forming the means of last columns; see section 103.

*Meteorological Conditions during Totality.*

105. The time during and near totality was marked by rather light gusts of wind of varying intensity and direction. Recording instruments located in a nearby shelter showed, during the first half of the eclipse, a drop of more than 5° C. in temperature and an increase in relative humidity from 55 per cent to 65 per cent. Comparison observations made later indicate that the changes at the observing stations were somewhat larger than those recorded in the shelter. The reference to clouds, in paragraph 90, should be qualified by a statement that light cirrus clouds developed several times during the afternoon. Very few clouds were in evidence, however, near the time of totality except the low cumuli noted in paragraph 90.

*Diurnal-Variation Observations.*

106. Mention has been made in the foregoing of the control observations made on June 5, 6, 9, and 12 for potential gradient, conductivity, and ionic content. In addition to serving as control observations, however, the results of such observations have a value quite independent of any association with the eclipse, by affording data, even though limited, for a region concerning which no published atmospheric-electric data are available. Partly to increase the amount of atmospheric-electric data in general, and partly because it seems natural to consider the passage of the moon's shadow during an eclipse as a miniature night, the observations beginning on the afternoon of June 12 were continued throughout 24 consecutive hours.

107. The general plan was to make successive observations for  $\lambda_+$ ,  $\lambda_-$ ,  $n_+$ , and  $R$ , for a period of about 20 minutes out of each hour and to make potential-gradient observations, at intervals of about 5 minutes, as nearly as possible without interruption. We have then for the various hours of the day mean values of  $\lambda_+$ ,  $\lambda_-$ ,  $n_+$ , and  $R$ , respectively, each mean based on all the observations of its kind made during a given 20-minute interval. Fig. 26 shows these mean values plotted against the corresponding mean times. The potential-gradient results, however, are individually represented in the graph at the bottom of the figure. The air-earth current-density shown in the upper part of the figure was computed from the 20-minute means of the total conductivity and the mean potential-gradient for the corresponding 20-minute periods. Dotted portions of curves indicate lack of data for the parts in question.

108. The data set forth in Fig. 26 show a very large diurnal-variation for all the elements under observation except the ionization in a closed vessel. The close agreement between late afternoon results on June 5, 6, 8, 9, and 12, would indicate that Fig. 26 gives a fairly good representation of the diurnal variation for the station and season in question. It should be noted that the station was located in a region devoted almost exclusively to the growing of alfalfa and that it was located in the middle of a large, irrigated, alfalfa field. The diurnal ranges of both temperature and relative humidity were rather large, the former being about 20° C., and the latter extending from 30 per cent to 75 per cent. Although observations for  $R$  could not be made as regularly during the night hours as was done for the other elements, enough data



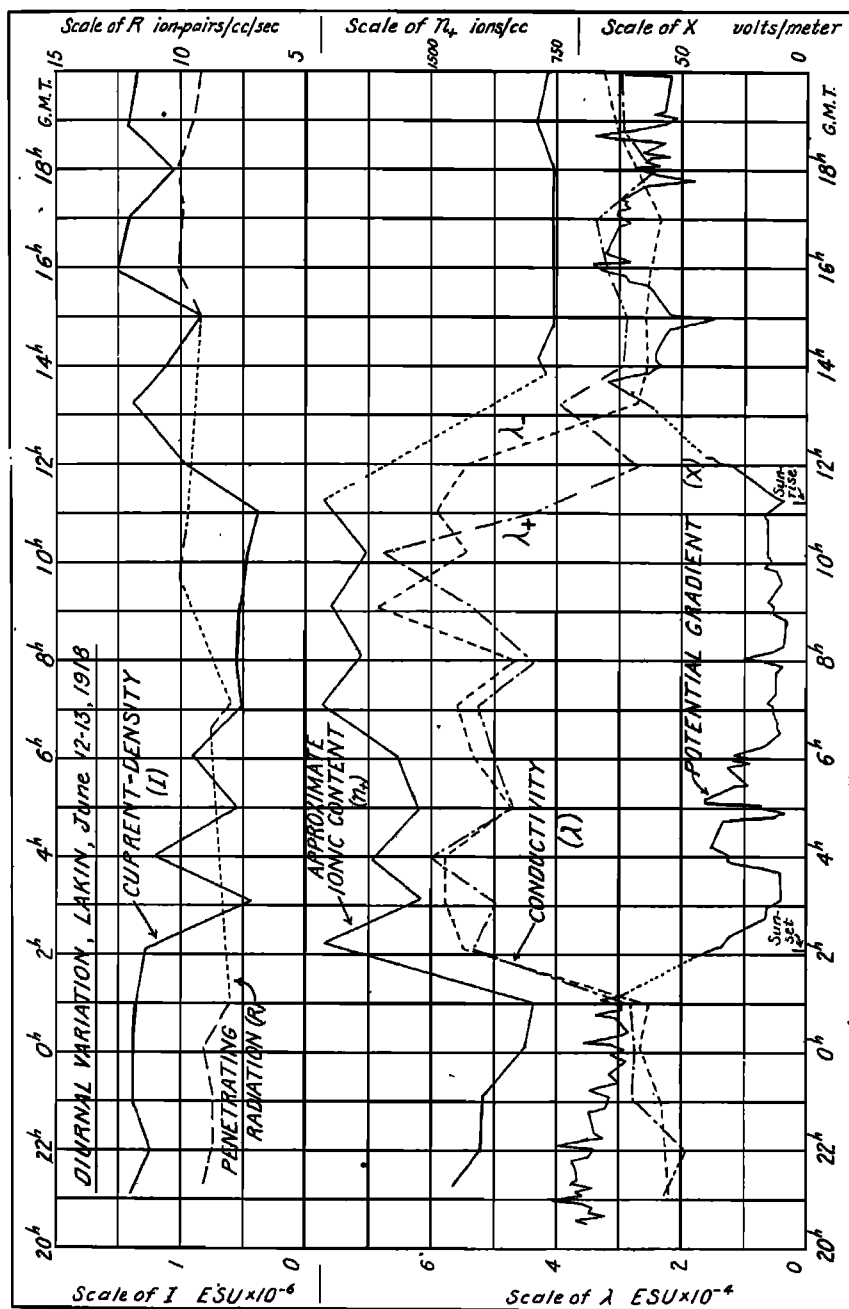


FIG. 26.—Diurnal Variation of Atmospheric-Electric Elements at Lakin for June 12 to 13, 1918.

were secured to make it appear that any diurnal variation of the rate of ionization in a closed vessel, at the given station and time, was small and certainly did not exceed 20 per cent of its mean value.

#### ATMOSPHERIC-ELECTRIC OBSERVATIONS AT WASHINGTON, D. C.

109. Continuous photographic records of the positive conductivity and of the potential-gradient were obtained on June 8 at the atmospheric-electric observatory of the Department of Terrestrial Magnetism, at Washington, D. C. The maximum obscuration at this station was 74 per cent and excellent traces were recorded. Neither trace shows effects which could with any degree of certainty be ascribed to the influence of the eclipse.

#### CHIEF CONCLUSIONS FOR PART III (ELECTRIC OBSERVATIONS).

110. At the Lakin station, located in the belt of totality at an elevation of 900 meters, on an irrigated, grassy plain, far from either sea or mountains, the observations<sup>1</sup> during the total solar eclipse of June 8, 1918, indicated:

*a. A decrease of about 20 per cent in the value of the potential-gradient at the time of totality and continuing for a period of about 20 minutes thereafter.*

*b. The short-period fluctuations which usually characterize the potential-gradient and which were very marked both before and after the eclipse were almost totally absent during the period of minimum potential-gradient, namely during totality and the 20 minutes immediately following.*

*c. The unipolar conductivities,  $\lambda_+$  and  $\lambda_-$ , each showed an increase, of the order of 20 per cent, during a period beginning several minutes before totality and continuing until about 30 minutes after totality. Inasmuch as  $\lambda_+$  and  $\lambda_-$  were similarly affected, the remark concerning them applies also to the total conductivity.*

*d. The air-earth current-density, as computed from total-conductivity and potential-gradient data, showed a rapid increase for about 10 minutes before totality followed by an equally rapid and pronounced decrease for about 10 minutes after totality. Neither of these movements, however, is in marked contrast to the course followed by this element throughout the afternoon.*

*e. The ionic content of positive sign,  $n_+$ , appears to have passed*

<sup>1</sup> Corrigenda to atmospheric-electricity installment appearing in March 1919 issue: Page 26, line 18, read *Table 32* instead of *Table 31*; page 26, line 8, paragraph 97, read *Elster* instead of *Geitel*.

through a maximum simultaneously with  $\lambda_+$ , but lack of observations during the middle part of the eclipse prevents a positive statement on this point.

f. The ionization in a closed vessel, due to the penetrating radiation, apparently was unaffected by the passage of the eclipse-shadow.

g. Observations throughout 24 consecutive hours showed a large diurnal-variation for all the elements under observation, except the ionization in a closed vessel. They also showed for all elements a strong similarity between night conditions and those prevailing on June 8 during and shortly after totality.

DEPARTMENT OF TERRESTRIAL MAGNETISM,  
CARNEGIE INSTITUTION OF WASHINGTON.

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By L. A. BAUER, H. W. FISK, AND S. J. MAUCHLY.

### CONTENTS.

	Vol.	Page
Part I. Magnetic Observations.....	23	95
General scheme of work.....	23	96
Stations and observations of the Department of Terrestrial Magnetism.....	23	99
Geographic positions and circumstances of the eclipse.....	23	105
Magnetic-declination data.....	23	106
Preliminary discussion of declination data.....	23	109
Additional declination data.....	23	158
Final discussion of declination effects.....	23	161
Remarks on the $H\Delta D$ -curves.....	23	167
Horizontal-intensity data.....	23	175
Horizontal-intensity changes at Goldendale, Washington, June 8, 1918.....	23	175
Magnetograph results at Lakin, Kansas, June, 1918.....	23	176
Vertical-intensity data.....	23	182
Discussion of horizontal-intensity effects ( $\Delta H$ -curves).....	23	182
Small preliminary effects.....	23	184
Discussion of vertical-intensity effects ( $\Delta Z$ -curves).....	23	187
First chief conclusion.....	23	190
Values of $\Delta X$ and $\Delta Y$ .....	24	1
Salient points of $\Delta X$ -, $\Delta Y$ -, and $\Delta Z$ -curves.....	24	4
Vector diagrams for June 8, 1918.....	24	8
Comparison of solar-diurnal magnetic variation and eclipse magnetic variation.....	24	11
Periods of solar-eclipse magnetic variation, June 8, 1918.....	24	14
Preliminary analysis of solar-eclipse magnetic variation.....	24	15
Chief conclusions for Part I (Magnetic Observations).....	24	16
Part II. Meteorological and Miscellaneous Observations.....	24	17
Temperature inside observing tents.....	24	17
Meteorological observations and shadow bands at Corona, Colorado.....	24	17
Some astronomical observations at Corona, Colorado.....	24	21

Part III. Atmospheric-Electric Observations.....	24	22
Atmospheric-electric observations at Lakin, Kansas...	24	22
Potential-gradient.....	24	22
Electrical conductivity.....	24	25
Ionic content.....	24	87
Penetrating radiation.....	24	89
Tabulation of results for June 8, 1918.....	24	91
Meteorological conditions during totality.....	24	93
Diurnal-variation observations, June 12 to 13, 1918	24	94
Atmospheric-electric observations at Washington, D.C.	24	96
Chief conclusions for Part III.....	24	96

## ILLUSTRATIONS

	Vol.	Page.
Plate I. Views of Solar Eclipse, June 8, 1918.....	23	95
Fig. 1. Photograph by L. A. Bauer at Corona, Colorado, before totality.....	23	95
Fig. 2. Photograph by L. B. Aldrich at Lakin, Kansas..	23	95
Figure 1. Map showing region of visibility of solar eclipse of June 8, 1918.....	23	97
Figure 2. Path of totality of solar eclipse, June 8, 1918, in the United States.....	23	97
Figure 3. H. W. Fisk's station at Goldendale, Washington.....	23	97
Figure 4. L. A. Bauer's station at Corona, Colorado; altitude 11,800 feet.....	23	101
Figure 5. S. J. Mauchly's station at Lakin, Kansas.....	23	101
Figure 6. Magnetograph operated by D. M. Wise at Lakin, Kansas.	23	103
Figure 7. Declination curves, solar eclipse, June 8, 1918.....	23	110
Figure 8. Declination curves, June 8, 1918—continued.....	23	155
Figure 9. $\Delta D$ -curves, solar eclipse, June 8, 1918.....	23	165
Figure 10. $H\Delta D$ -curves, solar eclipse, June 8, 1918.....	23	168
Figure 11. Horizontal-intensity curves, solar eclipse, June 8, 1918..	23	177
Figure 12. Vertical-intensity curves, solar eclipse, June 8, 1918.....	23	183
Figure 13. $\Delta H$ -curves, solar eclipse, June 8, 1918.....	23	185
Figure 14. $\Delta Z$ -curves, solar eclipse, June 8, 1918.....	23	189
Figure 15. $\Delta X$ -curves, solar eclipse, June 8, 1918.....	24	5
Figure 16. $\Delta Y$ -curves, solar eclipse, June 8, 1918.....	24	7
Figure 17. XY-vector diagram, Kakioka, June 8, 1918.....	24	9
Figure 18. XY-vector diagram, Cheltenham, June 8, 1918.....	24	10
Figure 19. Temperature curves, solar eclipse, June 8, 1918.....	24	19
Figure 20. Variation of potential-gradient at Lakin for solar eclipse, June 8, 1918, and mean curve.....	24	24
Figure 21. Variation of positive and negative conductivities at Lakin for solar eclipse, June 8, 1918, and mean curves..	24	27
Figure 22. Variation of total conductivity and air-earth current- density at Lakin for solar eclipse, June 8, 1918, and mean curves.....	24	28
Figure 23. Conductivity apparatus and shelter at Lakin.....	24	87
Figure 24. Variation of approximate ionic-content at Lakin for solar eclipse, June 8, 1918, and mean curve.....	24	88
Figure 25. Variation of penetrating radiation at Lakin for solar eclipse, June 8, 1918, and for June 9, 1918.....	24	90
Figure 26. Diurnal variation of atmospheric-electric elements at Lakin for June 12 to 13, 1918.....	24	95