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# CONCERNING SMITHSONIAN PYRHELIOMETRY

By

C. G. ABBOT, L. B. ALDRICH, and A. G. FROILAND
Astrophysical Observatory, Smithsonian Institution

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# CONCERNING SMITHSONIAN PYRHELIOMETRY

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Recently K. Wegener [1] has asserted that gross errors exist in Smithsonian pyrheliometry. P. Courvoisier [2] showed that Wegener's main contention is erroneous and also discussed at considerable length the behavior of the Smithsonian silver-disk pyrheliometer. The impression is left that certain not negligible errors, akin to that claimed by Wegener, still existed. The largest of these he stated to be of the order of 1 percent. But in a private communication, Dr. Morikofer, in whose laboratory Courvoisier worked, informs us that this estimate contained a numerical error and that the quantity considered is very much smaller, only of the order of 0.1 percent.

However, we wish to discuss the subject further. The late W. H. Hoover and A. G. Froiland [3] have given pyrheliometry careful attention in volume 7 of the Annals of the Astrophysical Observatory. We refer those interested to that source. We now present certain facts, not always remembered by critics, and we add experimental results on the magnitude of the errors suggested by Wegener and Courvoisier.

The silver-disk pyrheliometer is not a standard instrument. It can carry the standard scale of solar measurement only if it agrees, within admissible limits of error, under all usual circumstances, with a standard pyrheliometer. It is therefore of no consequence what errors might belong to the silver-disk pyrheliometer, if, when used with its accompanying Smithsonian papers, it will give, to the required degree of accuracy, the same results as a standard pyrheliometer.

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[1] Wegener, K., Die Messung der Sonnenstrahlung und der Solarkonstante. Journ. Geophys. Res., vol. 54, p. 53, 1949; Die Sonnenstrahlung und ihre Messung. Geof. Pura e Appl., vol. 22, p. 205, 1952.

[2] Courvoisier, P., Zur Definition der Sonnestrahlung. Arch. für Meteorologie, Geophysik und Bioklimatologie, ser. B, vol. 5, No. 2, p. 124, 1954.

[3] Hoover, W. H., and Froiland, A. G., Silver-disk pyrheliometry. Smithsonian Misc. Coll., vol. 122, No. 5, 1953. (Also, Ann. Astrophys. Obs., vol. 7, ch. 4, pp. 99-137, 1954.)

Thus two questions arise: (1) Is the Smithsonian water-flow pyrheliometer a standard pyrheliometer? (2) Do silver-disk pyrheliometers, used with Smithsonian directions, give the same results as the water-flow pyrheliometer, under usual ranges of conditions?

If the answers to these questions are yes, then critical discussions of errors of the silver-disk pyrheliometer are merely academic.

The water-flow pyrheliometer ceased to be a *primary* standard when in 1932 it was changed to be an electrical compensation instrument, following the suggestion of the Russian meteorologist W. M. Shulgin.[4] It can now be a standard pyrheliometer only if electrical heating is (a) completely measurable and (b) not more favorably applied for measurement than solar heating.

These requirements are discussed in Smithsonian Misc. Coll., vol. 110, No. 11, 1948, and in volume 3 of Annals of the Smithsonian Astrophysical Observatory, pages 60 to 67. As the mean of nearly 50 determinations, electrical heating was 100.0 percent recovered. Electrical heating was applied in some cases to coils wound on the rear surface of the receiving cone for solar rays, and perhaps more favorable to measurement than sun heat. But it was also applied in some cases to a coil in air, in front of the cone, where electrical heating was at a disadvantage. No difference between the results of the two windings was found. We therefore hold that the two conditions (a) and (b) are satisfactorily met.

In an absolute standard pyrheliometer, solar heat must be sensibly completely absorbed. This, we think, cannot be seriously questioned regarding our water-flow instrument. For considering the construction of the water-flow chamber, and that about 95 percent of the solar radiation is absorbed at first incidence on the blackened cone, repeated reflections within the blackened chamber must reduce the remaining 5 percent almost to zero.

The aperture for solar rays, used in 1932 and all subsequent observations with the water-flow pyrheliometer, was measured by means of a fitted plug with more than sufficient accuracy. The aperture was of such a diameter and distance from the receiving cone as to have the same solid angle as the aperture of the long-barreled silver-disk pyrheliometer. Its solid angle is 0.0013 hemisphere. Our pyrheliometers therefore measure a little sky light besides direct sunlight. What percentage this is must vary with the clearness of the sky. This consideration introduces a small uncertainty as to the absolute value of the solar constant of radiation. But when solar-constant

[4] Shulgin, W. M. Monthly Weather Rev., vol. 55, No. 8, p. 361, 1927.

measures are made day after day on the same high mountain, under very clear skies, this consideration can hardly be serious in studies of solar variation.

The remaining question about the standard quality of the water-flow pyrhelioineter concerns the loss of infrared radiation to space and the gain of infrared radiation from space, plus the gain of solar radiation reflected from the sky immediately surrounding the sun, when the shutter is opened.

Radiation from within the receiving chamber is mainly intercepted by the blackened walls and diaphragms of the vestibule. As this is bathed by the water stream, its temperature is the same as that of the chamber, and such losses from the chamber as are thus intercepted in the vestibule are exactly replaced by radiation from the vestibule. A part of the radiation from the chamber that reaches the outer end of the vestibule goes on toward the sun and sky when the shutter is opened, through the measured aperture above described. A cone of radiation from the chamber at other times is intercepted by the triple-leaved shutter. This shutter is blackened below, bright above. Its lower leaf certainly is at air temperature. When the shutter is opened, about half of this formerly intercepted part goes on outward through the measured aperture. The outer end of the vestibule has a blackened diaphragm 2.9 centimeters in diameter, situated 24 centimeters from the receiving cone.

All the sky rays that reach the receiving cone, either infrared from the atmosphere or reflected rays from the sun, enter through the smaller accurately measured aperture above described. All others from these sources are intercepted in the vestibule and cannot appreciably alter the measurement, because whatever warmth they contribute raises the temperature of both incoming and outgoing water equally. We think the incoming sky radiation, scattered sunlight and infrared combined, will generally exceed the outgoing infrared radiation, when the shutter is opened. On high mountains, under very clear and dry atmosphere, the result may be the opposite.

Froiland has recently investigated experimentally, at Table Mountain, Calif. (elevation 7,500 feet), the magnitude of the gain or loss of radiation on exposure of the water-flow standard pyrheliometer. The instrument was deflected away from the sun just far enough to avoid direct sun rays when exposed. But as the polished surface surrounding the two outer apertures reflected sun rays up onto the lower leaf of the shutter, and some scattered reflection of solar rays into the instrument might occur, he dispensed with the shutter. To take its place he used a cork, which he rapidly exchanged back and forth