THE MAGNITUDE OF THE ERROR IN MEASUREMENTS OF THE SOLAR RADIATION RECEIVED ON A HORIZONTAL SURFACE ARISING FROM THE ASSUMPTION THAT THE RATIO BETWEEN RADIANT ENERGY RECEIVED AND ELECTRICAL ENERGY RECORDED IS A CONSTANT

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In a recent paper[1] attention is invited to the error arising from the use of a constant factor to reduce records from pyranometers to heat units without regard to the angle of incidence at which the heat rays strike the receiving surface of the instrument, special reference being made to a paper by Kimball and Hobbs[2] in which this error is not mentioned.

In this last paper reference was made to other sources of error, as follows:

(1) The e. m. f. generated in the thermopile is not strictly proportional to the difference between the temperatures of the junctions attached to the black and the white rings, respectively. The efficiency of the thermopile appears to increase with temperature difference, and presumably with the temperature of the pile.

(2) The resistance of all the wires except that in the swamping resistance increases with temperature, but at a slower rate than the e. m. f. increases.

(3) It is not probable that the difference in the temperature of the junctions attached to the black and the white rings, respectively, is strictly proportional to the intensity of the radiation to which they are exposed.

(4) The hemispherical glass cover over the horizontally exposed thermopile may cause irregularities in the record unelss it is exactly spherical, is free from flaws of all kinds, and is large enough so that the caustic curve caused by reflection of light from its internal surface does not fall on either of the rings.

In Table 1 are given comparisons between Marvin pyrheliometer readings, Q, and thermopiles No. 5, resistance 86 ohms, and No. 9, resistance 28 ohms. All three instruments were similarly exposed in an insulated bulb at the lower end of a diaphragmed tube and supported on equatorial mountings to keep them pointed toward the sun. The radiation was received on the surface of their sensitive elements at normal incidence. Q = radiation intensity measured by the Marvin pyrheliometer, and S = the relative intensity indicated by the recorder actuated by the thermopile indicated.

TABLE 1.—*Comparison of Marvin pyrheliometer readings with records made by Weather Bureau thermoelectric pyrheliometers*

Comparison with thermopile No. 5, Apr. 2, 1923		Comparison with thermopile No. 9, April-June, 1924		
Q Gr. cal./min. cm²	$\frac{Q}{S}$	Number of comparisons	Q Gr. cal./min. cm²	$\frac{Q}{S}$
0.729	0.0634	24	0.676	0.0624
.816	.0628	18	.743	.0637
.979	.0648	22	.825	.0642
1.074	.0624	24	.947	.0650
1.091	.0634	26	1.032	.0654
1.174	.0638	39	1.162	.0659
1.222	.0636	48	1.238	.0657
1.309	.0664	21	1.335	.0658
Mean	.0638			.0648

[1] Middleton, W. E. Knowles. A source of error in measuring radiation on a horizontal surface. Gerlands Beiträge zur Geophysik.

[2] Kimball, H. H., and Hobbs, E. H. A new form of themoelectric pyrheliometer. MONTHLY WEATHER REVIEW, Vol. 51, pp. 239–242, 1923.

Both the single series of comparisons obtained with thermopile No. 5 and the many comparisons obtained with No. 9 indicate decreased sensitivity of the thermopile with increase in radiation intensity.

In Table 2 are summarized comparisons of the vertical component of solar radiation as received at normal incidence (Q, sin. h, when h is the solar altitude) and as measured by a thermoelectric pyrheliometer of the Eppley type, sealed in a glass bulb.[3] The Marvin pyrheliometer employed in obtaining Q in Table 1 was used in the comparisons summarized in Table 2. Thermopile No. 245 was compared with the Marvin instrument during the summer of 1931, when the sun was high in the middle of the day, and No. 255 in the late autumn when the sun did not reach a height much in excess of 40° above the horizon.

TABLE 2.—*Comparison of vertical component of direct solar radiation measured by Marvin and thermoelectric pyrheliometers*

Range of intensities, gr. cal./min./cm²	No. 245, number of comparisons	Mv. per gr. cal.	Range of mv. values	No. 245, number of comparisons	Mv. per gr. cal.
Less than 0.26 gr. cal	40	7.13	8.14–6.32	49	7.52
0.26 to 0.50 gr. cal	119	7.41	8.11–6.71	105	8.30
0.51 to 0.75 gr. cal	126	7.76	8.12–7.33	61	8.32
0.76 to 1.00 gr. cal	88	7.73	8.05–7.32	16	8.34
In excess of 1.00 gr. cal	118	7.75	8.11–7.45		

The data in these two tables have not been arranged in just the same way, but they show clearly that while when exposed with their surfaces normal to the incident solar rays the thermopile is less effective with high solar radiation intensity than with low intensity, the opposite is true when the thermopile is exposed with its surface horizontal, and this decrease in sensitivity of the thermopile with low radiation intensity, or what is the same thing, with low altitude of the sun, may be attributed to lower absorbing power, or higher reflecting power of the surfaces with increase in the angle of incidence. The comparisons in Table 2 do not indicate that this variation is so great as to introduce serious errors into the hourly amounts of radiation received upon a horizontal surface if a mean value of Q/S obtained from comparisons similar to those given in Table 2 is employed, especially since with low sun the direct solar radiation component of the total radiation received on a horizontal surface becomes relatively less and less important.

[3] The method by which the vertical component of solar radiation received on a horizontal surface is measured is described and illustrated in the paper by Kimball and Hobbs (see footnote 2, above), pp. 241–242, and fig. 4.