BLUE-SKY MEASUREMENTS AT APIA, SAMOA

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Observations on the blueness of the sky have been regularly made at Apia, Samoa (13° 48′ S., 171° 48′ W.), South Pacific Ocean from January, 1927, to October, 1928. The intensity or depth of the blue was determined on a scale devised by F. Linke by a method recently described in this journal.[1] The deepest blue, ultramarine, is designated tint 12; the lightest, a bluish white tint, is 2. The data are of interest on account of being taken at sea level on an island where contamination of the air by smoke or fog does not occur. The island, which is covered with dense vegetation, has an area of 450 square miles. Apia lies not far from the center of the south-east trade wind belt in extreme oceanic surroundings, the total land area within 1,500 miles being less than 1 per cent.

The color of sky was observed, when possible, at 9 a. m. and 3:15 p. m. In 19 months the sky has been found to vary from lightest tint 4, occurring once, to deepest tint 10, occurring eleven times. Table 1 shows the annual variation in blueness of the sky.

TABLE 1.—*Annual variation in blueness of sky at Apia, Samoa*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A. m.	7.0	7.4	7.3	7.0	7.6	6.8	8.0	7.8	7.8	7.9	7.5	7.3
P. m.	6.5	7.6	7.0	6.4	6.0	6.6	6.2	7.0	7.9	6.8	7.2	7.3

It is seen immediately that the sky is a deeper blue in the morning than in the afternoon, especially so during the trade-wind, or dry season, from May to September.

Dividing up the year into three seasons—wet, November to February; dry, May to August; and equinoctial, September, October, March, and April, the differences forenoon and afternoon are as follows:

	Mean	A. m.–p. m.
Dry	7.32	0.50
Equinoctial	7.11	.28
Wet	7.22	.15

[1] Linke, F. Mo. Wea. Review, June, 1928, **56**: 224.

There is obviously only a very slight seasonal change. The smallness of the a. m.–p. m value in the wet season is due to the frequency of the rain which produces constant humidity conditions throughout the day. In the dry season, the convection and vertical currents set up causes, both by the presence of slightly condensed water vapor and by the enlargement of salt particles, a whitening of the sky.

The blueness of the sky at any moment is closely related to the existing cloudiness and the visibility vide. (Table 2.) In the scale of cloudiness 10 is overcast and 1 the almost unchanging ring of cumulus cloud occurring in fine weather around the horizon at sea in the Tropics.

TABLE 2.—*Variation of sky blue with cloudiness and visibility*

Tint of blue	4	5	6	7	8	9	10
Number of observations	1	13	50	84	125	58	6
Mean cloudiness	6	5.7	5.0	3.9	2.3	1.9	1.8
Visibility	5	4.1	4.1	3.7	3.4	3.2	3.3

The visibility is measured according to an arbitrary scale from 1 to 6 in which visibility 6 represents seeing, such that light and dark area may be clearly distinguished on a mountain side 50 kilometers distant and, visibility 1 when an object 1 kilometer distant is just visible. All objects are viewed across water. Lighting effects were eliminated by having the objects in line and including only morning observations.

The presence of clouds is concomitant with the lighting up of the sky. This may arise either, as Linke suggests, from the hydroscopic enlargement of particles floating in the air or from the formation of thin clouds. The particles are doubtless largely of common salt formed by evaporation of sprays. These float principally in the lower stratum of the air so that their removal by rain increases both visibility and the depth of blueness of the sky.

SEVENTEEN-YEAR RECORD OF SUN AND SKY RADIATION AT MADISON, WIS., APRIL, 1911, TO MARCH, 1928, INCLUSIVE

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Introduction.—Beginning with April, 1911, a continuous record of the intensity of sun and sky radiation has been obtained at Madison, Wis., through the medium of the Callendar bolometric sunshine recorder. The record has been made by receiver No. 9864. For a description of the instruments, their errors, reduction factor, and exposure, the reader is referred to Kimball & Miller (1).

Radiation.—Summaries of the hourly, daily, weekly, and annual intensities and extremes have been tabulated and are presented here. Curves of normal and maximum intensities, etc., have been prepared from the data. The intensity of solar rays incident at a point on the earth's surface is chiefly dependent on the elevation of the sun with respect to that point. The incoming rays are absorbed in proportion to the thickness of the atmosphere; i. e., the air mass, m, through which they must pass. The regular fluctuations of daily and annual radiation are the result of the revolution of the earth on its axis, and the change in the sun's declination and distance effected by the earth's revolution in its orbit around the sun. The irregular variations are due to the effect of the weather and the change in the quality of the transmitting atmosphere.

Transparency.—The transparency of clear air is dependent upon three factors—the depletion of radiation due to the molecular scattering and absorption by dry air; by wet haze, or water vapor; and by dry haze, or dust. The last two vary greatly from a maximum in the warm season to a minimum in winter, as shown by Table 1. Transparency is here represented by means of the atmospheric transmission coefficient, a, computed from the equation, $a^m = \frac{Q'}{Q_0}$, where m equals air mass, Q' the value of the radiation intensity corresponding to m, reduced to mean solar distance, and Q_0 the value of the solar constant, here assumed to be 1.94.

Curves of radiation.—Curve 1, Figure 1, the maximum noon intensity of solar radiation on a normal surface as recorded by the Marvin pyrheliometer, although affected by the seasonal change in the value of m at noon, and the annual variation in the earth's solar distance, which is a maximum in July, shows the effect of a hazy atmos-

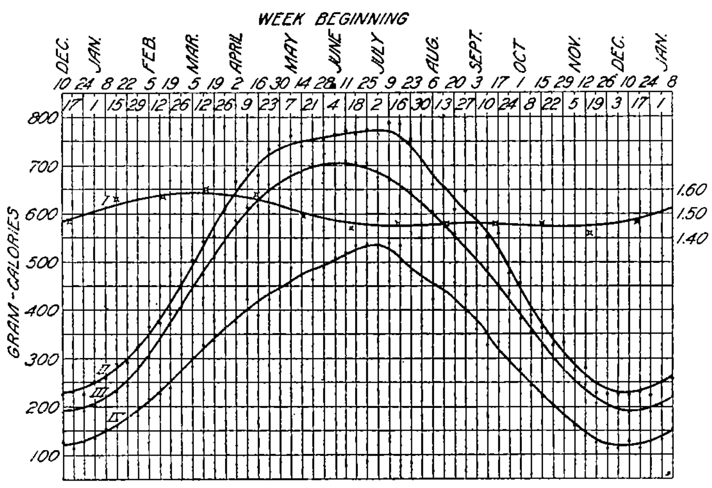

FIGURE 1.—Curve 1, maximum noon intensities of solar radiation on a normal surface as recorded by the Marvin pyrheliometer; 2, maximum daily amounts of sun and sky radiation on a horizontal surface; 3, mean daily amounts of sun and sky radiation on a horizontal surface under clear skies; 4, mean daily amounts of sun and sky radiation on a horizontal surface in calories per square centimeter

phere in reducing the intensity during the warm season of the year. Under cloudless skies the daily averages of the total radiation received on a horizontal surface give curve 3, Figure 1, which can be considered the normal curve of sun and sky radiation at Madison under clear-sky conditions. The maximum difference between it and shown the annual march of storminess to have a double maximum, the primary one in spring and a secondary in October. It is apparent from the time of occurrence of maximum storminess, that cloudiness is the principal disturbing influence on the regular annual march of sun and sky radiation. Comparison with Miller's curve of nine-year means (2) shows that curve 4 has smoothed out considerably with increase in the length of record.

Radiation history.—Figure 2 is constructed from the data partially presented in Table 7. That table gives the monthly and annual sums of the sun and sky radiation. The departure of these values from the normal is represented by the smooth dotted curve in Figure 2 and this is the most interesting, yet it is somewhat baffling. Since the beginning of the record it shows a quite steady decrease. Mention here must be made of the fact that the record for the first 16 months, during which period a different recorder was in use, is not considered entirely reliable and probably is too high. Were that period to be disregarded entirely, the steady decline in radiation would still appear. The atmospheric transmission coefficients, a, have been calculated for the different periods and are given in Table 2. It has been suggested that the increase in the smokiness, due to increased population in the city and to the replacing of hard coal by bituminous fuels, has decreased the transparency. Examination of the data in Table 2 fails to reveal anything to verify this assumption. The mean transparency for the winter months, for example, is very nearly 85 per cent for the four periods given. Location of the observing station north and west of the greatest smoke-producing sections of the city should be taken into consideration, as the bulk of the observations with the Marvin pyrheliometer, from which the transparency is computed, occur on days when the station is on the windward side of these smoke-producing centers.

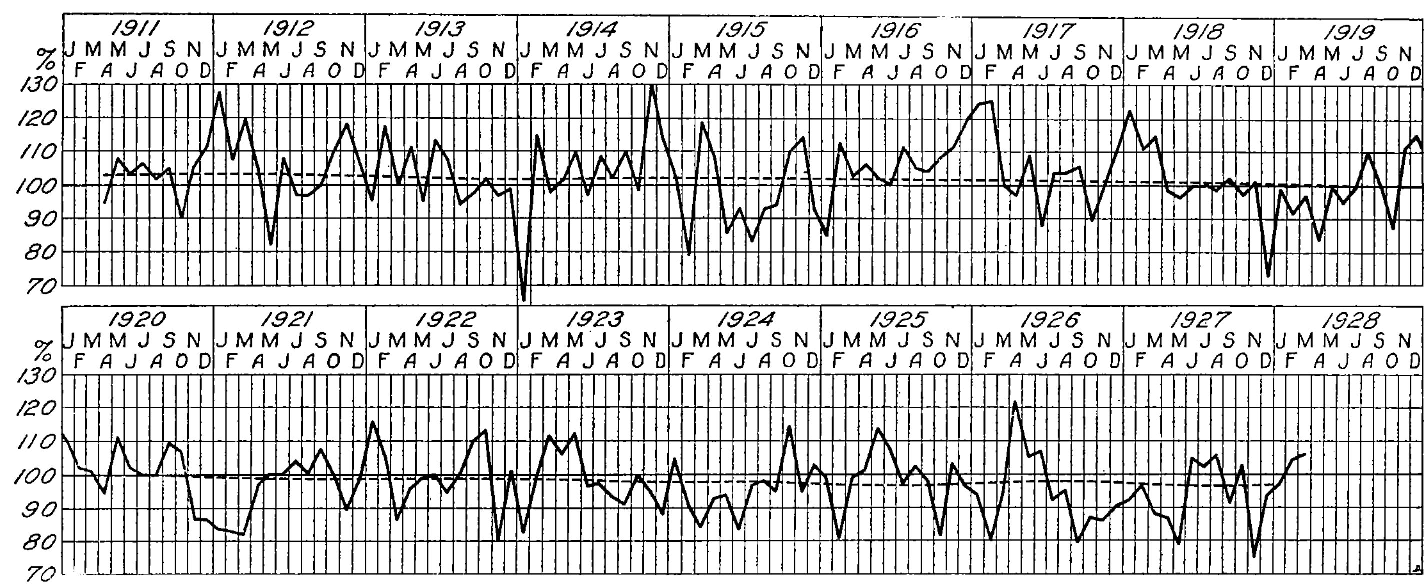

FIGURE 2.—History of sun and sky radiation at Madison, Wis., from April, 1911, to March, 1928, including monthy departures in percentages of the mean and annual departure, the smooth curve

curve 2, which latter gives the maximum daily amounts of sun and sky radiation, occurs in July, the time of maximum haziness. The greatest irregularity in the average daily totals of sun and sky radiation, as shown in curve 4, is a result of changes in the cloud cover incident to storminess. There is a decided depression in spring and more or less irregularity in autumn. In the Monthly Weather Review for June, 1920, Miller (2) has That fact more or less vitiates as a basis for comparison, the transparency factor obtained from the Marvin instrument. The officials of one of the leading fuel companies in the city estimates the use of anthracite fuel to have decreased 60 per cent in the last 15 years, while the population has doubled in the same period. Users of hard coal have sutstituted coke, fuel oil, gas, and principally bituminous fuels, thereby adding materially to the haziness during the cold season. Table 3 offers little light on the problem. The mean cloudiness during daylight hours is presented in percentages and shows clearer skies, on the whole, during the latter half of the record. It can not, however, be reasonably presumed that the increased haziness due to increased smokiness can account for the entire decrease in radiation unless one concludes it from the fact that considerable deficiencies in radiation are

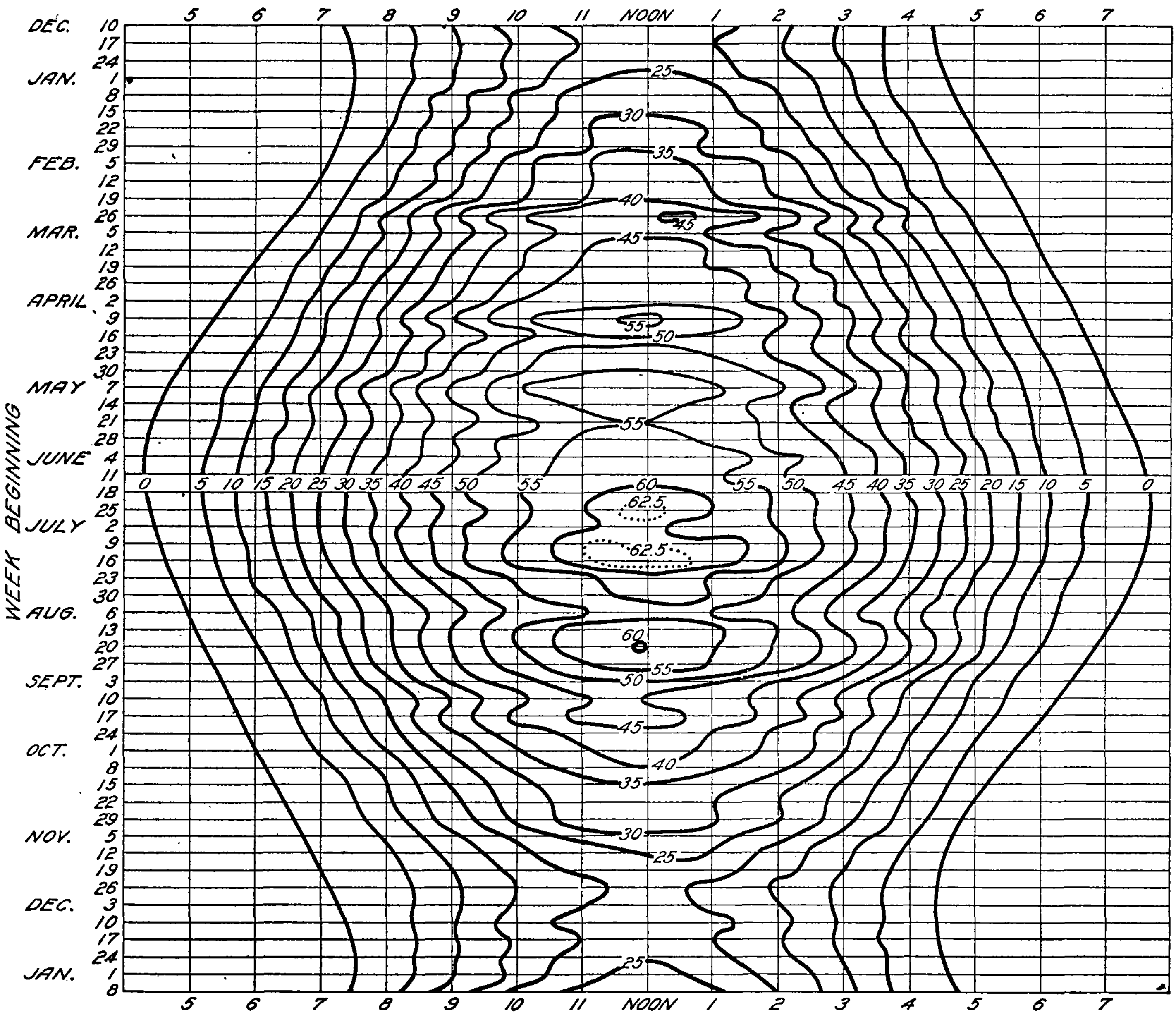

FIGURE 3.—Pyrhelisopleth for Madison, Wis.

shown by the majority of the winter seasons during the last 10 years. Another interesting feature of the graph is the long-continued deficiency extending from July, 1926, to May, 1927, inclusive, during which period the total loss was 12,591 calories, or more than the total of an average April. Winter months receiving low radiation totals have high temperature means as a rule, while those with high excesses of insolation are low in temperature value. The association of clear, cold weather with high radiation values, and the low radiation income with warm, cloudy weather is apparent.

Tables.—Table 4 gives the mean hourly and daily intensity of the vertical component of sun and sky radiation, from which curve 4, Figure 1, has been constructed. Table 5 gives the radiation values under clear sky conditions, and has been used to construct curve 3, Figure 1. Table 6 gives a summary of the means and extremes of radiation since the beginning of the record.

Acknowledgments.—The writer wishes to acknowledge his indebtedness to Doctor Kimball, of the central office, for the data from which Table 1 was computed, and to Mr. E. R. Miller, the official in charge of the Madison, Wis., station, for many helpful suggestions.

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TABLE 1.—*Atmospheric transmission coefficient, a, for Madison, Wis., computed from 16½ years' record of observations of solar radiation, normal incidence, with the Marvin pyrheliometer*

MORNING OBSERVATIONS

Month	Air mass 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
January			0.824	0.844	0.848	0.854	0.857	0.860	0.863
February		0.831	.831	.841	.851	.856	.862	.860	.863
March		.809	.821	.833	.843	.850	.854	.870	.872
April	0.737	.781	.796	.811	.827	.852	.857	(.862)	(.867)
May	.717	.746	.766	.785	.793	.820	(.841)	(.836)	(.849)
June	.702	.738	.766	.779	.802	.820	.828	.828	(.806)
July	.681	.719	.748	.770	.782	.795	.801	(.804)	.803
August	.691	.733	.763	.782	.791	.808	.815	(.825)	.829
September	.721	.758	.779	.794	.812	.822	.830	.843	.855
October	.712	.754	.779	.803	.814	.825	.830	.823	.823
November		(.762)	.809	.825	.832	.838	.847	.851	.849
December			(.812)	.839	.845	.854	.860	.863	.863

AFTERNOON OBSERVATIONS

Month	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
January				0.839	0.843	0.858	0.865	(0.881)	
February			0.831	.839	.838	(.850)	(.865)	(.895)	(0.877)
March		0.804	.815	.831	.840	.865	.859	(.872)	(.861)
April		.777	.796	.810	.823	(.832)	(.820)	(.809)	(.811)
May		.750	.739	.770	(.782)	(.786)			
June		.733	.751	.782	(.775)				
July		.709	.727	.779	(.782)				
August		.719	.751	.767	.765	.790	(.808)	(.817)	(.798)
September		.754	.776	.790	.807	.803	.815	(.817)	(.857)
October		.760	.779	.799	.804	.820	.823	(.819)	(.801)
November			.824	.827	.835	.836	(.854)	(.851)	
December				(.817)	.859	.850	.854	(.877)	

NOTE.—Coefficients in parentheses are based on normals of radiation obtained from less than six observations.

TABLE 2.—*Means of the atmospheric transmission coefficient, a, at Madison, Wis.*

	A. M. 5.0	A. M. 4.0	Air mass 3.0	2.0	1.0	P. M. 2.0	3.0	4.0	5.0	Mean
1911–1915										
Winter	0.852	0.882	0.856	0.831		0.836	0.859	0.845		0.852
Spring	.865	.857	.837	.789	0.686	.776	.854	.862		.816
Summer		.815	.771	.742	.649	.696	.728	.775	0.756	.742
Autumn	.820	.826	.807	.776	.696	.751	.809	.799	.774	.784
1916–1920										
Winter	.872	.867	.865	.846		.858	.868	.850	.873	.862
Spring	.865	.857	.830	.806	.758	.791	.814	.843	.815	.820
Summer	.806	.806	.783	.739	.670	.736	.779	.818	.826	.774
Autumn	.853	.841	.830	.799	.721	.799	.821	.843	.866	.819
1921–1925										
Winter	.873	.862	.851	.833		.809	.838	.865		.847
Spring	.852	.834	.809	.789	.747	.770	.821	.828	.837	.810
Summer	.820	.823	.799	.753	.686	.746	.751			.768
Autumn	.852	.845	.830	.799	.732	.806	.823	.835		.815
1926–1927										
Winter	.872	.859	.854	.836	.804	.840	.849	.865		.847
Spring	.889	.857	.817	.796	.747	.809	.856			.824
Summer		.826	.793	.748	.676	.736				.756
Autumn	.877	.850	.830	.806		.815	.823			.834

TABLE 3.—*Mean cloudiness, daylight hours, at Madison, Wis., 1911 to 1927, inclusive*

[Mean cloudiness and percentage of the mean]

Year	1911	1912	1913	1914	1915	1916	1917	1918	1919
Mean cloudiness	61	54	57	60	68	62	63	61	67
Percentage of mean	100	89	93	98	111	102	103	100	110

Year	1920	1921	1922	1923	1924	1925	1926	1927
Mean cloudiness	62	65	59	60	61	59	64	60
Percentage of mean	102	107	97	98	100	97	105	98

TABLE 4.—*Mean hourly and daily intensity of the vertical component of sun and sky radiation, at Madison, Wis., in gram calories, April, 1911, to March, 1928, inclusive*

Week beginning—	For the hour, apparent solar time, ending at— 5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	Daily
Jan. 1				0.7	6.1	13.6	20.2	24.5	24.4	21.0	14.4	6.4	1.1				132.3
Jan. 8				1.2	8.0	16.9	24.2	27.6	28.4	23.7	16.3	7.5	1.4				155.2
Jan. 15				1.4	8.1	16.7	24.4	28.6	28.6	24.3	17.3	8.6	1.9				160.0
Jan. 22				2.0	9.9	19.4	27.0	31.6	31.8	27.0	19.1	10.1	2.4				180.3
Jan. 29				2.6	10.3	19.3	26.8	31.1	31.0	27.0	20.3	11.0	2.9				182.2
Feb. 5			0.1	3.8	12.6	22.9	31.9	36.1	35.6	31.7	23.5	13.6	4.1	0.1			216.0
Feb. 12			0.1	4.9	14.5	24.1	31.8	36.8	36.7	32.3	24.7	15.1	5.2	0.3			226.2
Feb. 19			0.5	6.1	15.9	25.5	32.5	36.5	36.9	33.3	26.6	16.5	6.1	0.8			237.2
Feb. 26			1.2	9.2	22.1	34.5	43.5	47.2	45.8	41.3	33.3	21.7	9.0	1.6			310.4
Mar. 5			1.8	9.8	20.8	31.4	39.6	42.2	41.5	36.8	30.0	20.0	9.4	2.1			285.2
Mar. 12			2.7	11.7	23.6	34.9	42.6	46.3	46.5	42.9	35.5	24.7	11.9	3.1			326.4
Mar. 19			4.0	13.9	25.9	36.0	42.9	46.7	46.3	42.5	35.7	25.2	13.6	4.1			337.0
Mar. 26		0.1	4.9	15.7	27.5	37.8	44.8	48.7	49.2	45.6	38.6	27.6	15.7	5.2	0.3		362.0
Apr. 2		0.6	6.7	18.3	29.7	39.2	47.0	48.6	49.1	45.4	38.0	28.8	16.9	6.3	0.8		375.4
Apr. 9		1.0	8.5	20.6	33.4	45.2	51.8	54.9	54.3	49.8	41.8	31.0	19.2	7.8	1.3		420.5
Apr. 16		1.5	8.8	20.3	31.4	39.5	46.3	49.3	48.9	46.6	40.8	29.2	18.4	8.3	1.7		391.0
Apr. 23		2.3	10.8	22.1	33.9	43.7	50.8	52.6	52.2	47.1	40.3	31.2	20.7	9.8	2.4		420.1
Apr. 30		3.2	12.2	24.0	34.8	44.9	52.5	55.6	54.3	51.1	44.7	35.3	23.4	12.0	3.4	0.1	451.5
May 7		4.6	15.5	28.4	40.3	49.8	57.5	59.6	58.0	54.3	46.5	35.9	24.5	12.4	4.0	0.2	491.5
May 14	0.2	5.0	15.5	27.6	38.6	49.2	54.1	56.5	55.5	50.7	42.0	34.4	23.5	12.9	4.4	0.3	470.2
May 21	0.3	5.4	15.0	26.7	37.8	45.8	50.7	54.6	53.6	51.3	43.8	35.8	25.2	13.7	4.9	0.6	465.0
May 28	0.6	6.8	17.3	28.3	40.1	48.9	54.0	56.4	56.4	51.1	45.3	36.6	25.9	14.8	5.5	0.8	488.5
June 4	0.9	7.2	18.4	29.9	39.7	48.2	54.5	57.1	57.9	55.8	49.0	39.9	27.9	16.2	6.0	1.2	510.0
June 11	1.0	8.0	19.1	31.1	42.7	50.9	55.7	58.3	58.1	53.3	48.5	40.0	28.4	16.3	6.3	1.2	518.7
June 18	1.1	7.8	19.1	31.5	43.2	52.3	57.0	60.3	61.1	57.2	50.5	40.7	28.7	16.9	6.8	1.2	535.5
June 25	1.0	8.0	19.6	30.8	41.6	49.8	57.2	62.3	61.9	57.6	50.4	42.0	30.3	17.6	7.1	1.2	538.5
July 2	0.8	7.0	18.6	31.6	43.4	52.1	57.1	60.4	59.7	57.5	50.7	41.6	29.4	15.9	5.9	1.0	532.5
July 9	0.6	6.2	17.9	30.6	42.7	51.9	60.0	62.8	60.8	60.2	52.2	41.9	29.5	17.0	6.2	1.0	541.4
July 16	0.4	5.8	17.1	29.8	42.4	52.7	59.2	63.2	63.1	59.1	51.4	40.8	28.7	16.0	5.6	0.8	536.1
July 23	0.3	5.3	16.1	27.6	38.9	47.6	52.7	55.7	55.8	52.8	46.1	38.1	25.7	14.2	4.9	0.5	482.2
July 30		3.9	13.9	26.0	36.0	45.4	52.1	55.1	56.8	51.7	43.7	35.6	24.1	12.3	3.7	0.1	460.2
Aug. 6		2.8	11.3	22.9	33.5	42.2	49.1	50.4	50.5	48.9	42.4	33.0	22.1	11.4	3.3	0.1	423.8
Aug. 13		2.3	10.8	23.3	35.2	45.6	54.0	58.3	56.9	54.0	45.4	34.7	22.9	10.3	2.7		456.5
Aug. 20		1.5	9.6	22.3	34.7	45.0	54.1	59.3	58.2	52.5	47.0	36.6	23.6	10.1	2.1		456.8
Aug. 27		1.0	8.9	21.1	33.7	43.4	51.2	56.5	56.6	52.1	43.9	33.0	19.9	8.0	1.4		431.0
Sept. 3		0.6	6.6	17.3	29.0	39.0	45.7	48.1	46.9	42.0	36.3	26.5	14.9	5.4	0.7		359.2
Sept. 10		0.3	4.7	15.0	25.3	35.0	42.1	45.7	43.2	40.2	33.2	23.9	14.1	4.3	0.4		327.5
Sept. 17		0.1	4.2	14.6	26.6	37.2	43.8	47.1	45.6	41.1	34.8	24.2	12.6	3.4	0.1		335.4
Sept. 24			2.9	12.2	23.7	33.1	39.1	42.3	41.7	37.0	30.3	20.7	10.2	2.4			295.6
Oct. 1			1.8	9.5	20.4	30.3	37.6	40.8	40.7	36.8	30.1	19.5	8.5	1.8			278.0
Oct. 8			1.0	7.0	17.2	26.8	34.2	37.7	37.2	33.4	26.6	17.5	6.7	1.1			246.3
Oct. 15			0.5	5.9	15.7	24.5	31.2	34.3	33.8	29.9	23.5	14.4	5.2	0.7			219.8
Oct. 22			0.2	4.8	13.9	23.1	29.8	33.0	32.1	27.9	22.0	13.1	4.3	0.2			204.4
Oct. 29				3.6	12.6	21.8	29.8	33.2	32.0	28.0	21.7	12.3	3.6				198.8
Nov. 5				2.4	9.2	17.5	24.2	27.9	28.2	24.0	17.4	9.9	2.4				163.1
Nov. 12				1.5	7.6	15.5	21.5	24.7	24.4	20.8	14.5	7.7	2.0				140.3
Nov. 19				1.2	6.5	13.3	18.7	22.4	22.8	19.5	13.7	6.7	1.5				126.0
Nov. 26				0.8	5.8	12.3	17.6	20.2	20.2	16.7	12.1	5.6	1.1				112.2
Dec. 3				0.7	5.9	12.8	18.1	21.0	20.8	17.4	12.2	5.6	1.1				115.6
Dec. 10				0.6	5.8	13.9	19.9	23.1	23.5	19.2	13.1	5.8	1.0				126.0
Dec. 17				0.5	5.4	12.4	18.4	21.2	21.1	18.5	12.3	5.5	0.9				115.9
Dec. 24				0.6	5.9	13.7	19.7	23.8	23.3	19.2	13.2	6.1	1.1				126.4

TABLE 5.—*Average hourly and daily intensity of the vertical component of sun and sky radiation at Madison, Wis., under cloudless skies, in gram calories*

Week beginning—	For the hour, apparent solar time, ending at—																Daily
	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	
Jan. 1				1.3	10.4	22.6	32.3	38.0	38.2	31.6	21.6	8.7	1.5				206.2
Jan. 8				1.7	11.1	24.1	34.5	40.1	40.5	33.4	23.3	10.5	2.0				221.2
Jan. 15				2.1	12.6	25.3	35.4	41.8	41.0	34.2	23.6	11.4	2.2				229.6
Jan. 22				3.2	14.5	27.6	37.0	42.8	42.7	36.1	25.1	12.4	2.7				244.1
Jan. 29				3.8	15.6	30.0	40.9	46.7	47.2	41.0	30.6	16.2	4.0				276.0
Feb. 5				4.6	19.1	33.2	44.6	50.7	50.1	44.8	33.9	18.5	5.4				304.9
Feb. 12			1.2	6.9	22.1	38.0	49.3	55.3	53.9	47.4	36.6	22.1	6.6	1.0			340.4
Feb. 19			1.4	10.7	26.6	41.2	52.5	58.5	57.6	50.4	40.7	25.3	8.7	1.4			375.0
Feb. 26			1.3	10.9	28.7	44.6	56.6	62.2	61.5	55.2	45.3	29.4	11.2	2.2			409.0
Mar. 5			2.5	15.0	33.7	49.1	60.6	66.0	64.8	58.4	48.1	33.0	14.5	2.8			448.5
Mar. 12			3.9	18.3	36.4	51.7	62.8	67.7	67.0	60.8	50.2	34.9	16.6	4.0			474.3
Mar. 19			5.7	21.7	40.2	55.2	66.2	70.8	69.5	63.1	53.7	38.6	20.4	5.6			510.7
Mar. 26		1.0	7.4	24.7	43.4	58.3	69.3	74.4	73.4	67.1	55.9	40.8	22.1	6.5	1.2		545.5
Apr. 2		1.1	9.9	28.7	47.2	61.7	71.8	76.4	75.8	70.3	60.3	44.9	26.1	9.2	1.3		584.7
Apr. 9		1.4	12.3	31.4	50.3	64.3	74.2	78.9	78.0	72.0	61.1	46.7	28.0	11.4	1.9		611.9
Apr. 16		2.5	14.9	32.7	50.5	63.6	72.8	78.1	77.8	71.9	62.0	46.7	30.2	12.7	2.3		618.7
Apr. 23		3.5	17.9	36.5	53.7	67.8	77.4	81.4	80.3	75.0	65.8	51.0	33.5	14.3	3.4		661.5
Apr. 30		4.5	19.1	37.4	54.1	67.0	75.3	79.4	78.5	72.6	63.7	49.8	33.0	15.9	4.0		654.3
May 7		5.6	20.9	38.7	55.2	68.1	77.5	82.0	81.7	76.5	66.8	53.6	36.8	18.6	5.4	1.2	688.2
May 14	1.0	7.1	23.5	40.8	56.6	68.8	76.6	80.1	78.7	74.6	65.2	52.3	35.8	18.8	6.0	1.1	687.0
May 21	1.5	8.4	24.5	41.7	57.3	68.7	76.7	80.2	80.4	76.4	66.8	55.0	37.0	20.9	7.0	1.5	704.0
May 28	1.1	8.7	24.4	40.3	54.9	66.0	74.2	78.9	78.5	73.3	65.6	51.5	35.9	21.6	8.2	1.8	684.9
June 4	1.1	10.0	26.6	42.7	56.8	68.1	76.0	79.7	79.0	74.7	66.5	54.7	38.7	22.2	8.0	1.7	706.5
June 11	1.3	9.7	27.2	43.7	58.5	68.9	76.2	81.1	79.7	74.3	66.7	53.2	38.1	22.4	8.5	1.7	711.2
June 18	1.5	11.1	27.4	43.7	57.7	68.5	76.8	79.7	78.8	73.5	65.0	53.7	38.0	22.3	8.5	1.7	707.9
June 25	1.4	10.3	26.6	43.0	57.0	67.1	75.0	79.4	79.7	74.7	66.9	54.3	38.3	21.8	7.9	1.7	705.1
July 2	1.2	8.7	24.2	40.4	54.6	65.0	72.6	77.0	77.0	72.2	64.4	51.6	36.6	21.3	7.4	1.5	675.7
July 9	1.1	8.0	23.1	39.2	53.5	65.4	72.8	77.7	76.1	71.2	64.0	52.5	37.2	20.9	7.4	1.4	671.5
July 16	1.0	7.5	23.2	39.6	54.1	64.9	73.2	76.6	75.9	70.5	62.8	49.9	34.9	19.0	6.0	1.5	660.6
July 23	1.0	6.3	21.1	37.5	52.2	64.0	71.5	75.7	76.4	71.7	63.4	48.7	32.8	17.6	5.5	1.1	646.5
July 30		5.0	19.3	35.8	50.3	61.8	70.1	74.6	74.0	68.7	60.2	48.0	32.8	17.2	5.1	1.0	623.9
Aug. 6		4.1	17.6	34.3	49.3	60.6	69.4	72.2	71.9	67.6	59.7	46.8	31.9	15.1	4.2		604.7
Aug. 13		3.0	15.0	31.2	46.7	59.2	67.8	72.2	72.0	66.8	56.7	44.2	28.5	12.6	3.1		579.0
Aug. 20		1.9	12.8	29.4	45.3	57.8	67.2	70.6	69.0	64.5	56.8	43.5	27.0	11.0	2.2		559.0
Aug. 27		1.4	11.1	27.5	43.8	56.5	65.6	69.0	68.1	62.9	52.1	38.9	23.3	8.7	1.5		530.4
Sept. 3		1.2	9.2	25.4	41.0	52.8	61.0	64.9	63.8	58.3	49.4	37.5	19.3	6.1	1.3		491.2
Sept. 10		1.2	6.9	23.3	40.5	53.4	62.5	65.6	65.3	59.6	49.3	35.3	19.3	5.4	1.2		488.8
Sept. 17			4.9	19.5	35.8	49.8	59.0	63.0	62.0	56.7	47.2	33.3	16.5	3.9	1.0		452.6
Sept. 24			3.9	17.9	34.7	49.0	58.2	61.5	60.5	55.2	45.4	31.3	14.3	2.9			434.8
Oct. 1			2.4	13.3	29.2	42.3	52.3	56.5	55.7	50.2	40.3	26.9	11.2	2.2			382.5
Oct. 8			1.7	10.8	27.2	40.3	50.3	54.5	52.7	47.3	37.9	24.6	8.8	1.6			357.7
Oct. 15			1.0	8.0	23.4	36.9	46.7	51.9	51.1	45.8	35.6	21.7	7.1	1.3			330.5
Oct. 22			1.0	6.5	21.0	34.2	44.1	48.5	47.3	41.0	31.3	18.2	5.5	1.1			299.7
Oct. 29				4.6	18.0	30.9	41.3	46.1	45.4	39.4	29.9	16.4	4.2				276.2
Nov. 5				3.8	15.2	28.3	38.4	43.6	42.3	36.5	27.2	14.3	3.3				252.9
Nov. 12				2.6	13.1	26.6	36.7	42.7	42.7	36.9	27.1	13.7	3.1				245.2
Nov. 19				2.0	10.6	22.6	32.1	37.8	37.1	31.0	21.5	10.1	2.1				206.9
Nov. 26				1.4	9.6	21.0	31.2	36.2	35.7	30.5	20.4	8.7	1.7				196.4
Dec. 3				1.2	9.1	20.4	30.1	34.8	34.6	28.5	19.0	8.3	1.6				187.6
Dec. 10				1.2	9.1	20.6	29.6	34.7	34.8	29.3	19.8	8.4	1.7				189.2
Dec. 17				1.4	10.7	22.3	31.5	35.8	34.7	28.8	19.3	8.3	1.6				194.4
Dec. 24				1.3	9.7	21.1	30.6	36.2	35.2	28.8	19.4	8.6	1.5				192.4

TABLE 6.—*Summary of means and extremes of radiation, etc., at Madison, Wis.*

Week beginning—	Greatest daily	Month	Day	Year	Mean monthly amounts for all days	Mean monthly amounts for clear days	Duration of sunshine, for months. (Percentage of possible)	Mean cloudiness, daylight hours, for months
Jan. 1	252	1	1	1912	926	1,443		
Jan. 8	259	1	9	1912	1,086	1,548		
Jan. 15	289	1	19	1912	1,120	1,607	45	63
Jan. 22	282	1	23	1915	1,262	1,709		
Jan. 29	323	1	31	1918	1,275	1,932		
Feb. 5	363	2	9	1912	1,512	2,134		
Feb. 12	371	2	18	1923	1,583	2,383	47	65
Feb. 19	394	2	20	1917	1,660	2,625		
Feb. 26	455	2	29	1912	2,173	2,863		
Mar. 5	503	3	7	1920	1,996	3,140		
Mar. 12	544	3	16	1923	2,285	3,320	52	63
Mar. 19	552	3	22	1916	2,359	3,575		
Mar. 26	609	3	29	1912	2,534	3,819		
Apr. 2	666	4	7	1911	2,628	4,093		
Apr. 9	692	4	14	1911	2,944	4,283		
Apr. 16	682	4	17	1916	2,737	4,330	53	65
Apr. 23	734	4	24	1911	2,941	4,631		
Apr. 30	743	5	3	1911	3,161	4,580		
May 7	762	5	11	1916	3,441	4,817		
May 14	739	5	16	1927	3,291	4,809	59	62
May 21	751	5	27	1922	3,255	4,928		
May 28	755	5	30	1915	3,420	4,794		
June 4	765	6	9	1913	3,570	4,946		
June 11	769	6	16	1917	3,630	4,978	64	60
June 18	765	6	19	1916	3,749	4,955		
June 25	770	6	28	1911	3,770	4,936		

TABLE 6.—*Summary of means and extremes of radiation, etc., at Madison, Wis.*—Continued

Week beginning—	Greatest daily	Month	Day	Year	Mean monthly amounts for all days	Mean monthly amounts for clear days	Duration of sunshine, for months. (Percentage of possible)	Mean cloudiness, daylight hours, for months
July 2	764	7	2	1917	3,728	4,729		
July 9	789	7	12	1911	3,790	4,701		
July 16	788	7	21	1911	3,753	4,624	69	51
July 23	754	7	24	1913	3,375	4,526		
July 30	711	8	1	1913	3,221	4,367		
Aug. 6	661	8	6	1921	2,967	4,232		
Aug. 13	658	8	14	1921	3,196	4,053	64	52
Aug. 20	610	8	24	1923	3,198	3,913		
Aug. 27	649	8	29	1911	3,017	3,713		
Sept. 3	572	9	5	1921	2,514	3,438		
Sept. 10	554	9	11	1917	2,293	3,422	55	57
Sept. 17	559	9	19	1911	2,348	3,168		
Sept. 24	480	9	25	1921	2,069	3,044		
Oct. 1	456	10	2	1913	1,946	2,678		
Oct. 8	390	10	11	1914	1,726	2,504		
Oct. 15	364	10	15	1913	1,539	2,314	51	58
Oct. 22	327	10	27	1914	1,431	2,098		
Oct. 29	334	11	2	1911	1,392	1,933		
Nov. 5	275	11	8	1914	1,142	1,770		
Nov. 12	283	11	14	1916	982	1,716	37	69
Nov. 19	232	11	22	1914	882	1,448		
Nov. 26	228	11	29	1911	785	1,375		
Dec. 3	230	12	3	1911	809	1,313		
Dec. 10	225	12	15	1919	882	1,324	36	68
Dec. 17	232	12	18	1921	811	1,361		
Dec. 24	225	12	30	1914	885	1,347		

TABLE 7.—*Monthly and annual sums of the 17-year mean of the sun and sky radiation upon a horizontal surface at Madison, Wis., from April, 1911, to March, 1928, inclusive, in gram calories per square centimeter*

Year	January	February	March	April	May	June	July	August	September	October	November	December	Year
1911				11,742	15,843	16,153	17,202	14,072	10,598	6,533	4,554	4,217	100,644
1912	6,297	6,953	12,006	12,663	11,948	16,891	15,623	13,380	10,001	7,932	5,137	4,024	122,855
1913	4,651	7,584	10,008	13,380	13,906	17,704	17,413	13,028	9,829	7,380	4,218	3,717	122,818
1914	3,196	7,422	9,854	12,213	16,238	15,203	17,417	14,128	11,060	7,070	5,656	4,320	123,767
1915	4,988	5,062	11,883	13,069	12,494	14,605	13,273	12,884	9,429	7,934	4,947	3,519	114,087
1916	4,117	7,292	10,272	12,727	15,024	15,673	17,872	14,516	10,486	7,793	4,831	4,469	125,072
1917	6,106	8,147	10,031	11,730	16,002	13,630	16,736	14,239	10,562	6,400	4,319	4,190	122,092
1918	5,982	7,145	11,446	11,883	14,194	15,681	16,187	13,711	10,246	7,026	4,395	2,697	120,593
1919	4,878	5,926	9,739	10,042	14,752	14,779	16,014	15,297	9,970	6,298	4,820	4,342	116,857
1920	5,357	6,616	10,175	11,432	16,410	16,007	16,219	13,783	10,940	7,701	3,712	3,266	121,618
1921	4,130	5,394	8,219	11,649	14,794	15,671	16,842	13,837	10,889	7,317	3,864	3,680	116,286
1922	5,710	6,937	8,677	11,437	14,380	15,664	15,112	14,032	11,039	8,177	3,481	3,788	118,434
1923	4,025	6,502	11,122	12,712	16,529	14,986	15,655	12,928	9,069	7,218	4,149	3,302	118,197
1924	5,166	6,015	8,465	11,085	13,810	12,952	15,579	13,530	9,591	8,417	4,128	3,868	112,606
1925	4,869	5,161	9,916	12,167	16,795	16,920	15,596	14,050	9,810	5,823	4,478	3,649	119,234
1926	4,638	5,185	9,530	14,732	15,497	16,722	14,760	13,120	7,940	6,262	3,708	3,392	115,486
1927	4,532	6,286	8,816	10,515	11,592	16,362	16,489	14,601	9,131	7,444	3,282	3,502	112,552
1928	4,749	6,743	10,635										
Means	4,906	6,492	10,047	12,053	14,718	15,623	16,117	13,832	10,035	7,219	4,334	3,761	119,137

DISCUSSION

Note on Figure 2 of Piippo's paper.—The author intimates in his text that the rather steady decrease in the annual totals of radiation, as indicated by the broken line in Figure 2, can be accounted for in part only by increased smokiness of the atmosphere of Madison due to an increase in the consumption of bituminous coal as a fuel in recent years. Also, while there is, in general, accord between average annual cloudiness and the total annual radiation from year to year, there is no evidence of an increase in cloudiness in recent years as compared with the earlier years covered by the pyrheliometric record.

It remains to ascertain if the recording pyrheliometer may not have deteriorated during the 17 years it has been in use. There are three ways in which we might expect deterioration, as follows:—

(1) The blackened grids might become less black or the platinum wires of the bright grid might tarnish. Visual observations do not indicate that this is the case.

(2) The glass dome covering the grids might become less transparent. Visual observations do not show that this is the case. However, such observations are quite inconclusive.

(3) A sliding contact on a bridge wire maintains a balance in the two arms of the bridge which is a part of the register, and if this wire becomes worn its resistance increases and less movement is necessary to balance the heating of the black grids by radiation of a given intensity. In consequence there is lessened movement of the pen over the intensity scale of the record sheet. Since the wire has been kept coated with oil there can have been little wear on the wire.

Nevertheless, there is opportunity for deterioration of the apparatus in the manner indicated above, and the only practicable way to detect it is to recalibrate the pyrheliometer occasionally.

In Table 8 are given summaries of comparisons between the measurements of the intensity of the vertical component of direct sunshine by the Callendar and the Marvin pyrheliometers.

The ratios shown indicate that the Callendar register now records 3 per cent lower than it did in the years 1913–1915, and this will account for about half the decrease in annual radiation receipt during the above period. The remaining half I am inclined to attribute to increased smokiness, which is not apparent in the atmospheric transmission coefficients of Table 2 for the reason that observations with the Marvin pyrheliometer are not made on days when the atmosphere contains much smoke.

TABLE 8.—*Values (f) of a scale division of the Callendar pyrheliometer in gram calories per minute per square centimeter, as determined by comparisons between the Callendar and Marvin pyrheliometers*

Years	Solar altitude	Number of observations	f	Solar altitude	Number of observations	f	Solar altitude	Number of observations	f
1913–1915	58.3	15	0.0346	43.0	16	0.0342	29.8	14	0.0354
1917	60.6	10	.0353	43.6	7	.0354	30.2	5	.0377
1927				41.2	19	.0358	30.9	14	.0367
Ratio $\frac{1917}{1913\text{–}1915}$			1.020			1.035			1.065
Ratio $\frac{1927}{1913\text{–}1915}$						1.047			1.037
1913–1915	20.1	3	.0380	15.9	3	.0423	14.3	3	.0502
1917	21.8	4	.0371						
1927	22.5	8	.0382	15.6	2	.0417	12.6	1	.0489
Ratio $\frac{1917}{1913\text{–}1915}$			.0976						
Ratio $\frac{1927}{1913\text{–}1915}$			1.005			.0986			.0974

Weighted mean ratio (all Solar altitudes) $\frac{1917}{1913\text{–}1915}$, 1.024 $\frac{1927}{1913\text{–}1915}$, 1.032.

The Marvin pyrheliometer at Madison was compared with Smithsonian pyrheliometer No. 1 on September 29, 1928, and the mean of three series, each covering a period of about 30 minutes, gave for the ratio $\frac{\text{Marvin}}{\text{Smithsonian}}$ the value 1.002. Smithsonian No. 1 is frequently compared with substandards at the Smithsonian Institution. It was last compared on February 28, 1928, and was found to be in accord with them within the error of observation. This has been the result of all comparisons made since May 3, 1920; and since July 12, 1910, the change in the ratio between Smithsonian substandards and Smithsonian No. 1 has been only 0.7 ± 4.34 per cent, No. 1 appearing to read that amount lower at the present time.—*H. H Kimball.*