# Sensitivity distribution along the strips of compensation pyrheliometers

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(Manuscript received October 5, 1973; revised version April 10, 1974)

ABSTRACT

Different sensitivity distribution curves had been found for the sensor of compensation pyrheliometer by laboratory measurement and by calculation. To obtain the real sensitivity distribution a new measuring method was applied, which used the sun as radiation source. The results of laboratory and field measurements were in proper agreement. The sensitivity curve is determined mainly by the structure of thermojunction, but each strip has individual characteristics.

## Introduction

There exists a basic problem in comparative pyrheliometry: how to eliminate the effect of the difference of circumsolar fluxes entering into geometrically different pyrheliometers? A theoretical answer to this question was given by Pastiels (Bossy & Pastiels, 1948; Pastiels, 1959). According to Pastiels' theory the pyrhelimetric outputs should be analysed by using the effective penumbra functions of the pyrheliometers. For determining this function, a knowledge of the relative sensitivity distribution along the sensor is required. In absolute pyrheliometry the sensitivity distribution should also be known, since the output of radiation sensors is in direct ratio with the incident radiation flux only, when the sensitivity or the flux (or both of them) is uniform along the sensor (Fröhlich, 1972; Major, 1973).

Definition of the sensitivity at a point $(x, y)$ of a radiation sensor could be as follows when the surroundings of the $(x, y)$ point are illuminated by a narrow beam, the sensor will give an output $\Delta V$. The surface sensitivity can then be calculated:

$$k(x, y) = \frac{1}{Q} \lim_{\Delta F \to 0} \frac{\Delta V}{\Delta F}$$

where $Q$ is the intensity and $\Delta F$ is the cross-sectional are of the radiation beam. When making measurements, $Q$ and $\Delta F$ are constant, therefore the approximation can be used for the relative sensitivity:

$$k(x, y) = \frac{\Delta V(x, y)}{\Delta V_{\max}}$$

where $\Delta V_{\max}$ is the maximal value of outputs when the beam passes the whole sensitive surface.

## Earlier results

A calculated sensitivity distribution was determined for the compensation pyrheliometer by Major (1968) taking Ångström's elementary theory as a basis (Ångström, 1958). On the same physical principle, Fröhlich (1972) made calculations for several complex heat transfer factors. Laboratory measurements were made by Klevantsova (1969) for several variants of the Ångström-type sensor. The sensor unit had been removed from the tube and one of the strips was illuminated by a small spot (0.5 mm in diameter), while the deflection of zero-galvanometer was taken as output. Along the strip of the original Ångström pyrheliometer [$A_{198}$) forty readings were made in length and four in width. From the tabulated sensitivity values a mean relative sensitivity curve was constructed (curve 1 in Fig. 1).

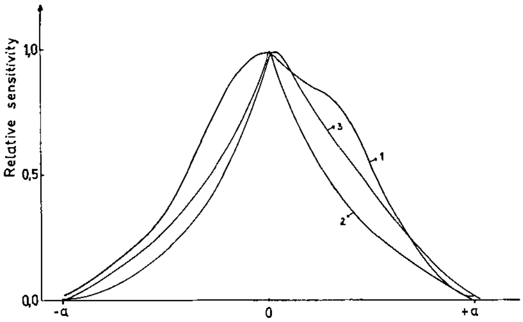


*Fig. 1.* Sensitivity distribution curves: curve 1: Klevantsova's measurements for $A_{196}$; curve 2: Major's calculation for ideal strip; curve 3: laboratory measurements for $A_U$. ($a$ is the half-length of strips).

To compare the results of calculation and measurement, the relative sensitivity curves are drawn altogether in Fig. 1. Two kinds of deviation can be observed. First, at the end-points the calculated curve becomes zero, while the measured one does not reach zero value. This shows that the heat conduction within the frame as well as between the frame and the manganese strips is not so perfect as the elementary theory supposes. Secondly, at the centre, the calculated curve has a sharp peak, while the measured one is rather smooth. Moreover, the measurements show some asymmetry to the centre. It is quite clear that the curve based on measurements is influenced by the thermojunction, which is not taken into consideration in the calculation, since it refers to an ideal strip. On the other hand, the method and conditions of laboratory measurements

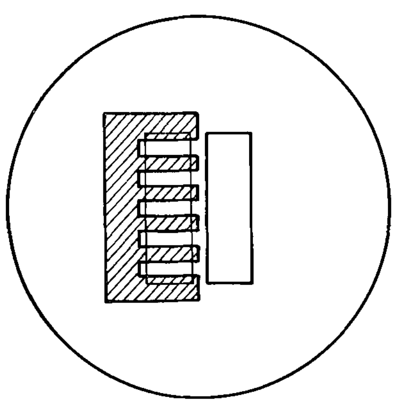

*Fig. 2.* The "comb" on the pyrheliometer entrance diaphragm.

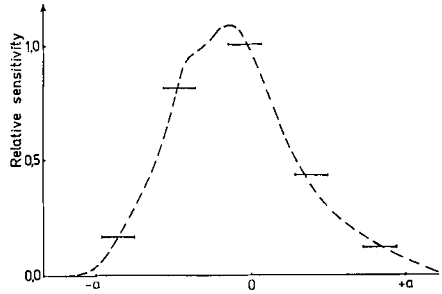


*Fig. 3.* Sensitivity distribution along the left strip of the $A_{596}$ pyrheliometer. —: determined by solar radiation; - - -: determined by laboratory measurement.

differ in much from the normal ones, when solar radiation is measured. Therefore the question arises: what is the real sensitivity curve? To answer this question it is not worth complicating the calculation, since the heat conductivity across the thermojunction is not known. A new method of measurement whould be applied using the sun as radiation source.

## Methods

For the entrance diaphragm of the compensation pyrheliometer a "comb" was prepared as is shown in Fig. 2. Each small hole can be opened or closed independently. On clear days the solar radiation penetrating across the different holes was measured by using compensation. The so-called "cold zero" (Rodhe, 1972) had to be applied, otherwise the compensation could not be reached for the outer holes.

Klevantsova's laboratory method was also applied to compare the results of two kinds of measurements made for the same sensor.

## Results

In Fig. 3 the relative sensitivity distribution for $A_{596}$ pyrheliometer can be seen, determined by both measuring methods. The asymmetry is due to the construction of the thermojunction. It was mentioned earlier that the hot and cold zero-points are different. This means that the two strips are not perfectly equivalent. In Fig. 4 the sensitivity curves are shown for

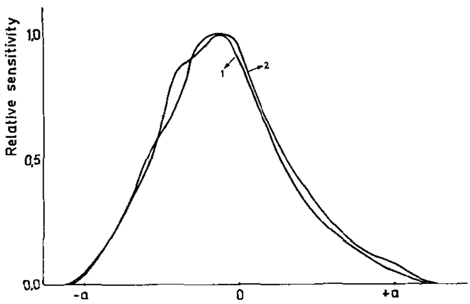


*Fig. 4.* The sensitivity curves for the left (curve 1) and right (curve 2) strip of the $A_{596}$ pyrheliometer.

both the left and right strip. (The left strip is on the left-hand side of the observer who normally operates the instrument.) The results obtained for the $A_{529}$ pyrheliometer are essentially the same as described for the $A_{596}$. The $A_U$ pyrheliometer was also investigated by the laboratory method. This compensation pyrheliometer is an old type; its geometrical characteristics are the same as those of the $A_{158}$. The structure of its thermojunctions differs from those of new sensor units. The measured sensitivity curve can be seen in Fig. 1.

## Conclusions

(1) Proper agreement exists between the sensitivity distributions determined by the described laboratory method and by using solar radiation. Therefore the most practical method for obtaining the real sensitivity curve of pyrheliometric strips is laboratory measurement. (2) The sensitivity distribution is determined mainly by the structure of the thermojunction. The earlier pyrheliometric sensors are not so far from the ideal strip of Ångström's theory as are the newer ones. (3) If high precision is required, the sensitivity distribution should be measured for each strip of each sensor, since they have individual characteristics.

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## РАСПРЕДЕЛЕНИЯ ЧУВСТВИТЕЛЬНОСТИ ВДОЛЬ ПОЛОС КОМПЕНСАЦИОННЫХ ПИРГЕЛИОМЕТРОВ

Путем лабораторных измерений и расчетов было найдено, что полосы датчика компенсационного пиргелиометра обладают различными кривыми распределения чувствительности. Для получения реального распределения чувствительности был применен новый метод измерений, использующий солнце в качестве источника радиации. Результаты лабораторных и полевых измерений согласуются между собой. Кривая чувствительности определяется главным образом структурой спая термопары, однако, каждая полоса обладает своей индивидуальной характеристикой.