THE EVOLUTION OF THE AMERICAN TROTTING HORSE

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By Dr. GEORGE ENGELMANN.

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ON THE EXPRESSION OF ELECTRICAL RESISTANCE IN TERMS OF A VELOCITY.

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COMPLIMENTS OF

Francis E. Nipher.

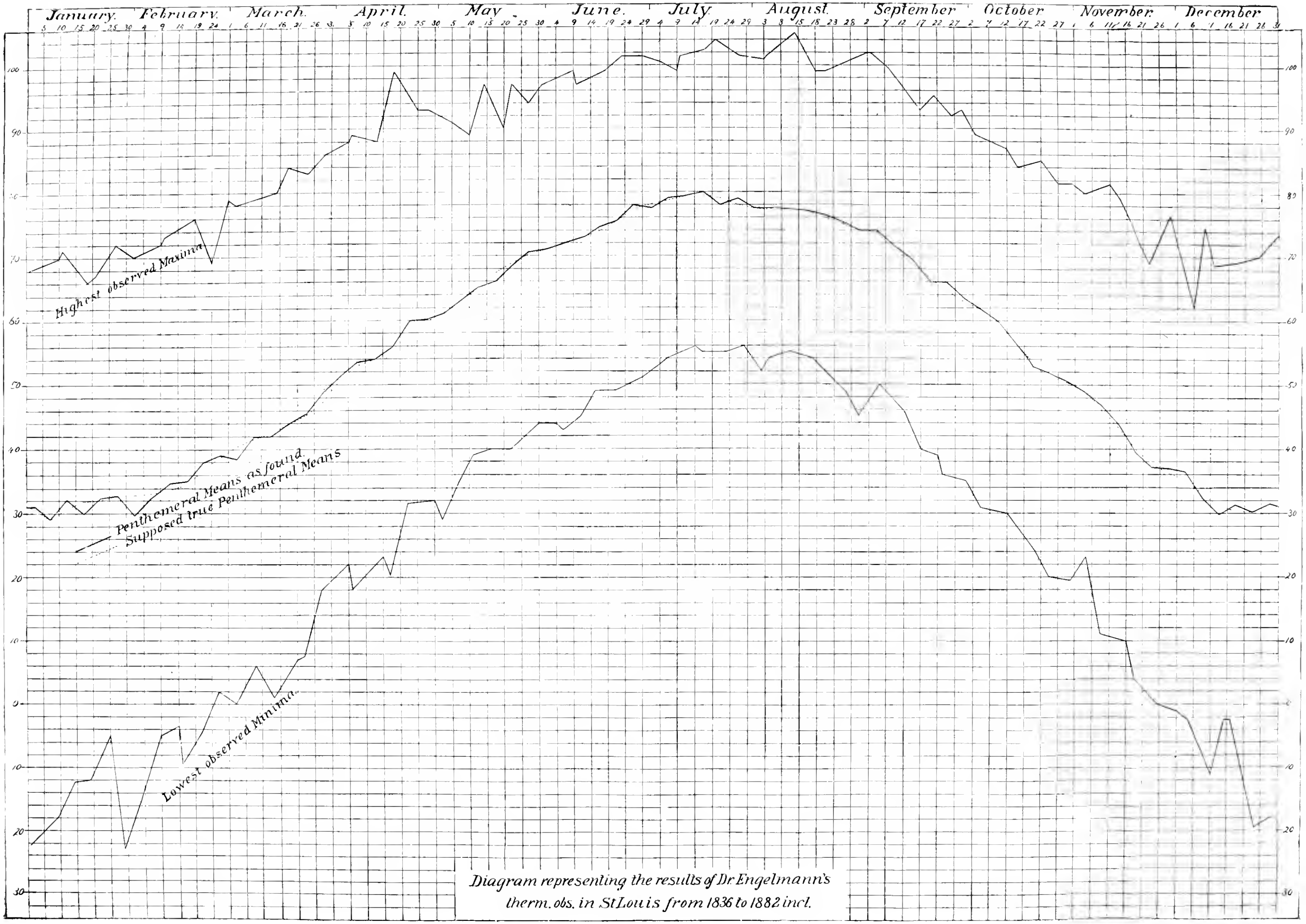

Diagram representing the results of Dr. Engelmann's therm. obs. in St Louis from 1836 to 1882 incl.

The mean and extreme daily Temperatures in St. Louis during forty seven years, as calculated from daily observations,

By Dr. George Engelmann.

Half a century has passed since I began to study the meteorology and climatology of this neighborhood, and since the year 1836 I have made regular meteorological observations, first on temperature, the winds and the condition of the sky, and soon afterwards on atmospheric pressure, rainfall and humidity.

I give here the results of my thermometrical observations, which I consider as the most important and most interesting of the series. They comprise, to be sure, only forty-seven years, and I might have waited until at least half a century was completed; but the results would scarcely have been different, and the task then perhaps problematical of accomplishment.

The observations were made within the city of St. Louis, and can thus not claim precision for this whole region. St. Louis, to be sure, was, when they commenced, a small town of perhaps 15,000 inhabitants, while now, at their completion, it is a large city of probably 400,000, with the necessary accompaniment of brick and stone, and especially with the smoke of thousands of chimneys, furnaces and factories, and the almost total absence of verdure. It has been held by some, that these influences had little effect on temperature, but that brisk breezes would soon dispel smoke and equalize temperature. This, however, is not quite so, and direct thermometrical comparisons prove that the extreme temperatures, and, remarkably enough, even the extreme heat, are less marked in the city than in the country, and that the mean temperature is higher in the city than in the country (Trans., vol. ii., p. 70); but, aside from instrumental observation, the state of the vegetation proves it every spring and fall, when we find in our city gardens the plants uninjured on mornings when in the country they have suffered from late or early frosts.

St. Louis lies very nearly in the centre of the Mississippi Valley, 600 miles north of the Gulf of Mexico and just as far south of Lake Superior, about 500 miles west of the Alleghanies and 800 miles east of the Rocky Mountains; its Washington University, one mile west of the river, lies in Lat. 38° 38′ 03″ and Long. 90° 12′ 15″; the low-water mark of the Mississippi is 379 feet above the Gulf, and the foot of Market street (City Directrix) is 413 feet above the same.

My observations were made in the first twelve years on the south-east corner of Second and Chestnut streets, only two blocks from the river and 75 feet above low-water mark of 1863; for the next 22 years on the south-west corner of Fifth and Elm streets, five blocks from the river and 110 feet above low-water mark; and for the last 13 years on the north-west corner of Thirtieth and Locust streets, two miles from the river and 177 feet above low-water mark. When I was absent from the city Dr. A. Wislizenus and lately Mr. B. D. Kribben have kindly filled the gaps.

My instruments were at first such as could then be obtained here; soon I imported correct thermometers from Europe, and for nearly 40 years I used those made by Jas. Green, then of Baltimore, and soon afterwards of New York.

For many years the observations were made at different periods of the day, and especially at hours when the extremes might be expected to occur, viz. at sunrise and at 3 P.M.; and the maximums and minimums were selected from all of them, often eight in a day, at whatever hour of the day they were found. Differential thermometers were observed only since the last 12 years. Thus I may not always have noted the absolute extremes of each day, and my tables can claim only approximate reliability; I give them for what they may be worth, but I can assure my readers that they furnish a record elaborated with zeal, conscientiousness, care and assiduity, and for a length of time such as probably few others, if any, exist in this valley.

The arrangement of the tables explains itself. The first two columns represent the means of the 47 minimum and of the 47 maximum observations made on each day of the year, and the third column the mean calculated from the two former. The next "Min." column gives the lowest and the "Max." column the highest temperature ever observed on that day; the column of years next to these gives the year in which these extremes did occur. The last column represents a supposed—or estimated—true mean for the day after eliminating excessive extremes.

The year has been divided into 73 periods of 5 days each, the means of which are printed in full-face type, to distinguish them. It will be seen, however, that the means of these periods do not progress, rise and fall, much more evenly than the single daily means; compare, e.g., the mean of Jan. 31st to Feb. 4th, which is so much lower than the mean of the foregoing or the following five days that one might suspect a regular and normal decline of temperature in these days, and not a mere accident.

A few facts must strike every one who examines the tables. The first is, that a time even as long as 47 years fails to give us anything approaching absolute and reliable means; and we come to the painful conclusion, that observations even continued for double that time, or for a century, may not yet obtain that desirable object. It seems that the excessive extremes of one or of a few days such as we often observe in our climate of extremes, especially in the winter season, will influence—or, I may say, vitiate—the means of a long series of observations; and the question with me arises, whether such extremes ought not to be eliminated from the series, and thus truer means be obtained. At the same time we may justly be astonished that from such heterogeneous data so much order and system result—which gives us hope that we cannot be quite on the wrong track.

Another fact, which strikes us in looking over the tables, is that the mean temperatures do not increase and decrease evenly, but sometimes quite rapidly, and at other times they may become almost stationary for a time. These points come out most strikingly on a diagram which embodies the essential parts of the results and shows the daily progress of the temperature. Thus we find very little change from the middle of December to the first part of February, though the temperature proves to be lowest from January 4th to 13th; then we notice a rapid rise from Feb. 6th to 20th, a slower rise to the middle of March, then a rapid one to the end of the month; in the forepart of April a slow and after the middle of that month a very marked one; then follows a tolerably even, at last quite slow, rise to July 9th, when between this date and the 18th the greatest elevation of the curve is obtained. After that the mean temperature falls slowly to the middle of August, followed by a more rapid decline to the end of September; after a slight pause in the first week in October, a more rapid fall takes place for the following two weeks and a slighter one in the two weeks succeeding them. After that the temperature sinks rapidly to about Dec. 10th, from which time till the beginning of February the changes are not very marked.

The mean temperature of April 17th to 19th and from October 12th to 17th correspond with the mean of the year.

The tables, and still more distinctly the diagram, show us also that the extreme highest and lowest temperatures diverge most in winter and least in summer, and that their values are much more variable in the former than in the latter season. The possibilities of range from the middle of December to the middle of March are 80 to 95 degrees, while in June and July they amount only to 40 or 45 degrees.

The same law is found when we compare the actually observed lowest minimum and highest maximum of every month; their divergence is greatest in January, and least, not much more than half, in July.

	Min.	Max.	Range.		Min.	Max.	Range.
January......	—22.5	72.0	94.5	July	53.0	104.0	51.0
February	—15.0	76.0	91.0	August	45.0	104.0	59.0
March	0.0	86.0	86.0	September ...	35.0	102.0	67.0
April	18.0	99.0	81.0	October	19.5	91.0	71.5
May	29.0	97.5	68.5	November....	— 0.5	81.5	82.0
June.........	43.0	101.5	58.5	December....	—19.5	72.5	92.0

Nearly the reverse is the case—i.e. the range in winter is much smaller than that in summer—if we compare the difference of the average daily minima and maxima for each month:

January..	13.27	April.....	18.29	July	18.24	October ..	18.00
February.	14.72	May......	18.77	August...	17.75	November	14.06
March....	16.40	June	18.14	September	19.05	December.	11.97

The range, it will be seen, is, on the whole, least in the cooler and greatest in the warmer months of the year; but this difference is not due to the lower or higher temperatures of those months, for it will be seen that in December the range is the smallest (smaller than in January) and in September greatest (greater than in July). This variation in the range of maxima and minima is undoubtedly owing to the condition of the sky in the different months. Gloomy weather prevails in the beginning of winter, and a clear sky with abundant evaporation, and thus a reduction of night temperature, in the autumn. The little table can give us an indication of the prevailing weather in the different months. Thus the difference, and its cause, the clearness of the sky, rises from December gradually till May, falls a little in June and July and more in August, rises to its highest point in September, is yet high in October and then falls rapidly till December, to rise again in January.

The temperature of our continental locality shows a great difference from that of the western coast of Europe; as a convenient example we may refer to the temperature of London. Their winters are warmer from the latter part of November until the beginning of March, and their summers much cooler from this period to the latter third of November; and the mean is much higher here.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Whole year.
St. Louis..	31.8	35.4	43.7	56.2	66.3	74.7	79.2	76.8	69.0	56.1	42.8	33.4	55.4
London...	37.2	39.3	42.7	48.1	54.5	60.8	63.6	62.0	57.6	50.4	42.7	39.7	49.9
Difference.	+5.4	+3.9	−1.0	−8.1	−11.8	−13.9	−15.6	−14.8	−11.4	−5.7	−0.1	+6.3	−5.5

MEAN AND EXTREME TEMPERATURES IN ST. LOUIS FROM 1836 to 1882.

1836-1882	Mean Values for each Day.			Extreme Maxima and Minima observed on each Day of the Year.				Supposed true Mean.
	Min.	Max.	Mean.	Min.	Year.	Max.	Year.	
Jan. 1	23.55	36.77	30.16	—22.5	1864	68.0	1876	31.5
2	25.35	37.97	31.66	—13.0	1879	65.5	1855	31,3
3	25.54	38.55	32.04	—15.5	"	66.5	1874, 1880	31.0
4	23.95	35.82	29.88	— 6.0	"	63.5	1880	30.5
5	23.45	39.22	31.33	— 8.5	1864	62.0	1876	30.2
	24.36	**37.66**	**31.01**	**—13.1**		**65.1**		**30.9**
6	23.76	37.63	30.69	— 9.0	1879	64.0	1880	30.0
7	22.33	33.95	28.14	— 1.0	1881	64.0	1839	29.4
8	22.75	34.61	28.68	— 6.0	1877	68.0	1876	29.0
9	22.65	35.48	29.06	—18.0	1875	65.5	"	29.0
10	22.67	34.82	28.74	—11.0	1881	70.0	1839	29.5
	22.83	**35.29**	**29.06**	**— 9.0**		**66.3**		**29.4**
11	25.42	39.20	32.31	— 1.0	1881	71.0	1839	30.0
12	26.69	39.27	32.98	— 2.0	1852	65.0	1863	30.2
13	24.61	36.81	30.71	0.0	"	59.0	"	30.6
14	25.61	38.11	31 86	—12.5	1881	64.0	1848	31.0
15	26.71	39.67	33.19	— 2.5	1875	66.0	1847	31.4
	25.80	**38.61**	**32.21**	**— 6 0**		**65.0**		**30.6**
16	24.03	36.27	30.15	2.0	1841	63.0	1845	31.8
17	21.09	34.27	27.68	—11.0	"	64.0	1842	32.0
18	21.65	34.32	27.98	—12.5	1857	66.0	"	32.0
19	23.63	38.09	30.86	—12.0	1852	61.0	1843	32.0
20	27.83	39.54	33.68	— 1.5	1866	64.0	"	32.0
	23.64	**36.49**	**30.07**	**— 7.0**		**63.6**		**31.9**
21	25.97	38.79	32.38	— 3.0	1854	67.0	1843	32.0
22	23.84	39.19	31.52	— 2.5	1857	62.0	1858	32.0
23	24.63	38.36	31.49	0.0	1854	62.0	1864	32.0
24	25.57	39.64	32.60	2.0	1873	65.0	1860	32.2
25	27.26	41.63	34.44	— 5 5	1840	65.0	1864	32.4
	25.45	**39.52**	**32.48**	**— 1.8**		**64.2**		**32.1**

1836-1882	Mean Value for each Day. Min.	Max.	Mean.	Extreme Maxima and Minima observed on each Day of the Year. Min.	Year.	Max.	Year.	Sup-posed true Mean
Jan. 26	26.76	40.36	33.56	1.0	1865	71.5	1843	32.6
27	26.96	39.53	33.24	— 0.5	1873	72.0	1864	32.6
28	24.85	39.15	32.00	— 6.5	"	67.0	"	32.7
29	25.32	39 30	32.31	—23.0	"	64.5	1852	32.8
30	24.79	41.09	32.94	— 2.0	1856	64.5	1842	32.8
	25.73	**39.88**	**32.81**	**— 6.2**		**67.8**		**32.7**
31	24.96	38.20	31.58	2.0	1875	65.5	1877	32.8
Feb. 1	23.32	37.20	30.26	— 8.5	1836	70.0	1854	32.8
2	23.55	35.77	29.66	— 3.5	1873	56.0	1846	32.9
3	21.71	35.72	28.72	—15.0	1856	62.5	1852	32.9
4	22.01	36.51	29.26	—11.0	"	61.0	1837	33.0
	23.11	**36.68**	**29.89**	**— 7.2**		**63.0**		**32.9**
5	24.67	39.29	31.98	— 3.5	1856	61.0	1837	33.0
6	26.00	41 04	33.52	3.0	1843	67.0	1855	33.1
7	26.08	41.19	33.63	— 3.5	1872, 1875	65.0	1851	33.1
8	24.74	39.98	32.36	2.0	1842	66.0	1847	33.2
9	24.37	40.05	32.21	— 5.0	1875	72.0	1876	33.3
	25.17	**40.31**	**32.47**	**— 1.4**		**66.2**		**33.1**
10	25.92	41.56	33.74	1.0	1841	73.0	1876	33.5
11	29.98	43.93	36.95	2.0	"	73.0	1845	33.7
12	29.00	43.44	36.22	2.0	"	70.5	1882	33.9
13	29.06	40.41	34.73	4.5	1838	69.0	1867	34.0
14	24.71	39.38	32.04	— 3.5	1866	64.0	1857	34.1
	27.73	**41.74**	**34.73**	**1.2**		**69.9**		**33.8**
15	26.53	41.09	33.81	— 9.5	1866	68.0	1848	34.2
16	26.07	42.59	34.33	— 5.0	"	63.5	1857	34.4
17	28.03	41.18	34.60	— 4.0	1838	74.5	"	34.6
18	28.05	42.39	35.22	— 2.5	1849	65.5	1873	34.8
19	30.26	44.57	37.41	5.0	1838	76.0	1859	35.0
	27.79	**42.36**	**35.07**	**— 3.2**		**69.5**		**34.6**
20	31.83	45.80	38.81	— 3.5	1870	68.5	1850	35.5
21	30.33	45.27	37.80	— 4.5	1838	68.0	1836	36.0
22	31.82	46.97	39.39	1.5	1858	68.5	1861	36.5
23	30.11	44.71	37.41	0.0	"	69.5	1851	37.0
24	29.38	45.91	37.64	6.0	1873	69.0	1880	37.5
	30.69	**45.73**	**38.21**	**— 0.1**		**68.7**		**36.5**
25	31.02	46.05	38.53	7.0	1855	67.0	1876	38.0
26	31.68	48.91	40.29	2.0	1846	68.5	1880	38.5
27	30.58	45.46	38.02	5.0	1836	73.5	1876	38.7
28	30.47	47.02	38.74	10.5	1836, 1869	74.0	1861	39.0
Mar. 1	32.35	49.02	40.68	10.0	1843	79.5	"	39.2
	31.22	**47.29**	**39.25**	**6.9**		**72.5**		**38.7**
2	31.36	45.97	38.66	8.0	1843	76.0	1861	39.8
3	29.29	43.89	36.59	0.0	1848	78.0	1842	40.0
4	29.50	44.54	37.02	6.0	1875	75.5	1882	40.5
5	30.62	47.38	39.00	8.0	1848	71.0	1855	40.8
6	34.94	49.20	42.07	4.5	1869	76.5	1860	41.0
	31.14	**46.19**	**38.67**	**5.3**		**75.4**		**40.4**
7	34.88	51.60	43.24	10.5	1857	77.0	1853, 1879	41.2
8	34.49	50.31	42.40	13.5	1875	77.0	1879	41.4
9	35.01	48.18	41.59	6.0	1877	78.5	1842	41.6
10	33.22	49.52	41.37	10.0	1856	79.5	1279	41.8
11	34.55	49.67	42.11	7.0	1836	69.0	1848	42.0
	34.43	**49.85**	**42.14**	**7.4**		**76.0**		**41.6**

1836-1882	Mean Value for each Day.			Extreme Maxima and Minima observed for each Day of the Year.				Supposed true Mean
	Min.	Max.	Mean.	Min.	Year.	Max.	Year.	
Mar 12	34.82	50.86	42.84	11.5	1836, 1857	71.0	1839, 1861	42.2
13	34.24	50.64	42.44	5.0	1867	75.0	1850	42.4
14	34.51	50.55	42.53	1.0	"	76.5	1875	42.5
15	33.87	48.89	41.38	7.5	1870	80.5	1854	42.6
16	34.14	50.03	42.08	9.0	1843	77.5	1868	42.8
	34.31	**50.19**	**42.25**	**6.8**		**76.1**		**42.5**
17	33.49	52.07	42.78	10.5	1879	79.0	1842	43.0
18	34.86	52.32	43.59	15.0	"	84.0	"	43.5
19	36.09	54.82	45.45	18.5	1875	84.0	"	44.0
20	36.91	52.52	44.71	14.0	1855	84.0	"	44.5
21	34.21	50.68	42.44	7.0	1876	76.0	1878	44.8
	35.11	**52.48**	**43.79**	**13.0**		**81.4**		**43.9**
22	35.56	54.04	44.80	13.0	1843	76.0	1857	45.0
23	37.09	55.48	46.28	7.5	"	82.5	1868	45.2
24	36.90	54.30	45.60	12.0	"	83.0	1842	45.4
25	37.21	53.76	45.48	13.0	"	82.5	1852	45.6
26	37.69	54.92	46.30	13.5	1873	78.5	1838	46.0
	36.89	**54.50**	**45.69**	**11.8**		**80.5**		**45.4**
27	39.16	56.81	47.98	23.5	1850	85.0	1838	46.5
28	39.77	57.31	48.54	18.0	1855	83.5	1879	47.0
29	40.42	58.31	49.36	23.5	1876	86.0	1842	47.5
30	41.07	57.91	49.49	28.0	"	84.0	1838	48.0
31	40.35	57.34	48.84	25.5	1856	84.0	"	48.5
	40.15	**57.53**	**48.84**	**23.7**		**84.5**		**47.5**
Apr. 1	39.70	57.25	48.47	24.0	1881	81.5	1882	49.5
2	40.92	61.12	51.02	24.0	"	85.0	"	50.0
3	44.66	62.44	53.55	24.5	1879	86.0	"	51.0
4	44.00	59.67	51.83	23.0	"	85.0	"	51.5
5	42.79	60.82	51.80	22.5	1857	88.5	1871	52.0
	42.41	**60.26**	**51.33**	**23.6**		**85.2**		**50.8**
6	43.61	62.89	53.25	18.0	1857	89.0	1871	52.5
7	44.77	63.98	54.37	29.0	1880	85.5	1860	53.0
8	45.59	60.96	53.28	24.0	1845	82.5	1836	53.0
9	43.84	61.86	52.85	27.0	1857	84.0	1844	53.2
10	45.07	61.94	53.50	28.5	1836, 1874	87.0	"	53.4
	44.57	**62.33**	**53.45**	**25.3**		**85.6**		**53.0**
11	43.81	62.53	53.17	27.0	1857	83.0	1842	53.6
12	45.35	62.44	53.89	26.0	"	84 0	1856	53.8
13	45.33	63.59	54.46	32.0	"	88.0	1845	54.0
14	45.03	63 26	54.14	28.5	"	84.0	"	54.2
15	44.52	62.02	53.27	23.0	1850	82.0	1856	54.4
	44.81	**62.77**	**53.79**	**27.3**		**84.2**		**54.0**
16	45.62	62.26	53.94	26.5	1875	91.0	1845	54.6
17	45.11	64.55	54.83	20.5	"	93.0	1855	55.0
18	45.78	64.34	55.06	26.0	"	99.0	"	56.0
19	47.20	66.47	56.83	29.0	1857	83.0	1847	57.0
20	48.47	67.92	58.19	34.0	"	85.0	1836	58.0
	46.43	**65.11**	**55.77**	**27.2**		**90.2**		**56.1**
21	49 76	69.01	59.38	36.0	1857, 1875	85.0	1867	59.0
22	51.37	69.70	60.53	31.5	1875	87.5	1842	60.0
23	49.88	69.90	59.89	31.5	1865	87.0	1842, 1854	60.0
24	50.24	68.92	59.58	34.0	1874	88.5	1854	60.0
25	51.89	70.82	61.35	33.5	1874, 1875	93.0	1843, 1855	60.0
	50.63	**69.67**	**60.15**	**33.3**		**88.2**		**59.8**

1836 1882	Mean Values for each Day.			Extreme Maxima and Minima observed on each Day of the Year.				Supposed true Mean
	Min.	Max.	Mean.	Min.	Year.	Max.	Year.	
Ap. 26	51.20	70.53	60.86	33.5	1873	88.0	1872	60.0
27	50.63	69.98	60.30	37.0	1857	93.0	1838	60.0
28	51.21	68.71	59.96	34.0	1854	83.5	1845	60.0
29	50.87	69.15	60.01	33.0	1874	89.5	"	60.0
30	50.68	69.07	59.87	32.0	1877	92.5	1855	60.0
	50.92	**69.49**	**60.20**	**33.9**		**89.3**		**60.0**
May 1	50.53	69.72	60.12	35.5	1877	91.5	1836	60.0
2	51.06	68.34	59.70	29.0	1851	87.0	"	60.2
3	51.05	69.67	60.36	38.0	1841	88.5	1849	60.4
4	53.60	71.04	62.32	37.0	1877	89.0	1860	61.0
5	53.72	71.88	62.80	37.0	1851	91.5	"	61.4
	51.99	**70.13**	**61.06**	**35.3**		**89.5**		**60.6**
6	52.85	71.47	62.16	37.5	1863	88.0	1872	61.8
7	53.77	73 49	63.63	35.0	1867	88.0	"	62.0
8	54.05	72.56	63.30	38.0	1855	88.0	"	62.5
9	54.40	73.21	63.80	39.0	"	88.0	"	63.0
10	53.37	73.16	63.26	40.0	1838, 1871	89.5	1844, 1863	63.5
	53.68	**72.78**	**63.23**	**37.9**		**88.3**		**62.5**
11	54.12	72.78	63.45	39.0	1864	91.5	1844	64.0
12	55.17	74.79	64.98	39.5	1857	91.5	1836	64.5
13	56.34	75.17	65.75	41.5	1878	90.0	1862	65.0
14	56.72	74.75	65.73	42.0	"	97.5	1836	65.5
15	55.61	75.53	65.57	40.5	"	93.0	"	66.0
	55.59	**74.60**	**65.05**	**40.5**		**92.7**		**65.0**
16	56.73	75.52	66.12	40.0	1837, 1875	92.0	1851	66.5
17	56.01	73.47	64.74	42.0	1857	91.0	1853	67.0
18	55.19	75.27	65.23	42.0	"	87.0	1836, 1870	67.5
19	57.24	77.30	67.27	43.0	1853	89.5	1871	68.0
20	57.61	77.34	67.47	42.0	1852	90.5	1836	68.2
	56.55	**75.78**	**66.17**	**41.8**		**90.0**		**67.4**
21	58.76	76.31	67.53	43.0	1857	96.0	1870	68.4
22	58.53	78.02	68.27	40.0	1838	97.0	"	68.6
23	59.26	77.68	68.47	44.0	1867, 1876	90.0	1839, 1856	68.8
24	59.66	78.80	69.23	45.0	1851	92.5	1873, 1879	69.0
25	60.21	77.40	68.80	44.0	1845	93.0	1860	69.5
	59.28	**77.64**	**68.46**	**43.2**		**93.7**		**68.8**
26	60.46	81.00	70.73	48.0	1853	93.0	1860	70.0
27	60.33	79.37	69.85	48.0	"	94.0	1874	70.2
28	60.46	80.59	70.52	45.0	1838	91 0	1848, 1851	70.4
29	61.08	79.24	70.16	44.0	1866	91.0	1852, 1879	70.6
30	61.68	79.94	70.81	44.0	1845	90.0	1841, 1854	70.8
	60.80	**80.02**	**70.41**	**45.8**		**91.8**		**70.4**
31	62.14	79.25	70.69	52.0	1856	97.0	1871	71.0
June 1	61.49	79.78	70.63	49.0	1843	91.0	1845, 1852	71.0
2	62.39	80.70	71.54	49.0	1838	94.0	1852	71.2
3	62.44	80.12	71.28	47.5	1879	93.0	1856	71.4
4	62.05	79.06	70.55	44.0	1859	94.0	1841	71.6
	62.10	**79.78**	**70.94**	**49.3**		**93.8**		**71.2**
5	61.36	79.45	70.40	43.0	1839	93.0	1871	71.8
6	62.57	81.88	72.22	43.0	1838	93.0	1836, 1874	72.0
7	62.18	81.34	71.73	50.0	1854	95.0	1874	72.2
8	63.83	81.95	72.89	49.0	"	96.0	1836	72.4
9	63.62	81.18	72.40	51.5	1852, 1877	99.5	"	72.6
	62.71	**81.16**	**71.93**	**47.3**		**95.3**		**72.2**

1836-1882	Mean Values for each Day.			Extreme Maxima and Minima observed on each Day of the Year.				Supposed true Mean
	Min.	Max.	Mean.	Min.	Year.	Max.	Year.	
Jun. 10	62.65	81.90	72.27	46.5	1877	97.5	1836	72.8
11	61.90	79.38	70.64	45.0	1842	94.0	1841	73.0
12	63.32	81.59	72.45	50.0	1858	94.5	1853	73.2
13	64.87	83.82	74.34	50.0	"	94.5	"	73.4
14	65.01	83.84	74.42	51.0	1856	96.0	1879	73.6
	63.55	**82.10**	**72.82**	**48.5**		**95.3**		**73.2**
15	65.11	83.79	74.45	49.0	1869	96.5	1868	73.8
16	65.26	82.32	73.79	53.0	1841	98.5	"	74.0
17	65.56	82.60	74.08	51.5	1876	98.5	"	74.3
18	65.78	83.97	74.87	49.5	"	99.0	"	74.6
19	65.59	84.37	74.98	52.0	1866	96.0	1853, 1869	74.8
	65.46	**83.41**	**74.43**	**51.0**		**97.7**		**74.3**
20	65.92	83.96	74.94	52.0	1862	98.0	1861	75.0
21	65.57	83.52	74.54	49.0	1863	97.0	1853	75.3
22	65.64	85.82	75.73	50.0	1868	99.0	1871	75.6
23	67.06	84.58	75.82	53.0	"	101.5	"	76.0
24	66.91	85.11	76.01	55.5	1853	97.5	1870	76.5
	66.22	**84.60**	**75.41**	**51.9**		**98.6**		**75.7**
25	68.13	86.54	77.33	56.0	1852	98.0	1870, 1882	77.0
26	68.73	87.88	78.30	55.0	1865	98.5	1870	77.5
27	70.26	87.21	78.73	59.0	1836	97.0	1854	78.0
28	69.36	87.48	78.42	55.5	1866	100.0	1870	78.0
29	69.26	86.08	77.67	51.0	"	101.5	"	78.0
	69.15	**87.04**	**78.09**	**55.3**		**99.0**		**77.7**
30	69.23	86.95	78.09	56.0	1871	101.5	1870	78.0
July 1	68.39	85.91	77.15	54.0	1851	98.0	1854	78.0
2	68.06	85.60	76.83	54.0	1861	98.5	1858	78.0
3	68.42	87.10	77.76	56.0	1857	99.5	1856	78.1
4	68.71	87.89	78.30	53.0	1859	100.5	1868	78.2
	68.56	**86.69**	**77.62**	**54.6**		**99.6**		**78.1**
5	69.24	87.39	78.32	56.5	1882	98.5	1870	78.3
6	70.11	88.05	79.08	54.0	1842	97.0	1868	78.6
7	70.20	87.84	79.02	58.0	"	98.0	1874	79.0
8	70.55	87.97	79.26	58.0	1870	97.0	1854, 1879	79.0
9	71.05	89.15	80.10	57.0	1842	99.0	1858	79.2
	70.23	**88.08**	**79.15**	**56.7**		**97.9**		**78.8**
10	71.46	87.84	79.65	61.0	1836	101.5	1881	79.2
11	70.35	86.99	78.67	58.0	1854, 1873	100.0	1841	79.4
12	70.64	87.50	79.07	58.0	1863	100.0	"	79.4
13	69.99	88.61	79.30	57.0	1861	100.5	1862	79.6
14	70.69	88.66	79.67	56.5	1882	100.5	1868	79.6
	70.62	**87.92**	**79.27**	**58.1**		**100.5**		**79.4**
15	71.44	89.38	80.41	58.0	1842	100.0	1856	80.0
16	71.42	89.02	80.22	55.0	1863	100.0	1870	80.0
17	70.66	90.07	80.36	56.0	"	102.5	1856	80.0
18	70.77	88.73	79.75	58.0	1846	101.5	1868	79.6
19	70.44	87.70	79.07	58.0	1878	100.0	1854	79.4
	70.94	**88.98**	**79.96**	**57.0**		**100.8**		**79.8**
20	69.94	86.92	78.43	57.0	1873	100.5	1854, 1860	79.2
21	69.08	86.42	77.13	57.0	1869	104.0	1860	79.0
22	68.63	85.63	77.94	57.0	1864	101.5	1870	79.0
23	68.72	87.16	78.01	55.0	1861	98.5	"	79.0
24	69.01	87.86	78.43	56.0	"	101.0	"	78.8
	69.07	**86.79**	**77.93**	**56.4**		**101.1**		**79.0**

1836-1882	Mean Values for each Day.			Extreme Maxima and Minima observed on each Day of the Year.				Sup-posed true Mean
	Min.	Max.	Mean.	Min.	Year.	Max.	Year.	
Jul. 25	70.24	88.38	79.31	59.0	1876	100.0	1870	78.6
26	70.73	88.27	79.50	58.0	1853	99.5	"	78.4
27	70.38	87.58	78.98	56.0	"	101.5	"	78 2
28	70.23	87.80	79.01	56.0	"	100.0	1838	78.0
29	70.58	87.58	79.08	61.0	1853, 1865	101.0	1854	78.0
	70.43	**87.92**	**79.17**	**58.0**		**100.4**		**78.2**
30	68.52	85.57	77.04	55.0	1847	101.0	1838	77.8
31	67.96	86.47	77.21	55 0	1849	100.0	1854	77.8
Aug. 1	68.38	87.33	77.85	52.0	1842	101.0	"	77.5
2	68.25	86.95	77.60	52.0	"	99.0	1861	77.5
3	68.61	86.59	77.60	55.0	"	101.0	"	77.5
	68.34	**86.58**	**77.46**	**53.8**		**100.4**		**77.6**
4	68.40	85.51	76.95	54.0	1880	101.5	1861	77.5
5	68.50	86.01	77.25	58.0	"	97.5	1858	77.5
6	68.97	87.18	78.07	58.0	1842	98.5	1838	77.5
7	69.11	87.07	78.09	57.5	1852	100.0	1861	77.4
8	68.96	87.09	78.02	56.0	1869	99.0	1850	77.4
	68.79	**86.57**	**77.68**	**56.7**		**99.3**		**77.4**
9	68.94	85.14	77.04	58.0	1879	104.0	1881	77.4
10	69.07	83.39	76.23	55.5	1882	98.0	"	77.4
11	69.37	86.44	77.90	57.0	"	100.5	"	77.4
12	68.38	86.47	77.42	56.0	1868	105.0	"	77.2
13	68.72	86.08	77.40	57.0	1860	101.5	1850	77.0
	68.89	**85.50**	**77.19**	**56.7**		**101.8**		**77.3**
14	68.49	85.30	76.89	56.5	1861	98.5	1857	77.0
15	68.52	85.39	76.95	59.5	"	97.0	1841	76.9
16	67.48	86.22	76.89	57.0	1866	96.0	1860	76.8
17	67.94	85.54	76.74	54.0	1855	97.0	1843, 1860	76.7
18	68.03	86.27	77.15	56.0	1855, 1866	99.5	1850	76.5
	68.09	**85.74**	**76.91**	**56.6**		**97.6**		**76.8**
19	68.19	85.25	76.72	56.0	1855	99.5	1850	76.4
20	66.88	85.72	76.30	52.0	1836	99.0	"	76.3
21	67.87	85.71	76.79	59.0	1864	97.0	1869	76.2
22	67.29	84.67	75.98	51.0	1837	97.5	1872	76.0
23	66.31	84.09	75.20	52.0	1866	97.5	1869	76.0
	67.31	**85.09**	**76.20**	**54.0**		**98.1**		**76.2**
24	66.63	85.29	75.96	49.0	1866	97.0	1872	75.8
25	66.38	84.42	75.40	50.5	"	100.0	"	75.5
26	67.02	84.94	75.98	49.0	1863	98.5	"	75.3
27	65.88	84.11	74.99	54.0	1856	97.5	1838	75.0
28	65.37	82.98	74.17	51.0	1844	97.5	1881	74.8
	66.25	**84.35**	**75.30**	**50.7**		**98.1**		**75.3**
29	64.80	83.05	73.92	49.0	1863	99.5	1881	74.5
30	64.55	84.34	74.44	45.0	"	100.5	1854	74.3
31	65.45	82.96	74.20	48.5	"	99.0	1854, 1873	74.2
Sept. 1	64.75	83.69	74.22	50.0	1849	98.5	1854	74.0
2	65.08	82.80	73.94	51.5	1850	102.0	1864	74.0
	64.93	**83.37**	**74.15**	**48.8**		**99.9**		**74.2**
3	64.54	83.00	73.77	51.0	1863	102.0	1864	74.0
4	65.10	83.59	74.34	51.0	1868	100.0	1881	74.0
5	65.33	82.15	73.74	50.0	1859	100.0	"	73.8
6	64.98	81.84	73.41	51.5	1848	97.0	"	73.6
7	65.61	83.17	74.39	52.0	1849	97.0	"	73.4
	65.11	**82.75**	**73.93**	**51.1**		**99.2**		**73.7**

1836-1882	Mean Values for each Day.			Extreme Maxima and Minima observed on each Day of the Year.				Supposed true Mean
	Min.	Max.	Mean.	Min.	Year.	Max.	Year.	
Sept. 8	64.48	83.47	73.97	49.5	1849	99.5	1854	73.0
9	63.79	80.63	72.21	50.0	1847, 1869	93.5	1841	72.0
10	62.59	79.95	71.27	46.5	1880	96.5	1842	71.0
11	61.01	78.90	69.95	47.5	1878	94.0	"	70.2
12	60.69	77.79	69.24	46.0	1839, 1878	92.0	1865	70.0
	62.51	**80.15**	**71.33**	**47.9**		**95.1**		**71.2**
13	60.27	77.85	69.06	47.0	1839, 1878	93.0	1851, 1864	70.0
14	60.37	79.16	69.76	43.5	1873	93.0	1846	69.5
15	60.51	77.88	69.19	47.5	1880	88.0	1849, 1862	69.0
16	60.76	79.34	70.05	47.0	1842	91.5	1857	69.0
17	60.54	77.72	69.13	40.5	1868	93.0	1843, 1857	68.5
	60.49	**78.39**	**69.44**	**45.1**		**91.7**		**69.2**
18	60.08	78.29	69.18	42.0	1863	92.5	1867	68.0
19	57.74	75.91	66.82	44.5	"	92.0	"	67.0
20	55.76	73.68	64.72	39.0	1875	93.5	1881	66.0
21	55.50	73.29	64.39	39.5	1866	95.0	1872	66.0
22	55.39	73.69	64.54	39.0	1875	92.0	1881	65.8
	56.89	**74.96**	**65.93**	**40.8**		**93.0**		**66.5**
23	58.17	76.82	67.49	36.0	1856	92.0	1881	65.5
24	58.15	76.23	67.19	37.0	"	92.5	"	65.0
25	57.09	75.37	66.23	42.0	1879	91.5	1850	64.8
26	54.61	73.81	64.21	40.0	1875	92.0	1847	64.5
27	54.87	73.82	64.34	41.5	1871	88.0	1854	64.3
	56.58	**75.21**	**65.89**	**39.3**		**91.2**		**64.8**
28	54.37	73.53	63.95	36.0	1839	90.5	1867	64.0
29	54.17	71.87	63.02	35.5	1846	93.0	1858	63.5
30	52.59	71.53	62.06	35.0	1851	90.0	"	63.0
Oct. 1	54.64	73.37	64.00	36.5	1856	87.0	1856	63.0
2	54.68	73.74	64.21	38.5	"	91.0	1867	63.0
	54.09	**72.81**	**63.45**	**36.3**		**90.3**		**63.1**
3	54.52	73.55	64.03	33.0	1840	89.0	1872	62.5
4	52.29	70.59	61.44	31.0	1836	88.5	"	62.0
5	52.18	70.36	61.27	34.0	"	88.0	1879	61.5
6	52.52	70.03	61.27	34.0	1855	88.5	1852	61.5
7	51.93	70.62	61.27	34.0	1873	87.0	1860	61.0
	52.69	**71.03**	**61.86**	**33.2**		**88.2**		**61.7**
8	51.70	71.14	61.42	31.5	1868	85.0	1856	60.5
9	51.49	70.66	61.07	36.5	1842, 1864	87.0	1879	60.0
10	51.26	69.91	60.58	37.0	1849	86.0	"	59.5
11	49.98	67.14	58.56	31.5	1872	86.0	"	59.0
12	48.73	64.91	56.82	30.0	1875	87.0	"	58.5
	50.63	**68.75**	**59.69**	**33.1**		**86.2**		**59.5**
13	45.99	65.96	55.97	29.5	1860	81.5	1879	58.0
14	47.20	65.24	56.22	29.5	1872	84.0	1878	57.5
15	46 88	65.82	56.35	28.0	1845	84.5	1881	57.0
16	47.34	65.64	56.49	27.0	1838	83.0	1842	56.0
17	46.80	65.42	56.11	31.0	1836, 1868	83.0	1839, 1842	55.0
	46.84	**65.61**	**56.23**	**29.0**		**83.2**		**56.7**
18	44.64	60.55	52.59	34.5	1875	82.5	1867	54.5
19	42.70	61.62	52.16	30.0	1846	84.0	1837	54.0
20	42.75	62.31	52.53	24.0	1836	83.0	1843	53.5
21	44.60	62.47	53.53	25.0	"	84.0	1837	53.0
22	44.15	61.47	52.81	30.0	1869	85.0	"	52.5
	43.77	**61.68**	**52.72**	**28.7**		**83.7**		**53.5**

1836-1882	Mean Values for each Day.			Extreme Maxima and Minima observed on each Day of the Year.				Sup-posed true Mean
	Min.	Max.	Mean.	Min.	Year.	Max.	Year.	
Oct. 23	43.41	61.54	52.47	20.0	1863	79.5	1839	52.0
24	44.32	60.64	52.48	20.0	"	78.0	1875	51.8
25	42.51	59.96	51.23	22.0	1841	78.5	1882	51.6
26	43.64	60.56	52.10	21.5	1862	81.5	1874	51.4
27	42.15	61.11	51.63	26.0	1869	81.5	1870	51.0
	43.20	**60.76**	**51.98**	**21.9**		**79.8**		**51.5**
28	43.54	60.56	52.05	27.0	1873, 1878	80.5	1874	51.0
29	43.71	60.77	52.24	22.0	1873	81.5	1875	50.5
30	42.34	57.28	49.81	26.5	1863	81.5	1876	50.5
31	39.75	56.66	48.20	19.5	"	80.0	"	50.0
Nov. 1	42.01	59.97	50.99	22.0	1873	78.0	1842, 1876	50.0
	42.27	**59.05**	**50.66**	**23.4**		**80.5**		**50.4**
2	43.20	58.00	50.60	30.5	1848	77.0	1847	50.0
3	41.11	56.59	48.85	25.5	1879	75.5	1859	49.8
4	42.01	58.66	50.33	23.0	"	80.0	1850	49.4
5	41.23	55.70	48.46	25.0	1865	72.5	1874	49.0
6	38.91	55.29	47.10	23.5	1877	73.0	1874, 1878	48.5
	41.29	**56.85**	**49.07**	**25.5**		**75.6**		**49.3**
7	40.78	57.55	49.16	24.0	1856	77.0	1874	48.0
8	40.30	55.78	48.04	11.0	1838	75.5	1868	47.0
9	37.43	51.88	44.66	16.0	"	75.0	1844	46.0
10	39.03	52.71	45.87	20.0	"	76.0	"	45.5
11	40.23	53.53	46.88	26.5	1869	81.5	1837	45.0
	39.55	**54.29**	**46.92**	**19.5**		**77.0**		**46.3**
12	36.93	51.66	44.29	17.0	1859	71.5	1879	44.5
13	36.66	52.82	44.74	15.0	"	79.0	"	44.0
14	36.67	51.86	44.26	20.0	1872	71.5	1855	43.5
15	35.18	50.01	42.59	18.0	1838	72.0	1873	43.0
16	36.11	49.60	42.85	10.0	"	69.0	1865	42.0
	36.31	**51.19**	**43.75**	**16.0**		**72.6**		**43.4**
17	35.55	47.80	41.67	12.0	1838	69.0	1853	41.0
18	33.62	45.58	39.60	6.0	1880	72.0	"	40.5
19	31.60	45.03	38.31	7.5	"	71.0	"	40.0
20	32.59	45.11	38.85	9.5	1872	72.5	1837	39.5
21	33.09	45.84	39.46	10.5	1880	69.0	1841	39.0
	33.29	**45.87**	**39.58**	**9.1**		**70.7**		**40.0**
22	32.28	45.92	39.10	6.5	1880	71.0	1843	38.5
23	32.14	43.97	38.05	9.5	1871	69.0	1867	38.0
24	29.85	41.93	35.89	5.5	1860	65.5	1850	37.8
25	29.83	41.92	35.87	0.0	1839	64.5	1856	37.6
26	31.25	44.06	37.65	14.0	"	65.0	1850	37.4
	31.07	**43.56**	**37.31**	**7.1**		**67.0**		**37.6**
27	31.44	43.22	37.33	5.0	1845	67.0	1870	37.0
28	31.64	44.05	37.84	— 0.5	"	72.0	1864	36.8
29	29.04	42.76	35.90	2.0	1872	76.5	"	36.4
30	28.55	42.98	35.76	6.5	1845	72.5	1837	36.0
Dec. 1	30.33	45.57	37.95	— 1.0	"	72.5	"	36.0
	30.20	**43.71**	**36.95**	**2.4**		**72.1**		**36.4**
2	31.06	44.95	38.00	4.0	1876	72.0	1864	35.8
3	30.61	43.00	36.80	8.0	1859	61.0	1842, 1873	35.6
4	30.75	42.18	36.46	— 2.5	1871	59.0	1877	35.4
5	29.45	41.33	35.39	2.5	"	61.0	1879	35.2
6	29.56	41.88	35.72	3.5	1859	62.0	1861	35.0
	30.28	**42.67**	**36.47**	**3.1**		**63.0**		**35.4**

1836-1882	Mean Values for each Day.			Extreme Maxima and Minima observed on each Day of the Year.				Supposed true Mean
	Min.	Max.	Mean.	Min.	Year.	Max.	Year.	
Dec. 7	28.00	40.23	34.11	—11.0	1882	63.0	1851	34.0
8	27.79	39.11	33.49	— 4.0	"	65.0	1861	33.5
9	25.07	35.35	30.21	— 5.0	1876	74.5	"	33.0
10	23.89	36.06	29.97	0.0	1868	68.0	"	32.5
11	28.19	37.61	32.90	—11.0	"	68.0	1873	32.0
	26.59	**37.67**	**32.13**	**—6.2**		**67.7**		**33.0**
12	25.54	37.15	31.34	— 0.5	1868	68.5	1877	31.8
13	26.25	36.70	31.47	4.0	1865	62.5	1881	31.6
14	23.46	33.79	28.62	— 1.0	"	59.0	1861	31.4
15	23.57	33.46	28.51	— 2.5	1851	67.5	1877	31.2
16	24.29	34.83	29.56	— 0.5	"	62.0	"	31.0
	24.62	**35.18**	**29.90**	**—0.1**		**63.9**		**31.4**
17	25.10	36.91	31.00	— 2.5	1875	67.0	1877	31.0
18	25.76	38.87	32.31	1.0	1876	69.0	"	30.8
19	26.37	38 10	32.23	0.5	1863	67.5	"	30.6
20	23 51	35.84	29.67	— 2.0	1871	65.0	"	30.4
21	24.84	36.97	30.90	— 2.0	1865	66.0	"	30.0
	25.11	**37.34**	**31.22**	**—1.0**		**66.9**		**30.5**
22	22.64	33.86	28.25	—14.0	1872	62.0	1877	30.0
23	22.51	35.34	28.92	— 7.0	1870	61.0	1875	30.2
24	23.90	36.62	30.26	—19.5	1872	66.0	"	30.5
25	25.42	37.95	31.68	—11.0	"	70.0	1867	31.0
26	25.63	38.06	31.84	— 5.0	"	65.0	1875	31.2
	24.02	**36.36**	**30.19**	**—11.3**		**64.8**		**30.6**
27	26.47	38.41	32.44	— 6.0	1872	65.0	1846	31.3
28	26.34	37.80	32.07	— 6.0	1880	59.0	1862	31.5
29	25.83	37.49	31.66	—18.0	"	64.0	1851	31.5
30	23.26	36.73	29.99	— 8.0	"	66.0	1875	31.5
31	24.25	38.43	31.34	—10.5	1863	73.5	"	31.5
	25.23	**37.77**	**31.50**	**—9.7**		**65.5**		**31.5**

The annexed diagram, for the construction of which I am indebted to Dr. G. Hambach, represents the principal results of these tables. The perpendicular lines divide the year into 73 periods of 5 days each, while the horizontal ones mark the degrees. The central full-faced curve indicates the Mean Temperature of the penthemeral periods of the 47 years, as actually found, while the dotted line represents the supposed real Mean Temperature as suggested in the last column of these tables. The uppermost curve shows the Highest Temperatures and the lowest curve the Lowest Temperatures observed in those same penthemeral periods within the s me number of years. It will be noticed that while the points of Mean Temperature occupy the centre of each period, the Maxima and Minima do not show in the middle of the spaces, but on that one of the 5 days of the period on which they actually did occur.

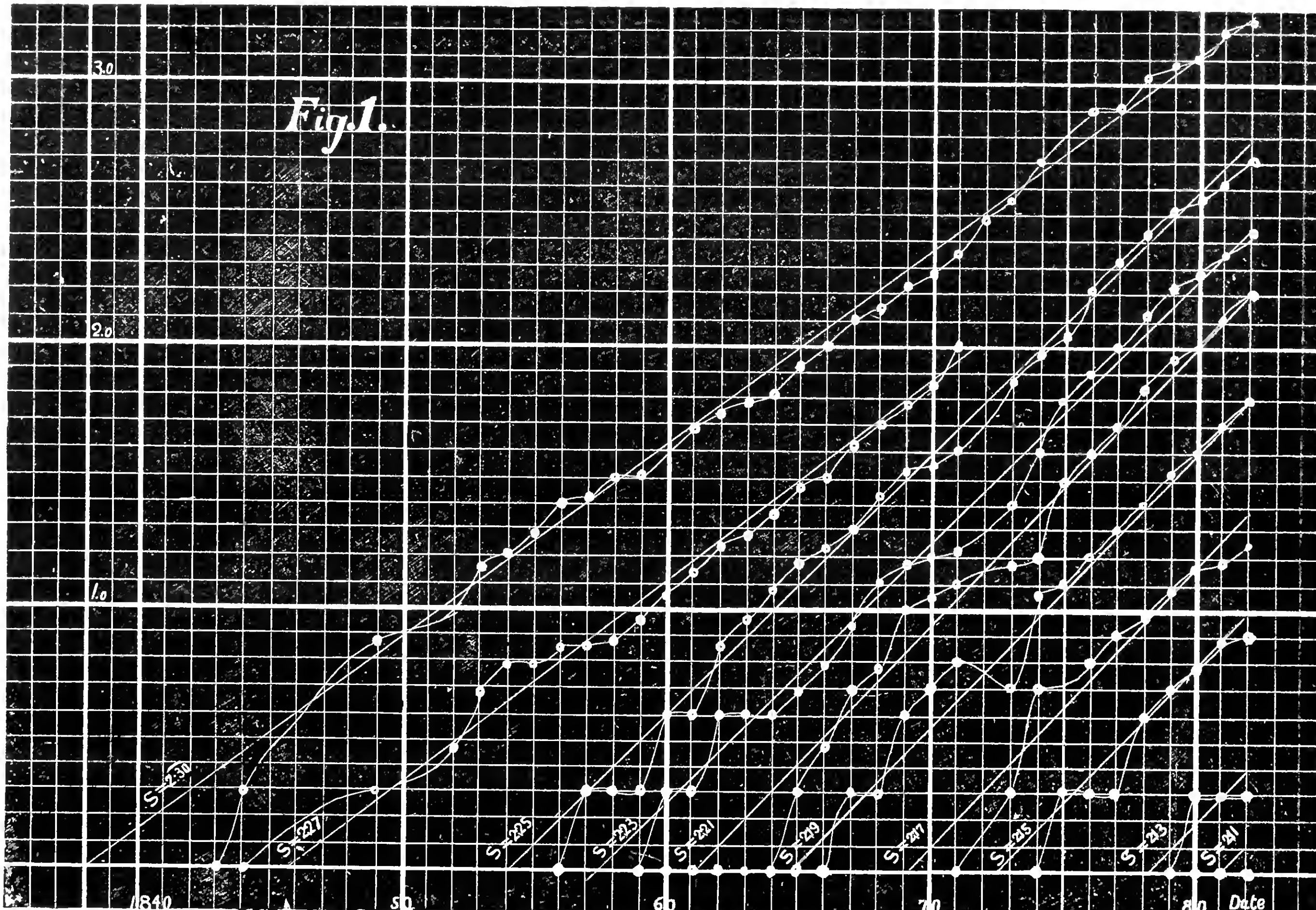
Fig.1.
3.0
2.0
1.0
1840
50
60
70
80
Date
S=2.30
S=2.27
S=2.25
S=2.23
S=2.21
S=2.19
S=2.17
S=2.15
S=2.13
S=2.11

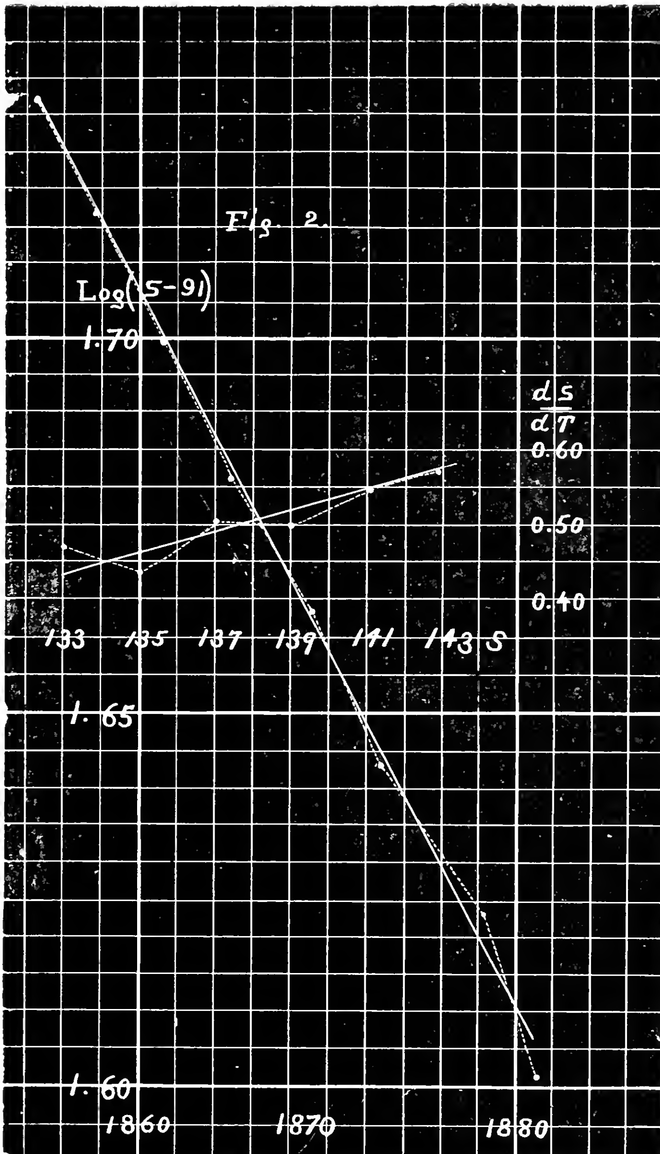

Fig. 2.
Log(S-91)
1.70
1. 65
1. 60
dS/dT
0.60
0.50
0.40
133
135
137
139
141
143 S
1860
1870
1880

*The Evolution of the American Trotting-Horse.**

By FRANCIS E. NIPHER.

In the American Journal of Science for April, 1883, Prof. W. H. Brewer has furnished data for the discussion of the change in speed of the American trotting-horse. His table is here reproduced.

TABLE SHOWING THE NUMBER OF HORSES UNDER THE RESPECTIVE RECORDS.

Year.	2:30 or better	2:27 or better	2:25 or better	2:23 or better	2:21 or better	2:19 or better	2:17 or better	2:15 or better	2:13 or better	2:11 or better
1843	1	......	......	......	......	......	......	......	......	......
1844	2	1	......	......	......	......	......	......	......	......
1849	7	2	......	......	......	......	......	......	......	......
1852	10	3	......	......	......	......	......	......	......	......
1853	14	5	......	......	......	......	......	......	......	......
1854	16	6	......	......	......	......	......	......	......	......
1855	19	6	......	......	......	......	......	......	......	......
1856	24	7	1	......	......	......	......	......	......	......
1857	26	7	2	......	......	......	......	......	......	......
1858	30	7	2	......	......	......	......	......	......	......
1859	32	9	2	1	1	......	......	......	......	......
1860	40	11	4	2	1	......	......	......	......	......
1861	48	14	4	2	1	......	......	......	......	......
1862	54	17	7	4	1	......	......	......	......	......
1863	59	19	9	4	1	......	......	......	......	......
1864	66	22	12	4	1	......	......	......	......	......
1865	84	29	15	5	2	1	......	......	......	......
1866	101	32	17	6	3	1	......	......	......	......
1867	124	42	21	9	5	2	......	......	......	......
1868	146	52	28	13	6	2	......	......	......	......
1869	171	63	34	15	10	4	......	......	......	......
1870	194	72	35	16	11	5	......	......	......	......
1871	233	99	40	17	12	6	1	......	......	......
1872	323	......	......	......	......	......	......	......	......	......
1873	376	......	74	28	15	5	2	......	......	......
1874	506	......	98	40	16	11	5	1	......	......
1875	......	......	134	61	30	13	5	2	......	......
1876	794	......	165	81	39	16	6	2	......	......
1877	836	......	214	105	51	19	8	2	......	......
1878	1025	......	270	129	68	24	9	4	......	......
1879	1142	......	325	164	88	33	11	5	1	......
1880	1210	......	366	192	106	41	14	6	2	1
1881	1532	......	419	227	126	49	15	7	2	1
1882	1684	......	495	275	156	60	18	8	2	1

Prof. Brewer states that the data for the speeds 2:30 and 2:27 are very unsatisfactory, but for all the others are reasonably correct.

On taking the logarithms of all the numbers N of horses capable of trotting a mile in s seconds, it results that the plotted values of log. N for their proper dates give a straight line for each value of s. For the speeds s of 2:30 and 2:27 these lines are parallel to each other, and the lines representing the remaining

* Read May 7th, 1883.

speeds are also parallel to each other, but the two groups are not parallel.

For the first set, the lines can be represented by the equation

$$\log N = A' + 0.075\ T,$$

where A' is a function of s, and T is estimated in years from any arbitrarily assumed date.

For the second group,

$$\log N = A' + 0.10\ T.$$

It is apparent that for the speed of 2:30 and 2:27 the values of N are too small, for the reason perhaps that in earlier years, when this was called good time, less general attention was paid to the breeding of trotters, while in later years, as this became a common speed, a constantly increasing number of horses of this grade have been used as roadsters and remained undiscovered in private hands.

These plotted lines are shown in Fig. 1. It is clear that the intersection of any one of these lines with the time axis determines the date when this speed may be supposed to have originated, or when $N = 1$, and that this determination of the date, based as it is upon a number of observations running through a series of years, is much more reliable than the date when some accidentally arranged trotting match revealed the fact that the horse capable of making this speed had already come.

The dates for the origin of the speeds of 2:13 and 2:11 cannot yet be determined very accurately, and this fact is to be remembered in considering the discussion which follows.

The following table gives the values of s in seconds and the dates for the origin of these speeds, determined as before explained. The third column contains the change in speed per year, calculated in a well known manner from alternate differences in the two previous columns.

s.	YEAR.	$\frac{ds}{dT}$
145	1854.0	.....
143	1857.4	0.571
141	1861.0	0.547
139	1864.7	0.500
137	1869.0	0.506
135	1872.6	0.430
133	1878.3	0.476
131	1881.0	.....

When the values of $\frac{ds}{dT}$ are plotted with the simultaneous values of s, we get a somewhat irregular series of points shown in Fig 2, and represented fairly well by the equation

$$\frac{ds}{dT} = A + Bs \qquad - \quad - \quad - \qquad (1)$$

The constants A and B can be determined graphically with as great precision as the nature of the data will warrant.

The values are found to be

$$A = -1{\cdot}_{00}$$
$$B = +0{\cdot}_{0110},$$

and the differential equation (1) becomes

$$\frac{ds}{dT} = -1{\cdot}_{00} + 0{\cdot}_{0110}\, s \qquad - \quad - \qquad (2)$$

This equation being put into the form

$$\frac{ds}{s - 90{\cdot}_9} = 0{\cdot}_{0110}\, dT,$$

it admits of direct integration as follows,

$$\int_{s_0}^{s} \frac{ds}{s-90{\cdot}_9} = 0{\cdot}_{0110} \int_{T}^{T_0} dT$$

on performing the indicated operations

$$l\,(s-90{\cdot}_9) = l\,(s_0 - 90{\cdot}_9) + 0{\cdot}_{0110}\, T_0 - 0{\cdot}_{0110}\, T,$$

where s_0 and T_0 are simultaneous values at any assumed date.

Placing the initial values in a single term, we have

$$l\,(s-90{\cdot}_9) = C - BT \qquad - \quad - \qquad (3)$$

or for the primitive equation

$$s = 90{\cdot}_9 + e^{C-BT} \qquad - \quad - \qquad (4)$$

where e is the Naperian base.

It thus appears that the limiting speed of which the trotting-horse is capable, which he will continually approximate and never reach, is 1 :31. This follows from (2) by making $\frac{ds}{dT} = 0$, or from (3) and (4) by making $T = \infty$.

The constants B and C are best determined by taking the logarithms of $(s-91)$ for the vaiious values of s, and plotting them on the time axis. These values are given in the following table:

s.	$s-91$.	log $(s-91)$	YEAR.	T.	s calc.	DIFF.
145	54	1·732	1854·0	— 6.0	144·8	—0·2
143	52	1·716	1857·4	— 2·6	142·9	—0·1
141	50	1·699	1861·0	+ 1·0	140·9	—0·1
139	48	1·681	1864·7	+ 4·7	139·2	+0.2
137	46	1·663	1869·0	+ 9·0	137·2	+0.2
135	44	1·643	1872·6	+12.6	135·2	+0.2
133	42	1·623	1878·3	+18.3	132·6	—0·4
131	40	1·602	1881·0	+21.0	131·4	+0·4

The constants are determined by well known graphical methods, and it is thus found that the observations are represented by the equation

$$\log (s-91) = 1.703 - 0.0046\, T, \qquad (5)$$

where the logarithms are common, and T is estimated in years from 1860. Substituting in (4) the values of T for the dates of the above table, the values of s and their differences from the observed values of s have been determined and are given in the final column. These differences are seen to be greatest for the later dates, where the possible errors are known to be greatest; but the error in s even here coriesponds to an error of only a year in date, which is certainly within the error of observation.

From (5) it is easy to determine the date when the horse will have reached within one second of the limiting speed. Making $s = 92$, this value of T turns out to be 370 years. By the close of the present century the time of trotting a mile will be reduced to 2:04, and the time of 2:00 will be reached in the year 1912. But they indicate that the trotting-horse will finally be able to make his mile in a time not differing materially from the time of the running-horse, which is at present about 100 seconds. Whether or not the trotting-horse will finally beat the running-horse, as the present results seem to indicate, it is perhaps not possible to decide at present with the insufficient data at our command. A weighty consideration is found in the fact that a well trained trotter carries his body more steadily, or with less of rise and fall, than the racer, and this may possibly result to the final advantage of the trotting-horse after the process of developing and adjusting of his muscles and chest shall have been sufficiently carried on, so that the contest between the trotter and the racer shall have been reduced to a matter of muscular capacity.

It is well known that some herds of wild horses on the Texas plains were natural pacers, and even when pushed to the utmost, and for days together, by the best running-horses, the greater portion of them held to their gait. One large white pacer became widely known and his capture was often attempted, but he always proved more than a match for the best horses that could be brought against him.

Whatever may be said about the particular numerical results of this discussion, it is clear that the trotting-horse is very likely to reach a much higher speed than has been heretofore thought possible.

Added Nov. 7, 1883.

In the November number of the American Journal of Science Mr. W. H. Pickering has criticised the method of reduction used in the present paper (which had been printed from advance sheets in the July number of that journal), and has reached a very different conclusion from that reached in the present paper.

Mr. Pickering thinks that it is objectionable to determine the value of $\frac{ds}{dT}$ by taking the alternate differences in s and T, and he has reduced the observations by taking differences between consecutive values in the table. In this way he gets the values of the third column in the table below.

s.	YEAR.	$\frac{ds}{dT}$	$\frac{ds}{dT}$ calc.	e.
145	1854.0			
		0.59	0.59	0.0
143	1857.4			
		0.55	0.56	− 0.1
141	1861.0			
		0.54	0.54	0.0
139	1864.7			
		0.46	0.51	− 0.4
137	1869.0			
		0.55	0.49	+ 0.4
135	1872.6			
		0.35	0.46	− 1.4
133	1878.3			
		0.75	0.44	+ 1.8
131	1881.0			

Plotting these values of $\frac{ds}{dT}$ and the corresponding values of s, he then goes on to say that the points so determined may be represented by a curve, such that the value of $\frac{ds}{dT}$ increases as s

diminishes, and thus indicating disturbing causes not easily discussed. Assuming that a straight line will represent the values, he determines the value of the constants, and finds that the line intersects the axis of s at a point where the value of s is — 25. This would mean that the limiting speed of the trotter is 25 seconds less than no time at all.

When making his first discussion of the subject, the writer considered the propriety of determining the value of $\frac{ds}{dT}$ by means of consecutive differences, and unfortunately rejected the method without even giving it a trial, for the reason that the dates $1881._0$ and $1878._3$, corresponding to the values 131 and 133 of s, were very imperfectly determined. It was clear that the additional point thus secured would deserve very little weight. It was thought to diminish the irregularity of the line by combining these with previous and better determined dates. Mr. Pickering has not only used this method (which properly used is capable of yielding good results), but he has given equal weights to the values of $\frac{ds}{dT}$ for all the dates in the table. This is the fatal defect which entirely vitiates the conclusion reached by him. A reference to Fig. 1 of this paper will show that for the earlier dates from $1854._0$ down to $1872._6$ the graphically determined dates differ from the real dates when the record was actually lowered by from one to two years.

It will also be seen that the dates $1878._3$ and $1881._0$ are subject to errors which may be as great as two years. After having made a preliminary examination, these dates might indeed have been "adjusted" so as to make them agree better with the others, but they now stand exactly as they did when first made and before any other work had been done. It is clear that the most weight should be given to the earlier dates. I have therefore plotted the new values of $\frac{ds}{dT}$ with the values of s, and have drawn the line representing the values so as to give most weight to the best determined values. The equation of this line is

$$\frac{ds}{dT} = -1._{24} + 0._{0127}\, s. \qquad - \quad - \quad - \qquad (6)$$

From this equation the values of $\frac{ds}{dT}$ were calculated as given in the fourth column of the last table. The fifth column, headed e, gives the time in years by which the corresponding time intervals dT must be increased in order to bring Mr. Pickering's values of $\frac{ds}{dT}$ into accordance with the values calculated from the above equation. In this case the intervals are supposed to be separately adjusted. If the later dates were simultaneously adjusted or changed by intervals ranging from two-tenths to three-fourths of a year, the values of $\frac{ds}{dT}$, which Mr. Pickering prefers to use, would agree exactly with the values calculated from the last equation. Now it is perfectly clear that these later dates, and particularly the last two, are subject to just such errors as this.

Whatever these values of $\frac{ds}{dT}$ may be said to prove, they certainly do not prove that my results as before published are absurd, and they do not indicate a limiting speed of -25 seconds. If $\frac{ds}{dT} = 0$, the limiting speed of the horse is found to be 98 seconds.

I desire to express my thanks to Mr. Pickering for his criticisms and suggestions, as he has corrected a tendency which I had begun to feel, to attach too much importance to the numerical result reached; but I maintain that his method, correctly applied, gives in general, substantially, the same result as my own. It is not necessary to assert that this result is really correct if any person feels inclined to doubt it, because at present it is not possible to demonstrate it more fully than has been done in the present paper. I only insist that it is not wholly unwarranted by the facts which we now know.

Most horsemen seem to think that the limiting speed of the trotting-horse will be somewhere near a mile in 120 seconds. If this were true, the differential equation could hardly be a linear one. The equation

$$\frac{ds}{dT} = k\sqrt{s - L} \qquad (7)$$

where k is a constant and L is the limiting speed, would however be in harmony with this view. But this equation gives on integration an equation of the form

$$\sqrt{s - L} = C - AT \qquad (8)$$

According to this equation the horse would absolutely reach the limiting speed L in a finite time, $\frac{C}{A}$. Practically this may be true, as is in fact shown by my own equation (4), so that some such equation might really represent the results sufficiently near for all practical purposes. But the relation is not a rational one, since it cannot be supposed that the horse will really attain his limiting speed in a finite time. After he had come within a thousandth of a second, it would take a great interval of time to compass the next millionth of a second. Furthermore, this equation could not hold for values of T greater than $\frac{C}{A}$, as the value of s would then begin to increase according to equation (8). I therefore claim that equation (4), in all probability, represents the relation between the values of s and T, and that the constants in the equation will be determined with greater and greater precision as the data becomes more and more complete.

Magnetic Survey of Missouri. Fifth Annual Report.

By Francis E. Nipher.

During the summer of 1882 the survey was continued under the same auspices as in the previous year. The friend who furnished the entire means for conducting the work enlarged upon his former bounty, and furnished the party with two fine spring-wagons designed with reference to the needs of camp life, and provided with all needed conveniences. Two paid assistants, Messrs. Joseph Cunningham and Albert Meyer, were also sent with the expedition, and Mr. Frank Ringling of the Sophomore class accompanied the expedition as volunteer assistant, paying his own expenses.

The work of the summer was interfered with in a serious manner by the sickness of the horses, and more particularly by the horrible condition of the roads, due to heavy and long-continued rains. During the entire summer we were compelled to improve roads and fords, and to build bridges, and this frequently took up a quarter of our time during an entire week. This made it impossible to make complete observations after Aug. 7th, as we were obliged to travel every day in order to reach St. Louis within the time which could be devoted to the survey. After the above date, therefore, only declination observations were made, the magnetic meridian being determined from the morning elongation as explained in the previous report.* The true meridian was in nearly all cases obtained by pole-star observations, but the great number of cloudy nights made it necessary in some cases to observe at other times than at elongation.

A description of the stations where observations were made is here given, the numbers being continued from the previous report.

STATION 101—*Kirkwood, St. Louis Co.* Lat. 38° 36′; lon. 90° 24′. In the orchard of H. W. Leffingwell, 128 feet from the street fence on the south, and 150 feet from that on the east. Polaris observation on elongation.

STATION 102—*Gray's Summit, Franklin Co.* Lat. 38° 29′; lon. 40° 49′. On the Union road about half a mile to the S.W. from the railroad crossing, and in the second depression, 20 ft. from the road, and on the N.W. side. Polaris obs. on elongation.

STATION 103—*Newport, Franklin Co.* Lat. 38° 36′; lon. 91° 06′. In the "old town" on the summit of a small ridge, 128 ft. N.W. from the N.W. corner of the church. A large elm to the N.W. across the small water-course is said to be at, or very near, the N.W. corner of the S.E. qr. of sec. 11, tp. 44, r. 2 W. Polaris obs. on elongation.

STATION 104—On the farm of August Goebel, near *Newport.* Lat. 38° 34′; lon. 91° 06′. The station was within a few feet of the middle point of the line dividing the E. half of the S.W. qr. from the W. half of the S.E. qr. of sec. 15, tp. 44, r. 2 W. Polaris obs. on elongation. In this immediate vicinity Dr. Goebel, grandfather of the present owner of the farm, had established two magnetic stations, where he made extended and careful observations. The original records of this work were given to the U. S. Coast Survey some years since by his son, Mr. Gert Goebel.

The earlier station of Goebel is found by going from our station in a line bearing S. 93° 34′.5, E. 255 ft. and thence N. 83 ft. This station of Goebel's is 61 ft. W. and 14 ft. N. of the S.W. corner of the house of August Goebel The observations here were made in the year 1839. The declination was 9° 21′ E.

The other station of Dr. Goebel was occupied in the year 1849. It is at the S. window of a now abandoned stone house, the N.W. corner of which is 158 ft. W. and 193 ft. S. of our station. The house is a one-story structure, having the dimensions of N. and S. sides 18 ft., and E. and W. sides 24 ft. The window where his observations were made is in the middle ot the S. side. His value for declination in 1849 was 9° 05′ E. Our value determined June 22d, 1882, was 7° 36′.

STATION 105—*In Franklin Co.* Lat. 38° 41′; lon. 91° 20′. The station is on timber land of Elijah Ruck, 315 ft. N. and 15 E. of the well in

* Trans. iv. 3, p. 454.

front of the house of John Bedts, and about 325 ft. from the line between Franklin and Gasconade counties. The station was said to be in sec. 10, tp. 45, r. 4 W. Polaris obs. on elongation.

STATION 106 — *In Gasconade Co.* Lat. 38° 37′; lon. 91° 29′. On the land belonging to Fred. Bruhns. a quarter of a mile N. and 260 ft. E. of the S.W. corner of sec. 19. tp. 45, r. 5 W. The station is on the bank of First creek. The value for declination here was very much smaller than at surrounding stations, but no error could be detected in our work. Whether the discrepancy was due to some minute local effect or not, we could not remain to determine, as sickness at home made it desirable to reach the telegraph as soon as possible. This is the only case of the kind so far reached, excepting in the Iron Mountain region. Two Polaris observations were made on elongation.

STATION 107 — *In Osage Co.* Lat. 38° 28′; lon. 91° 41′. On the land of Fritz Kaldeweiher, near the centre of the S.E. qr. of the S.W. qr. of sec. 9, tp. 43, r. 7 W. The station was 50 ft. N. and 33 ft. W. of the N.W. corner of Kaldeweiher's house. Polaris obs. on elongation.

STATION 108 — *Linn, Osage Co.* Lat. 38° 28′; lon. 91° 50′. Station on L'Ours creek* on the Jefferson city road, about half a mile from town. The S.E. corner of James N. Clark's yard is 72 ft. W. and 68 ft. S. of the station. Polaris obs. on elongation.

STATION 109 — *In Callaway Co.* Lat. 38° 43′; lon. 92° 01′. On Little Auxvasse creek at the crossing of the New Bloomfield and Fulton road, about 40 rods S.W. of the N.E. corner of sec. 28, tp. 46, r. 10 W. A spring across the creek and just at the ford lies N. 65° E. 165 ft. Polaris obs. on elongation.

STATION 110 — *Near Stephens' Store, Boone Co.* Lat. 38° 58′; lon. 92° 05′. About one half mile S. of the village. The old Fulton road is 12 ft. W. and the bank of Cedar creek is 105 ft. N. Polaris obs. on elongation.

STATION 111 — *Centralia, Boone Co.* Lat. 39° 13′; lon. 92° 05′. The station was on a vacant lot 48 ft. W. of the centre of the street leading directly S. to the depot and crossing of the Chicago & Alton R.R., which is about a square and a half distant. The centre of the street to the N. is distant 77 ft. and leads E. to a flouring mill, the smokestack of which bears S. 90° 44′.1 E. Polaris obs. on elongation.

STATION 112 — *In Monroe Co.* Lat. 39° 24′; lon. 92° 10′. On the S. bank of the Long Branch of Salt river. The station was 150 ft. from the creek and midway between the road and the W. fence. The station is on the W. line of sec. 20, tp. 53, r. 11 W., and about 120 yds. from the middle of this line. Polaris obs. on elongation. — Some years since the county surveyor of Audrain Co. called my attention to this region as showing

* Named after the first (French) settler on its banks. A postoffice near the stream was afterwards named "Loose Creek" P. O. by some poor speller, and this official name has since been applied to the stream, which appears on some maps as "Loose Creek."

marked local effects. The region is level prairie, and long N. and S. lines run by compass are greatly and uniformly curved, showing an abnormally great easterly declination. This station and station No. 144, about 12 miles E., show an area of abnormal easterly declination. The disturbed region extends over an area of many miles.

STATION 113—*Moberly, Randolph Co.* Lat. 39° 26′; lon. 92° 26′. On the fair grounds 184 ft. E. and 289 ft. S. of the W. entrance. Polaris obs. on elongation.

STATION 114—*Macon, Macon Co.* Lat. 39° 46′; lon. 92° 30′. In the stock-yard of O. S. Bearce. directly in front of his barn and 20 ft. from the Vine-st. fence. The city school-house is one square W. and one square N. Polaris obs. on elongation.

STATION 115—*In Macon Co.* Lat. 39° 48′; lon. 92° 37′ On the farm of Isaiah Lewis. which is the N. half of N.E. qr. of sec. 21, tp. 58, r. 15 W. The station was in front of the house, and midway between the road and the yard fence. Polaris obs. on elongation.

STATION 116—*Near Mercyville, Macon Co.* Lat. 39° 57′; lon. 92° 42′. About half a mile N. of town. A corner-stone in the road, a quarter of a mile S. of the middle point of the N. line of sec. 35, tp. 60, r. 16 W., bears S. 3° 23′ W. 589 ft. Polaris obs. on elongation.

STATION 117—*In Linn Co.* Lat. 39° 54′; lon. 93° 07′. In the bottom of the west branch of Yellow creek. The station is within a few feet of the corner, a quarter of a mile due E. of the middle point of the E. line of sec. 22, tp. 59, r. 19 W. A large white-oak tree stands 20 ft. W., and the east end of the bridge is 261 ft. distant. The mark used was an iron rod on the bridge, 11 ft. west of the centre of the bridge. Polaris obs. on elongation.

STATION 118—*Linnæus, Linn Co.* Lat. 39° 51′; lon. 93° 13′. On a vacant lot on the summit of the hill E. of the Burlington & South-western R.R. depot. The S. line of the yard of Chas. B. Purdin lies 166 ft. N., the N. line of the farm of Joel Wilkinson lies 166 ft. S., while the field to the E. across the road is 237 ft. distant. The court-house spire was used as a mark. Two polaris observations on elongation.

STATION 119—*Near Laclede, Linn Co.* Lat. 39° 47′; lon. 93° 17′. Station one mile W. of town, on the E. side of Muddy creek; about 350 ft. E. of the bridge and 20 ft. N. of the road centre. The station is said to be on the S E. qr. of sec. 36, tp. 58, r. 21 W. Polaris obs. on elongation.

STATION 120—*In Livingston Co.* Lat. 39° 38′; lon. 93° 45′. On the farm of Wm. E. Wolfort, in the N.E. qr. of the S.E. qr. of sec. 33. tp. 56, r. 25 W. The station was in the cattle-yard 25 ft. from the road fence to the east (the road being on the section line), and 40 ft. N. of the door-yard fence. The middle line of the section is in the E. and W. road perhaps, 100 ft. N. Polaris obs. on elongation.

STATION 121—*Kingston, Caldwell Co.* Lat. 39° 41′; lon. 94° 04′. The station will be found by going from the S.W. corner of the court-house square W. 1646 ft., and S. from the middle of the road 62 ft. It lies 91 ft. E. of the summit of the small ridge. Polaris obs. on elongation.

STATION 122 — *In Caldwell Co.* Lat. 39° 39′; lon. 94° 11′. On land of Christian Smitt, 50 ft. W. and 212 ft. N. of the middle of sec. 29, tp. 56, r. 29 W. Polaris obs on elongation.

STATION 123—*Maysville, DeKalb Co.* Lat. 39° 43′; lon. 94° 24′. On the grounds of the public school building, 65 ft. W. and 21 ft. N. of the N.W. corner of the building. Polaris obs. on elongation.

STATION 124 — *In DeKalb Co.* Lat. 40° 01′; lon. 94° 23′. On land of Harvey Johnson, 50 ft. S. and 206 ft. E. of the middle of the N. line of sec. 14, tp. 60, r. 31 W. Polaris obs. on elongation.

STATION 125 — *Albany, Gentry Co.* Lat. 40° 15′; lon. 94° 21′. The station is 979 ft. E. of the N.E. corner of the court-house square and 8 ft. S., these measurements being along the streets. The station is 11 ft. W. and 8 ft. S. of the N.E. corner of lot 2, block 5, of Hundley's second addition. Polaris obs. on elongation.

STATION 126 — *In Gentry Co.* Lat. 40° 16′; lon. 94° 17′. The fence E. on the E. edge of sec. 15, tp. 63, r. 30 W., is 107 ft. distant. The fence S , which is the S. line of the N. half of the N.E. qr. of the section, is 193 ft. distant. There appears to be a double corner here. The evening-mark reading was missed, but the station was on raw prairie and the instrument was certainly not disturbed between the star observation and the morning mark reading. Polaris was observed on elongation.

STATION 127—*Bethany, Harrison Co.* Lat. 40° 16′; lon. 94° 03′. On a vacant lot of Mrs. R. J. Turner, 365 ft. E. of the N.E. corner of her house. The station is about 320 ft. S. of the N. line and 346 ft. W. of the E. line of sec. 15, tp. 63, r. 28 W. The line fence of T. B. Shearer's yard is 101 ft. E. Polaris obs. on elongation.

STATION 128 — *Farm of John Honan, in Harrison Co.* Lat. 40° 08′; lon. 93° 56′. The station was in the meadow, 133 ft. S. and 289 ft. W. of the N.E. corner of sec. 36, tp. 62, r. 27 W. Meridian determined by equal altitudes of the sun. Small cumulus clouds cut off five observations out of a series of seven. The two differed 1′.

STATION 129—*In Daviess Co.* Lat. 40° 04′; lon. 93° 53′. The station was in the road about midway between the track and the S. fence, and 334 ft. E. of the N.W. corner of the S. half of the S.W. qr. of sec. 28, tp. 61, r. 26 W. By reason of a very heavy rain which came up while the camp was being made it was impossible to get an evening-mark reading. The rain lasted until 9:15 P.M., and then a small patch of sky cleared around polaris for about half an hour, and a pole-star observation was made.

When the star-observation was made the whole hillside was covered with a sheet of water three to four inches inches in depth, which filled the trenches around the tent and ran through the tent in a torrent. The ground was however firm, and the tripod was as usual mounted firmly on large stakes driven eight to ten inches into the ground. The observation was therefore deemed entirely satisfactory. At the next station on the next night an observation was made the same interval before elongation, and the difference between the azimuth of the star and that of elongation agreed within a quarter of a minute with that at Station 129.

STATION 130—*Trenton, Grundy Co.* Lat. 40° 03′; lon. 93° 39′. Station in a grove of Dr. Harris, in the east part of town. The station is found by starting at the front (S.) fence of the door-yard and measuring S. along the centre of the road 112 ft., thence E. 415 ft. Polaris obs. on elongation.

STATION 131—*In Grundy Co.* Lat. 40° 13′; lon. 93° 38′. Station in the road about midway between the track and the E. fence, and 150 ft. S.W. from the front gate of the farm of Faust Amick. The station is near the S.E. corner of the N.E. qr. of N.E. qr. of sec. 34, tp. 63, r. 24 W. Polaris was observed before elongation, and its azimuth calculated as before described.

STATION 132—*Princeton, Mercer Co.* Lat. 40° 24′; lon. 93° 39′. The station is at the base of the bluff, 395 ft. W. of the W. side of Lincoln st. and 563 ft. N. of the centre of Hickland st. Polaris observations were made at 9 and 12h. 30m.

STATION 133—*In Putnam Co.* Lat. 40° 27′; lon. 93° 21′. On land of Joseph Williams, about a quarter of a mile W. of the centre of sec. 7, tp. 65, r. 21 W. The station was about 20 ft. N. of the centre of the road, and 250 ft. E. of the front gate of the house of Crede Yocum. Polaris obs. on elongation.

STATION 134—*In Putnam Co.* Lat. 40° 27′; lon. 93° 21′. Station in a lane near the house of Joseph Ward, in sec. 12, tp. 65, r. 20 W. The middle stone of the S. line of the section is 189 ft. S. of the station. Polaris observed at 11 o'clock P.M.

STATION 135—*Unionville, Putnam Co.* Lat. 40° 29′; lon. 93° 03′. The station is on an open square 562 ft. N.W. of the W. corner of the court-house square and 150 ft. N.W. of the same. These measurements are made along the streets which lie diagonally in reference to the points of the compass. The sky was again cloudy at elongation, and polaris was observed at 9 h. 11 m. and 10 h. 46 m.

STATION 136—*In Sullivan Co.* Lat. 40° 19′; lon. 93° 07′. On the farm of Nathan Bankes, on the N.E. qr. of the S.E. qr. of sec. 28, tp. 64, r. 19 W. The station is in the meadow 26 ft. S. of the S.W. corner of Bankes' house and 249 ft. W. of the middle of the road. Polaris obs. on elongation.

STATION 137—*Milan, Sullivan Co.* Lat. 40° 12′; lon. 93° 11′. On the common, 160 ft. S. of the S.W. corner of the public school building. Polaris obs. on elongation.

STATION 138—*Sticklerville, Sullivan Co.* Lat. 40° 09′; lon. 92° 58′. Near the S.W. corner of the N.W. qr. of sec. 22, tp. 62, r. 18 W. The N. W. corner of the church bears S. 31° 15′ W., and is distant 731 ft. The same corner of the church is 137 ft. S.E. of the qr. sec. corner before mentioned. Polaris obs. not at elongation.

STATION 139—*Kirksville, Adair Co.* Lat. 40° 12′; lon. 92° 37′. In a vacant lot, owned by Dr. Hurley, on the S.W. corner of Fifth and Fillmore sts., 76 ft. from the centre of the latter and 83 ft. from the centre of the former street. The left side of the tower of the State Normal school building bears S. 69° 02′.5 E. Polaris obs. on elongation.

STATION 140—*La Plata, Macon Co.* Lat. 40° 00′; lon. 92° 34′. Station in the street about midway between the track and the N. fence. The middle, E. and W. line of sec. 7, tp. 60, r. 14 W., is 486 ft. N., and the E. line of the section is 637 ft. E. These distances were measured along the streets. The house of B. F. Bragg is on the S. side of the street, a little E. of the station. Polaris obs. on elongation.

STATION 141—*In Macon Co.* Lat. 39° 53′; lon. 92° 22′. Station on Bear creek bottom, 304 ft. N. and 832 ft. E. of the middle of the S line of sec. 23, tp. 59, r. 13 W., near Harris's farm. Some error was made in reading the verniers in the star observation. It is conjectured that the altitude was read too high by 10′. This conjecture is baesd on observations at the next station. made at elongation and an equal interval after elongation, allowance being made for the change in latitude.

In the magnetic determination on the morning of the 12th marked disturbances of the needle were observed. The declination diminished 9′ between 6 and 7 o'clock.

STATION 142—*In Shelby Co.*, 3 miles S. of Shelbyville. Lat. 39° 44′; lon. 92° 04′. The middle stone on the N. line of sec. 5, tp. 57, r. 10 W., bears N. 4°, 50′ E., and is distant 910 ft. Polaris obs. on elongation.

STATION 143—*In Monroe Co.*, on the farm of Henry Winkler, 40 ft. E. of the centre of the road, and 669 ft. N. of the S. line of sec. 35, tp. 56, r. 10 W. The road, which runs N. and S., divides the S.W. qr. of the section in halves. Polaris obs. on elongation.

STATION 144—*In Monroe Co.* Lat. 39° 22′; lon. 91° 59′. On the summit of the S. bluff of Long Branch of Salt river, W. of the road, on land of B. F. Dowell. The land is in sec. 30, tp. 53, r. 9 W. The station was about 75 ft. W. of the road, which is on the E. line of the section. The Baptist church across the road is about 50 ft. farther S. than the station. These measurements were forgotten, and the distances were estimated the same day after having left the locality. Polaris observation on elongation.

STATION 145—*Montgomery City.* Lat. 39° 00′; lon. 91° 30′. The station is 105 ft. W. of the middle (N. and S.) line of the S.E. qr. of sec. 32, tp. 49, r. 5 W., and a perpendicular laid off to the track of the Wabash-

Pacific R.R. track measures 200 ft. Passing freight trains caused the needle to swing through 2′. Polaris obs. on elongation.

STATION 146—*Warrenton, Warren Co.* Lat. 38° 46′; lon. 91° 08′. The station is at the W. end of town, about a mile from the station of 1881. Starting at the creek bridge W. of the court-house, the station will be found by going along the road westwardly 705 ft., thence southwardly at right angles to the road a distance of 45 ft. The court-house spire bears S. 79° $14._8$′ E. Polaris obs. on elongation.

STATION 147—*In St. Charles Co.* Lat. 38° 43′; lon. 90° 40′. The station is in the Booneslick road about midway between the track and the S. fence, and almost due south of O'Fallon.* The O'Fallon road is 250 ft. E. The house of D. Heald lies a few rods to the W. Polaris observation on elongation.

STATION 148—*In St. Louis Co.* Lat. 38° 41′; lon. 90° 21′. On the St. Charles rock road. The station was in a gap in the fence opposite the grounds of J. B. Lucas. From the station to the centre of the road the distance is 30 ft. From thence along the road to a point opposite the gate is 165 ft., while the distance in the opposite direction to a point opposite the S.E. corner of the Lucas grounds is 158 ft. Polaris observation on elongation.

STATION 149—*Near Atalissa, Muscatine Co., Iowa*, on the farm of Mrs. Grace Aikins, on the N.E. qr. of the N.W. qr. of sec. 3, tp. 78, r. 3 W. The station is on the front path, exactly between the front gate and the house. This station is a mile west of station 33 in the report of 1880.† Polaris obs.

STATION 34—This station was occupied in 1880, and is described in the report for that year. Polaris obs. on elongation.

At six of the stations of the summer deflection determinations were made with the University magnetometer, with magnet C_6 deflecting and C_{17} deflected, and these observations have been used in determining the value of P, and in calculating the magnetic moment of C_6 for the summer. The latter was sensibly constant, the observed difference between the extreme value observed and the mean of all being about $0._{0005}$ of the average moment. In the reduction of the work the magnetic moment was therefore assumed to be constant. The calculations for P and for the magnetic moment are given in the adjoining tables.

* In the report for 1880 the lon. of O'Fallon should be 99° 40′.

† Station 33 is on the N.E. qr. of the N.W. qr. of sec. 2, and not N.E. qr. of N.E. qr. as was given in the report of 1880.

Determination of *P* for the Summer of 1882.

Station.	Date.	LOGARITHMS. $r^3 \tan u$.	$r'^3 \tan u'$.	$r \tan u$.	$r' \tan u'$.	A.	B.	$\frac{A}{B}$	P.
Kirkwood......	June 17	9.49088	9.48780	8.88882	9.00183	7.34242 *p*	8.36211 *n*	8.98031 *n*	— 0.0956
Goebel's.......	" 21	9.48396	9.48699	8.88190	9.00092	7.33041 *n*	8.38057 *n*	8.94984 *p*	+ 0.0891
Centralia......	July 5	9.49880	9.49785	8.89674	9.01178	6.83885 *p*	8.37858 *n*	8.46027 *n*	— 0.0289
Linneus.......	" 14	9.51036	9.51033	8.90830	9.02426	5.47712 *p*	8.39393 *n*	7.08319 *n*	— 0.0012
Kingston......	" 22	9.50580	9.50984	8.90374	9.02377	7.47422 *n*	8.40671 *n*	9.06751 *p*	+ 0.1168
Trenton.......	Aug. 1	9.51217	9.51383	8.91011	9.02776	7.09342 *n*	8.40312 *n*	9.69030 *p*	+ 0.0490
								Mean........	+ 0.0215

Magnetic Moment of C_6 for Summer of 1882.

Station.	Date.	t.	$t-80._7$	$\log 1+(t-80.7)q$.	$\log m_t$.	$\log m$.	Days.	d.	$y = \log m_0 - \log m$	yd.	d^2.
Kirkwood.....	June 17	86.5	+ 6.5	0.00121	9.86290	9.86411	0	—26	+ 0.00004	—0.00104	676
Goebel's.......	" 21	90.8	+10.1	0.00211	9.86165	9.86376	4	—22	+ 0.00039	—0.00858	484
Centralia......	July 5	77.1	— 3.6	9.99924	9.86447	9.86371	18	— 8	+ 0.00044	—0.00352	64
Linneus.......	" 14	76.5	— 4.2	9.99912	9.86568	9.86480	27	+ 1	— 0.00065	—0.00065	1
"	" 15	70.0	—10.7	9.99776	9.86565	9.86341	28	+ 2	+ 0.00074	+0.00148	4
Kingston......	" 22	82.5	+ 1.8	0.00037	9.86476	9.86513	35	+ 9	— 0.00098	—0.00882	81
Trenton.......	Aug. 1	81.0	+ 0.3	0.00003	9.86440	9.86446	45	+19	— 0.00031	—0.00589	361
"	" 1	81.4	+ 0.7	0.00014	9.86370	9.86384	45	+19	+ 0.00031	+0.00589	361
	Means	80.7			$\log m_0 =$	9.86415	26		Sums	—0.02113	2032

The value of P, as determined in the first of the tables, gives for the value of $1 - \frac{P}{r^2}$ the values

$$1 - \frac{P}{2^2} = 0.9946 \qquad \log = 9.99765$$

$$1 - \frac{P}{(1.75)^2} = 0.9930 \qquad \log = 9.99695$$

These values were used in the reduction of the deflection series made for the determination of the magnetic moment of magnet C_6.

In the second table, the decrease (a) in the value of log m is determined, and it is found that for the summer of 1882, and at a temperature of 80.7, the value of (a) is

$$a = \frac{-0.02113}{2032} = -0.000,009,$$

or
$$\log m = 9.86415 + 0.000,009\, d,$$

where d is estimated in days from July 13. The value of log m was therefore considered constant during the summer.

In all of the intensity determinations the time of vibration was determined by means of a Waltham watch belonging to Mr. Ringling. This watch had been cleaned just before leaving St. Louis, but it had not been rated. The error of the watch was determined, at intervals during the summer, by comparison with clock-beats from the observatory of Washington University, transmitted daily to the telegraph lines of various railways in the State. Its rate during the summer was a loss of 20 seconds per day, fluctuating however between 17 and 22 seconds. The correction on the time of vibration was + 0.0016 second at all the stations, the time of vibration at the stations not varying sufficiently to change the value of this correction. The effect of neglecting this correction altogether would be equivalent to the effect of an error of half a degree in temperature.

The intensity determinations were all made with magnet C_6 in the University declinometer, C_{17} being used as a deflected magnet. The moment of inertia of C_6 was obtained from the table given in the 4th report.* The values for H are not corrected for

* Trans. vol. iv. No. 3, p. 468.

the effect of magnetic brass-work of the magnetometer. This correction is given in the 4th report, p. 472.

The observations for inclination were not very satisfactory, as the axes of the needles were both bent during the early part of the summer.

The following observations for meridian, by equal altitudes of the sun, were made. The method of reduction has been explained in previous reports.

Sun Observations for Meridian.

Station.	Date.	No. of Obs.	Mean Time of Series. A. M.	Mean Time of Series. P. M.	t.	½ $(A+A')$.
			h. m. s.	*h. m. s.*	*deg. m.*	*deg. m.*
Little Auxvasse Cr.	June 30	5	9 36 58	2 32 40	37 03.7	244 56.7
Honan's	July 30	2	9 38 25	2 23 18	35 42.5	176 38.5

log Δ d''.	a. c. log cos φ.	a.c. log sin t	Cor.	South reads	Mark reads	Az. of Mark.
1.67112	0.10777	0.21992	+ 0′.8	244° 57′.5	180° 02′.0	S. 64° 55.5 E.
2.23805	0.11660	0.23384	+ 3.2	176 41 .7	180 01 .2	S. 3 19.5 W.

Polaris Observations for Meridian.

Station.	Lat. φ.	Alt. h.*	Polar D. p.	½ Sum = S.
Daviess Co., Sta. 129.	40° 04′	39° 42′.5	1° 19′.3	40° 32′.9
Amick's	40 13	39 34 .0	"	40 33 .1
"	"	39 46 .0	"	40 39 .2
Princeton	40 24	39 58 .0	"	40 50 .6
"	"	40 05 .0	"	40 54 .2
Ward's	40 27	40 48 .0	"	41 17 .2
Unionville	40 29	40 12 .5	"	41 00 .4
"	"	40 45 .5	"	41 16 .9
Sticklerville	40 09	39 37 .0	"	40 32 .7
"	"	39 46 .5	"	40 37 .4
Harris's	39 53	40 25 .0†	"	40 48 .6

* The altitudes are all corrected for refraction.

† This altitude was recorded 40° 36′.0. It should have been 40° 26′, as was determined at the next station (Shelbyville) by an observation made the same time interval after elongation.

Reduction Polaris Observations.

Station.	a. c. cos. S.	a. c. cos. $(S-p)$.	sin $(S-h)$.	sin $(S-\varphi)$.	$\tan^2 \frac{1}{2} A$.	A.	Polaris reads.	North reads.	Mark reads.	Azimuth of Mark.
Daviess Co. (St. 29)	0.11932	0.11094	8.16181	7.93231	16.32438	1°39′.8	180°00′.7	178°20′.9	None used	....
Amick's	0.11929	0.11091	8.23529	7.76687	16.23236	1 29 .8	329 55 .5	328 25 .7	180°00′.7	S. 31°35′.0 W.
"	0.11995	0.11155	8.18962	7.88202	16.30314	1 37 .4	330 03 .0	328 25 .6	180 00 .7	S. 31 35 .1 W.
Princeton	0.12119	0.11273	8.18470	7.88861	16.30723	1 37 .9	309 41 .0	308 03 .1	180 01 .7	S. 51 58 .6 W.
"	0.12158	0.11310	8.15567	7.94372	16.33407	1 41 .0	309 44 .0	308 03 .0	180 01 .7	S. 51 58 .7 W.
Ward's	0.12412	0.11552	7.92910	8.16441	16.33315	1 40 .9	309 53 .7	358 12 .8	None used	....
Unionville........	0.12226	0.11375	8.14405	7.96065	16.34071	1 41 .6	251 53 .2	250 11 .6	180 00 .7	S. 109 49 .1 W.
"	0.12418	0.11549	7.96065	8.14405	16.34437	1 42 .2	251 55 .7	250.13 .5	180 00 .7	S. 109 47 .2 W.
Sticklerville	0.11975	0.11087	8.17043	7.91704	16.31858	1 39 .1	329 41 .5	328 02 .4	180 00 .5	S 31 58 .1 W.
"	0.11925	0.11136	8.20956	7.83848	16.27806	1 34 .6	329 36 .5	328 01 .9	180 00 .5	S. 31 58 .6 W.
Harris's	0.12097	0.11256	7.83664	8.20878	16.27895	1 34 .8	312 11 .2	310 36 .4	180 01 .0	S. 49 24 .6 W.

Polaris Observations on Elongation for Meridian.

Station.	Azim. Circle. Vernier A. Mark reads	Azim. Circle. Vernier A. Polaris reads	Azimuth of Elongation	North reads	Azimuth of Mark S.	Remarks.
Kirkwood	359°.59′.8	328°51′.0	1°41′.2	327°09′.8	147°10′.0 E.	
Gray's Summit	180 00 .7	92 57 .0	1 41 .2	91 16 .6	91 15 .9 E.	
Newport	180 01 .2	210 40 .0	1 41 .2	208 58 .8	151 02 .4 W.	
Goebel's	180 00 .7	97 08 .0	1 40 .9	95 27 .1	95 26 .4 E.	
Ruck's	180 01 .0	4 34 .5	1 41 .7	2 52 .8	2 52 .5 E.	
Bruns'	180 01 .0	357 27 .7	1 41 .2	355 46 .5	4 14 .5 W.	
"	180 01 .2	357 28 .5	1 41 .2	355 47 .3	4 14 .9 W.	No morning mark reading.
Kaldeweiher's	180 01 .7	133 56 .5	1 41 .2	132 15 .3	132 13 .8 E.	
Linn	180 00 .7	52 13 .0	1 41 .2	50 31 .8	50 31 .1 E.	
Little Auxvasse Creek	180 00 .7	66 40 .3	1 41 .7	64 58 .6	64 57 .9 E.	
Stephen's Store	180 01 .5	158 07 .5	1 42 .0	156 25 .5	156 24 .0 E.	
Centralia	180 00 .7	92 27 .2	1 42 .4	90 44 .8	90 44 .1 E.	
Long Branch	180 00 .7	177 10 .5	1 43 .0	175 27 .5	175 26 .8 E.	
Moberly	180 00 .7	237 08 .7	1 43 .0	235 25 .7	124 35 .0 W.	No morning mark reading.
Macon	180 01 .2	319 48 .7	1 43 .1	318 05 .6	41 55 .6 W.	
Lewis'	180 01 .2	294 58 .0	1 43 .1	293 14 .9	66 46 .3 W.	
Mercyville	180 00 .7	349 49 .7	1 43 .5	348 06 .2	11 54 .5 E.	
Yellow Creek	180 00 .7	302 19 .2	1 43 .4	300 35 .8	59 24 .9 E.	
Linneus	180 01 .2	242 11 .5	1 43 .3	240 28 .2	119 33 .0 W.	
"	180 00 .7	242 11 .5	1 43 .3	240 28 .2	119 32 .5 W.	
Laclede	180 01 .0	62 02 .5	1 43 .1	60 19 .4	60 18 .4 E.	
Wolford's	180 00 .7	270 40 .0	1 42 .9	268 57 .1	91 03 .6 W.	
Kingston	180 00 .7	98 17 .7	1 43 .0	96 34 .7	96 34 .0 E.	
Smitt's	180 00 .7	66 45 .5	1 42 .9	65 02 .6	65 01 .9 E.	

Maysville	180 00 .7	200 07 .0	1 43 .0	198 24 .0	61 36 .7 W.	
Johnson's	180 00 .7	44 58 .5	1 43 .5	43 15 .0	43 14 .8 E.	
Albany	180 00 .7	187 45 .5	1 43 .4	186 02 .1	173 58 .6 W.	
Near Albany	13 54 .0	101 30 .7	1 43 .4	99 47 .3	94 06 .7 W.	No evening mark reading.
Trenton	180 00 .5	156 11 .6	1 43 .5	154 28 .0	154 27 .5 E.	
Williams'	....	179 57 .0	1 44 .4	178 12 .6	....	No mark used.
Bankes'	180 00 .5	114 38 .5	1 44 .0	112 54 .5	112 54 .[illegible] E.	No morning mark reading.
Milan	180 00 .5	166 05 .2	1 43 .8	164 21 .4	164 20 .9 E.	
Sticklerville	180 00 .5	329 47 .0	1 43 .9	328 03 .1	31 57 .4 W.	See previous table.
Kirksville	180 01 .2	70 47 .5	1 43 .8	69 03 .7	69 02 .5 E.	
La Plata	180 01 .0	91 07 .0	1 43 .5	89 23 .5	89 22 .5 E.	
Shelbyville	....	179 49 .7	1 43 .1	178 06 .6	....	No mark used.
Winkler's	....	180 03 .7	1 42 .8	178 20 .9	....	" " "
Long Branch*	180 01 .0	94 22 .3	1 42 .4	92 39 .9	92 38 .9 E.	
Montgomery City	180 00 .7	245 53 .2	1 42 .0	244 11 .2	115 49 .5 W.	
Warrenton	180 00 .5	80 57 .0	1 41 .7	79 15 .3	79 14 .8 E.	
Heald's	....	180 00 .7	1 41 .7	178 19 .0	....	No mark used.
Lucas'	165 54 .2	180 00 .7	1 41 .7	178 19 .0	167 35 .2 W.	No evening mark reading.
G. Aikins'	180 00 .5	69 53 .5	1 46 .0	68 07 .5	68 07 .0 E.	No morning " "
E. Aikins'	180 01 .0	1 27 .5	1 46 .0	359 41 .5	0 19 .0 W.	

* Near Long Branch Post-office and about 12 miles east of station 112.

Magnetic Declination or "Variation."

STATIONS.	MAGNET SCALE.					AZIMUTH CIRCLE.				DECLINATION.		Date.
	Elongations.		Mean.	Axis reads.	Reduction to Axis.	Circle reads	Magnetic South reads	Mark reads	True South reads	Uncorrected.	Corrected.	
	East.	West.										
Kirkwood	82d 5	76d 25	79d ·37	78d ·24	+2′·2	153°29′·7	153°31′·9	359 59′·8	147°09′·8	6°22′·1	6°24′·1	Jun. 17
Gray's Summit ..	80·0	*	76 ·3	78 ·2	—3 ·6	278 13 ·0	278 09 ·4	180 01 ·0	271 16 ·9	6 52 ·5	6 54 ·5	" 19
Newport	80·3	74·1	77 ·2	[78 ·2]	—1 ·9	35 58 ·5	35 56 ·6	180 02 ·0	28 59 ·6	6 57 ·0	6 59 ·0	" 20
Goebel's	80·2	75·5	77 ·8	78 ·2	—0 ·8	283 04 ·0	283 03 ·2	180 00 ·5	275 26 ·9	7 36 ·3	7 38 ·3	" 22
Ruck's	81·9	*	78 ·2	[78 ·2]	0 ·0	190 42 ·8	190 42 ·8	180 01 ·2	182 53 ·7	7 49 ·1	7 51 ·1	" 24
Bruns'	80·8	74·9	77 ·8	[78 ·2]	—0 ·8	182 37 ·8	182 37 ·0	180 01 ·2	175 46 ·6	6 50 ·4	6 52 ·4	" 25
Kaldeweiher's	80·0	*	76 ·3	[78 ·2]	—3 ·6	320 01 ·2	319 57 ·6	180 01 ·5	312 15 ·3	7 42 ·3	7 44 ·3	" 27
Linn	81·5	*	77 ·8	[78 ·2]	—0 ·8	238 07 ·5	238 06 ·7	180 00 ·7	230 31 ·8	7 34 ·9	7 36 ·9	" 28
Little Auxvasse ...	81·4	75·9	78 ·7	77 ·9	+1 ·5	252 51 ·0	252 52 ·5	180 01 ·2	244 59 ·1	7 53 ·4	7 55 ·4	" 30
Stephen's Store ...	81·6	74·4	78 ·0	[77 ·9]	+0 ·2	344 00 ·7	344 00 ·9	180 02 ·2	336 26 ·2	7 34 ·7	7 36 ·7	July 3
Centralia	82·5	74·5	78 ·5	[77 ·9]	+1 ·1	278 38 ·8	278 39 ·9	180 00 ·7	270 44 ·8	7 55 ·1	7 57 ·1	" 5
Long Branch	82·6	*	78 ·9	[77 ·9]	+1 ·9	363 31 ·0	363 32 ·9	180 01 ·6	355 28 ·4	8 04 ·5	8 06 ·5	" 6
Moberly	83·2	77·55	80 ·4	[77 ·9]	+4 ·8	62 58 ·5	63 03 ·3	180 00 ·7	55 25 ·7	7 37 ·6	7 39 ·6	" 7
Macon	81·0	*	77 ·3	[77 ·9]	—1 ·1	146 04 ·2	146 03 ·1	180 01 ·7	138 06 ·1	7 57 ·0	7 59 ·0	" 9
Lewis'	81·0	*	77 ·3	[77 ·9]	—1 ·1	121 13 ·5	121 12 ·4	182 02 ·0	113 15 ·7	7 56 ·7	7 58 ·7	" 10
Mercyville	81·2	75·3	78 ·3	[77 ·9]	+0 ·8	176 19 ·7	176 20 ·5	180 00 ·0	168 05 ·5	8 15 ·0	8 17 ·0	" 11
Yellow Creek	80·5	*	76 ·8	[77 ·9]	—2 ·1	128 54 ·5	128 52 ·4	180 03 ·2	120 38 ·3	8 14 ·1	8 16 ·1	" 13
Linneus	81·2	75·7	78 ·5	78 ·1	+0 ·6	68 22 ·2	68 22 ·8	180 01 ·2	60 28 2	7 54 ·6	7 56 ·6	" 14
"	80·3	73·3	76 ·8	[78 ·1]	—2 ·5	68 24 ·7	68 22 ·2	180 01 ·5	60 29 ·0	7 53 ·2	7 55 ·2	" 15
Laclede	80·1	*	76 ·4	[78 ·1]	—3 ·2	248 31 ·0	248 27 ·8	180 00 ·7	240 19 ·1	8 08 ·7	8 10 ·7	" 17
Wolford's	81·2	74·4	77 ·8	[78 ·1]	—0 ·6	97 35 ·7	97 35 ·1	180 00 ·7	88 57 ·1	8 38 ·0	8 40 ·0	" 20
Kingston	81·2	73·0	77 ·1	[78 ·1]	—1 ·9	285 46 ·7	285 44 ·8	180 00 ·7	276 34 ·7	9 10 ·1	9 12 ·1	" 22

Smitt's	79.9	*	76.2	77 .9	—3 .2	254 40 .7	254 37 .5	180 00 .7	245 02 .6	9 34 .9	9 36 .9	July 23
Maysville	81.0	7.60	78.5	[77 .9]	+1 .1	27 39 .0	27 40 .0	180 00 .7	18 24 .0	9 16 .0	9 18 .0	" 24
Johnson's	81.6	*	77.9	[77 .9]	0 .0	232 47 .5	232 47 .5	180 01 .5	223 16 .3	9 31 .2	9 33 .2	" 25
Albany	80.9	74.7	77.8	[77 .9]	—0 .2	14 26 .5	14 26 .3	180 00 .9	6 02 .3	8 24 .0	8 26 .0	" 26
Near Albany	80.9	*	77.2	[77 .9]	—1 .4	288 20 .0	288 18 .6	13 54 .1	279 47 .4	8 31 .2	8 33 .2	" 27
Bethany	80.7	74.7	77.7	[77 .9]	—0 .4	255 52 .7	255 52 .3	179 59 .7	247 10 .8	8 41 .5	8 43 .5	" 28
Honan's	80.8	72.0	76.4	[77 .9]	—2 .8	185 30 .5	185 27 .7	180 01 .2	176 41 .7	8 46 .0	8 48 .0	" 30
Daviess Co., st. 129	81.2	*	77.5	[77 .9]	—0 .8	70 06 .0	7 05 .2	none used	358 20 .9	8 44 .3	8 46 .3	" 31
Trenton	81.0	76.0	78.5	[77 .9]	+1 .1	342 28 .7	342 29 .8	180 00 .4	334 29 .9	8 01 .9	8 03 .9	Aug. 1
Amick's	80.1	*	76.4	[77 .9]	—2 .9	156 50 .0	156 47 .1	180 00 .7	148 25 .7	8 21 .4	8 23 .4	" 2
Princeton	81.0	*	77.3	[77 .9]	—1 .1	136 52 .0	136 50 .9	180 02 .7	128 05 .5	8 45 .4	8 47 .4	" 3
Williams'	81.0	*	77.3	[77 .9]	—1 .1	6 50 .5	6 49 .4	none used	358 12 .6	8 36 .8	8 38 .8	" 4
Ward's	80.4	*	76.7	[77 .9]	—2 .3	186 42 .2	186 39 .9	"	178 12 .8	8 27 .1	8 29 .1	" 5
Unionville	*	75.2	78.9	77 .6	+2 .5	78 11 .2	78 13 .7	180 01 .0	70 11 .9	8 01 .8	8 03 .8	" 5
"	80.0	*	76.3	[77 .6]	—.2 .4	78 10 .0	78 07 .6	180 00 .9	70 11 .8	7 55 .8	7 57 .8	" 6
Bankes'	82.0	*	78.3	[77 .6	+1 .3	301 31 .5	301 32 .8	180 03 .0	292 57 .0	8 35 .8	8 37 .8	" 7
Milan	81.1	*	77.4	[77 .6]	—0 .4	352 38 .0	352 37 .6	179 59 .8	344 20 .7	8 15 .9	8 17 .9	" 8
Sticklerville	80.7	*	77.0	[77 .6]	—1 .1	156 53 .7	156 52 .6	180 00 .5	148 02 .6	8 50 .0	8 52 .0	" 9
Kirksville	80.1	*	76.4	[77 .6]	—2 .3	257 21 .0	257 18 .7	180 01 .7	249 04 .2	8 14 .5	8 16 .5	" 10
La Plata	80.5	*	76.8	[77 .6]	—1 .5	277 32 .7	277 31 .2	180 01 .5	269 24 .0	8 07 .2	8 09 .2	" 11
Harris'	82.0	*	78 3	[77 .6]	+1 .3	138 10 .5	138 11 .0	180 01 .5	130 36 .9	†7 34 .9	7 36 .9	" 12
Shelbyville	80.7	*	77.0	[77 .6]	—1 .1	5 52 .7	5 51 .6	none used	358 06 .6	7 45 .0	7 47 .0	" 13
Winkler's	81.8	*	78.1	[77 .6]	+0 .9	6 02 .5	6 03 .4	"	358 20 .9	7 42 .5	7 44 .5	" 14
Long Branch	81.5	*	77.8	[77 .6]	+0 .4	280 37 .5	280 37 .9	180 01 .2	272 40 .1	7 57 .8	7 59 .8	" 15
Montgomery City	82.4	*	78.7	[77 .6]	+2 1	71 14 .5	71 16 .6	180 01 .0	64 11 .5	7 05 .1	7 07 .1	" 17
Warrenton	81.5	*	77.8	[77 .6]	+0 .4	265 46 .7	265 47 .1	180 00 .5	259 15 .3	6 31 .8	6 33 .8	" 18
Heald's	81.7	*	78.0	[77 .6]	+0 .7	365 02 .7	365 03 .4	none used	358 19 .0	6 44 .4	6 46 .4	" 19
St. Charles	81.6	*	77.9	[77 .6)	+0 .6	364 24 .7	364 25 .3	....	358 19 .0	6 06 .3	6 08 .3	" 20
G. Aikins'	81.2	*	77.5	77 .8	—0 .6	255 28 .2	255 27 .6	180 00 .5	248 07 .5	7 20 .1	7 22 .1	" 26
"	*	75.0	78.7	[77 .8]	+1 .8	255 22 .7	255 24 .5	180 00 .7	248 07 .7	7 16 .8	7 18 .8	" 27
E. Aikins'	80.5	71.5	76.0	[77 .8]	—3 .5	187 31 .5	187 28 .0	180 00 .6	179 41 .6	7 46 .4	7 48 .4	" 29

* Only one elongation taken. See 4th report, Trans. vol. iv., No. 3, p. 454.

† See description of this station, No. 141.

Intensity — Oscillations.

STATION.	Date.	t'. Temp.	LOGARITHMS. T'^2.	$1+\frac{h}{f}$	$1-(t'-t)q$	T^2.	k.	mH.	H.	H.
Kirkwood	June 17	86°.5	1.67682	0.00034	9.99886	1.67602	1.22331	0.54159	0.67869	4.772
Goebel's	" 21	90 .8	1.67582	0.00046	9.99788	1.67416	1.22339	0.54353	0.68188	4.807
Linn	" 27	90 .6	1.67310	0.00034	9.99792	1.67136	1.22338	0.54632	0.68217	4.810
Auxvasse Creek	" 30	90 .0	1.67800	0.00032	9.99806	1.67638	1.22337	0.54129	0.67714	4.755
Stephen's Store	July 3	91 .2	1.67630	0.00032	9.99781	1.67443	1.22339	0.54326	0.67911	4.777
Centralia	" 5	77 .1	1.68216	0.00036	0.00075	1.68327	1.22315	0.53418	0.67003	4.678
Moberly	" 7	80 .0	1.68802	0.00036	0.00015	1.68853	1.22320	0.52897	0.66482	4.622
"	" 7	100 .2	1.69250	0.00028	9.99590	1.68860	1.22354	0.52916	0.66501	4.624
Mercyville	" 11	75 .5	1.68926	0.00037	0.00108	1.69071	1.22313	0.52672	0.66257	4.598
Linneus	" 14	76 .5	1.69238	0.00042	0.00087	1.69367	1.22314	0.52377	0.65962	4.567
"	" 15	70 .0	1.69130	0.00032	0.00225	1.69387	1.22303	0.52346	0.65931	4.564
Wolford's	" 20	78 .2	1.68910	0.00034	0.00051	1.68995	1.22317	0.52752	0.66337	4.607
Kingston	" 22	82 .5	1.69306	0.00046	9.99962	1.69314	1.22324	0.52440	0.66025	4.574
Maysville	" 24	86 .2	1.68948	0.00027	9.99886	1.68861	1.22330	0.52899	0.66484	4.622
Albany	" 26	83 .7	1.69680	0.00034	9.99937	1.69651	1.22326	0.52105	0.65690	4.537
Bethany	" 27	82 .1	1.69764	0.00036	9.99971	1.69771	1.22323	0.51982	0.65567	4.525
Trenton	Aug. 1	81 .0	1.69790	0.00028	9.99994	1.69812	1.22322	0.51940	0.65525	4.521
"	" 1	82 .7	1.69866	0.00028	9.99958	1.69852	1.22324	0.51902	0.65487	4.517
Princeton	" 2	76 .5	1.69774	0.00035	0.00087	1.69896	1.22314	0.51848	0.65433	4.512
Unionville	" 5	75 .6	1.70110	0.00032	0.00106	1.70248	1.22313	0.51495	0.65080	4.475
Milan	" 7	83 .0	1.69916	0.00025	9.99956	1.69897	1.22325	0.51858	0.65443	4.523

Intensity — Deflections.

Station.	Date.		t.	r ft.	Logarithms.			
					$u^{div.}$	$1 + \frac{h}{f}$	Corrected tan u.	m.
Kirkwood	June	17	89.6	2.00	1.66214	0.00080	8.58779	9.18750
"	"	17	86.3	1.75	1.83294	0.00074	8.75879	9 18382
Goebel's	"	21	90.1	2.00	1.65528	0.00075	8.58087	9.18058
"	"	21	90.0	1.75	1.83203	0.00075	8.75788	9.18291
Centralia	July	5	77.8	2.00	1.66992	0.00094	8.59571	9.19542
"	"	5	81.6	1.75	1.84267	0.00094	8.76874	9.19369
Linneus	"	14	75.2	2.00	1.68147	0.00094	8.60727	9.20698
"	"	14	74.8	1.75	1.85513	0.00094	8.78122	9.20625
Kingston	"	22	74.4	2.00	1.67710	0.00075	8.60271	9.20242
"	"	22	77.1	1.75	1.85506	0.00052	8.78073	9.20576
Trenton	Aug.	1	84.1	2.00	1.68352	0.00070	8.60908	9.20879
"	"	1	85.8	1.75	1.85878	0.00077	8.78472	9.20975

INCLINATION, OR DIP.

Needle No 2.

STATION.	Marked End.		Means by Polarities.		Resulting Dip.	Date.
	North.	South.	Series I.	Series II.		
Kirkwood*..	68°59′.9	66°44′.9	69°01′.1	66°48′.8	67°52′.4	June 17
Goebel's..................	68 53 .4	69 18 .1	68 58 .6	69 12 .8	69 05 .7	" 22
Linn	68 35 .0	68 58 .8	68 39 .0	68 54 .7	68 46 .9	" 27
Little Auxvasse Cr'k.	68 50 .6	69 19 .5	68 54 .5	69 15 .6	69 05 .0	" 30
Centralia............ .	69 26 .2	69 48 .2	69 44 .6	69 29 .6	69 37 .2	July 5
Moberly..................	65 25 .2	69 45 .4	69 30 .1	69 37 .8	69 35 .3	" 7
Mercyville	69 54 .4	70 07 .5	69 57 .0	70 04 .8	70 00 .9	" 11
Linneus	69 51 .4	70 10 .6	69 53 .0	70 08 .5	70 00 .7	" 15
Wolfort's*.......... ...	70 41 .2	71 07 .4	70 34 .9	71 13 .7	70 54 .3	" 20
Kingston................	70 04 .8	70 15 .4	70 05 .2	70 14 .8	70 10 .1	" 22
Maysville................	69 34 .4	69 51 .9	69 33 .8	69 52 .5	69 43 .2	" 24
Albany.......	70 04 ·6	70 25 .4	70 08 .8	70 21 .2	70 15 .0	" 26
Bethany..................	70 04 .9	70 29 .0	70 12 .0	70 21 .9	70 16 .9	" 27
Trenton	70 04 .8	70 24 .8	70 04 .4	70 25 .2	70 14 .8	Aug. 1
Princeton	70 13 .6	70 30 .0	70 16 .2	70 27 .4	70 21 .8	" 2
Unionville..............	70 23 .6	70 05 .4	70 20 .6	70 08 .4	70 14 .5	" 5
Milan	70 05 .8	70 27 .9	70 10 .2	70 23 .4	70 16 .8	" 8

* Some error.

Needle No. 3.

STATION.	Marked End.		Means by Polarities.		Resulting Dip.	Date.
	North.	South.	Series I.	Series II.		
Kirkwood................	69°34′.7	69°15′.7	70 39′.5	68°10′.9	69°25′.2	June 17
Goebel's..................	69 19 .1	68 48 .4	68 15 .8	69 51 .6	69 03 .7	" 22
Little Auxvasse Cr'k.	67 34 .8	68 43 .8	68 23 .5	69 55 .1	69 09 .3	" 30
Moberly..................	69 54 .8	69 18 .8	68 44 .3	70 29 .3	69 36 .8	July 7
Mercyville...............	70 24 .6	69 36 .4	69 04 .4	70 56 .6	70 00 .5	" 11
Linneus	70 21 .5	69 45 .2	69 08 .8	70 57 .8	70 03 .4	" 15
Maysville	70 03 .5	69 30 .5	69 33 .2	70 00 .8	69 47 .0	" 24
Bethany	70 52 .9	69 59 .8	70 27 .8	70 24 .9	70 26 .4	" 27
Trenton	70 35 .6	69 55 .9	70 07 .4	70 24 .2	70 15 .8	Aug. 1

On the Expression of Electrical Resistance in Terms of a Velocity.

By FRANCIS E. NIPHER.*

If a spherical shell of radius r be charged with Q units of electricity, the density of electrification being ρ, the force dF over any element ds of its surface will be $2\pi\rho^2 ds$. This force is directed radially outward, and is due to the action of the electrification Q on the quantity ρds upon the element.

If the radius r be diminished to r', the energy of the electrification will increase if Q remains constant, this increase in energy being due to work done on the sphere by some external source, causing the sphere to collapse. If the element ds sweeps through a distance dr, the stored energy will be

$$dE = dF\,dr \quad - \quad - \quad - \quad (1)$$

in which both dF and dr are essentially negative.

Substituting in (1) the above value of dF and remembering

that
$$\rho = \frac{Q}{4\pi r^2}$$

and
$$ds = r^2\,d\omega,$$

where $d\omega$ is the solid angle subtended by the element ds, we have

$$dE = \frac{Q^2}{8\pi}\frac{dr}{r^2}\,d\omega,$$

or
$$E' - E = \frac{Q^2}{8\pi}\iint \frac{dr}{r^2}\,d\omega,$$

where one integration is carried over the surface of the sphere, and the other is carried inwards between the limits r and r'. Performing the integrations, we have

$$E' - E = \frac{Q^2}{2}\left(\frac{1}{r'} - \frac{1}{r}\right) \quad - \quad - \quad (2)$$

But $\frac{1}{2}\frac{Q^2}{r'}$ is the energy of a sphere of radius r', charged with Q units of electricity, and hence the potential of the sphere on itself between the limits r and r' is equal to the difference in its initial and final energy.

If the sphere were connected with the ground by a wire of resistance (R), the radius (r) might be changed in such a manner

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as to preserve the potential (V) constant. In this case a current of constant intensity would flow through the wire, and as $V = \frac{Q}{r}$ it is clear that r must change at a uniform rate, or

$$\frac{r - r'}{v} = t' - t \qquad - \quad - \quad - \qquad (3)$$

where $t' - t$ is the duration of the operation. Further,

$$V = \frac{Q}{r} = \frac{4\pi r^2 \rho}{r} = 4\pi r \rho$$

and

$$\rho = \frac{V}{4\pi r};$$

hence

$$dE = dF\,dr = 2\pi\rho^2\,ds\,dr = \frac{V^2}{8\pi}\,dr\,d\omega,$$

or

$$E - E' = \frac{V^2}{8\pi}\iint dr\,d\omega = \frac{V^2}{2}(r - r') \qquad - \quad - \qquad (4)$$

This is the stored energy during the operation. But the energy of the electrification at first was $\frac{1}{2}\,r\,V^2$, and at the end is $\frac{1}{2}\,r'\,V^2$, so that there has nevertheless been a diminution of energy of

$$E - E' = \frac{V^2}{2}(r - r') \qquad - \quad - \quad - \qquad (5)$$

It appears that, under conditions of our experiment, the sphere has less energy at the close of the experiment than at the beginning by a quantity $\frac{V^2}{2}(r - r')$, while the equal energy represented by the potential of the electrification on itself was added. The total energy lost by the shell was, therefore,

$$E = V^2(r - r') \qquad - \quad - \quad - \qquad (6)$$

The current in the wire was, by Ohm's law,

$$C = \frac{dQ}{dt} = \frac{V}{R};$$

hence

$$Q - Q' = \frac{V}{R}(t' - t),$$

and hence the energy of the current during the operation was

$$E = \frac{V^2}{R}(t' - t),$$

or by (3),

$$E = \frac{V^2}{R}\,\frac{r - r'}{v} \qquad .. \quad - \quad - \qquad (7)$$

The expressions (6) and (7) must be equal to each other, and hence

$$Rv = 1, \qquad \text{or} \qquad R = \frac{1}{v},$$

where v is the constant velocity of each point in the surface of the shell during the operation.