Proceedings of the Iowa Academy of Science

Volume 43 | Annual Issue Article 10

1936

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THE RADIOMETER: A SIMPLE INSTRUMENT FOR THE MEASUREMENT OF RADIANT ENERGY IN FIELD STUDIES

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During the past decade important advances have been made in the measurement of light and radiant energy. Although previous to this time emphasis was placed on the refinement of instruments for measuring light, during this period emphasis has been placed on the measurement of radiant energy since plants are affected by rays both longer and shorter than those of the visible spectrum.

For measuring radiant energy in the field, Shirley's molification of the Wilson thermopile (4) and a thermopile perfected by Gast (1) have proven to be effective instruments. They are both portable and adapted to field studies, but, probably because of the difficulty of construction and operation, they are not in general use in ecological studies.

In 1930 the author, in searching for a simple field instrument for use in the measurement of radiant energy to supplement data on light intensity obtained by means of the Macbeth illuminometer, decided to make use of the principle of black and white thermometer sets. These sets had previously been used by several workers; Graham (2), Hall (3).

After the first attempts, the thermometers were enclosed in pyrex glass tubes in order to eliminate the cooling effect of the atmosphere. The first pair of instruments as they are now used (Figure 1) were made in the spring of 1931 according to the author's specifications, by L. E. Pinney of the College Instrument Shop. The mounted thermometers were wedged into the tubes and fastened by fusing the glass rod to the side of the tube in order to prevent movement of the thermometer-set within the tube. The glass tube was then exhausted with a Cenco Hyvac pump and sealed. Some of the later tubes were exhausted of air to a greater extent by means of a mercury-vapor pump. These tubes give about a ten per cent higher reading than do those evacuated by the Hyvac pump.

Since the enclosed thermometers are largely protected from heat loss by convection, the difference in the reading of the two instruments gradually increases with exposure. For this reason

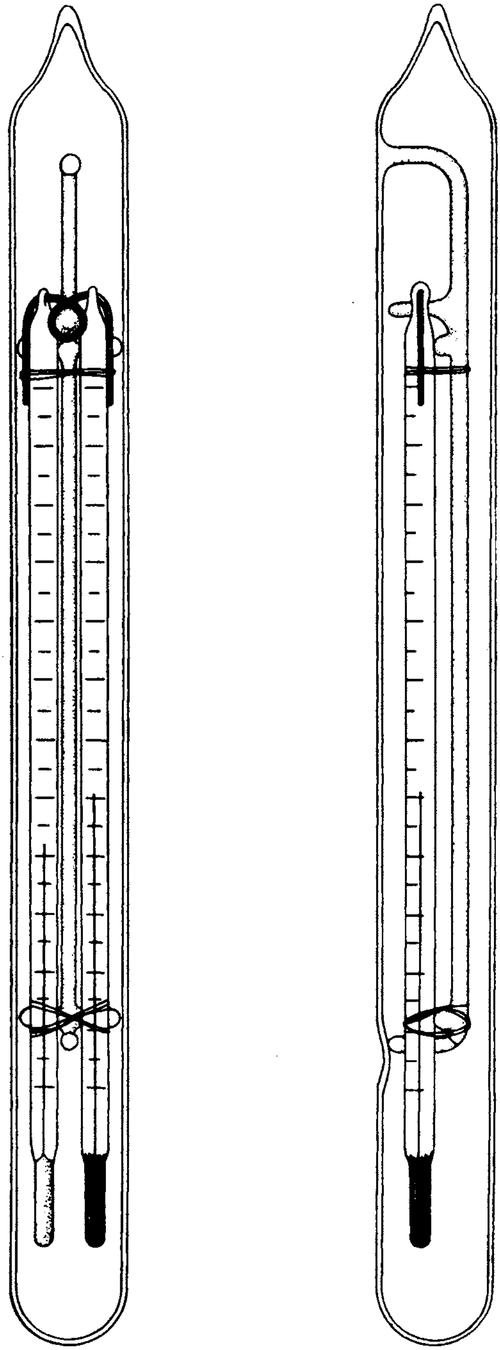

Fig. 1. Front and side view of the radiometer.

the tubes are protected in a light-proof box between readings and are exposed in the habitat to be measured for a definite length of time: five minutes. By reading the difference in the temperature of the two thermometers at an exact time after exposure comparative results are obtained which may be standardized against different types of instruments for measuring radiant energy and light. Differences between the readings of the two thermometers as high as 17 degrees Centigrade have been obtained.

Although perfect correlation with readings of light instruments was not expected, since the radiometer is a non-selective instrument except for the rays which are excluded by the pyrex glass, the correlation is high. The greatest variation between the readings of the radiometer and of the Macbeth Illuminometer seems

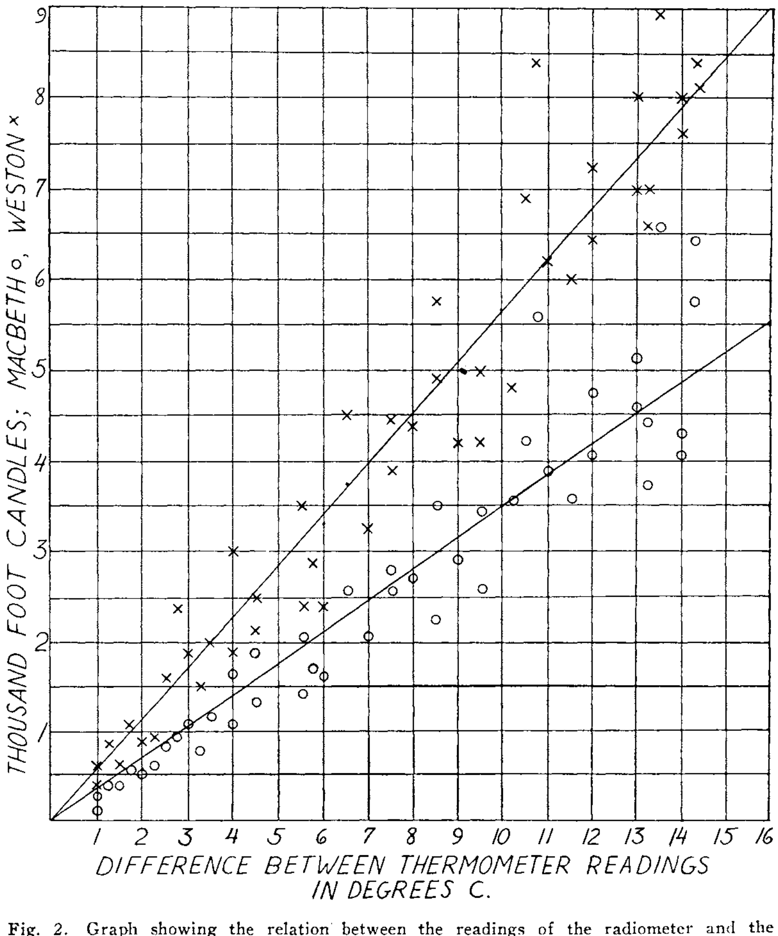

Fig. 2. Graph showing the relation between the readings of the radiometer and the Weston photoelectric cell and the Macbeth illuminometer.

to occur under conditions of white clouds when skylight is high. Under these conditions the light readings are much higher than the radiant energy readings.

Figure 2 shows the curves obtained when readings of the Macbeth illuminometer and the Weston Photoelectric cell in thousand foot candles are plotted on the difference between the thermometer readings in degrees Centigrade. The readings with the Weston cell are higher than those of the Macbeth Illuminometer. In fact, they are so high that the maximum reading of the instrument (10,000 foot candles) is reached late in the Spring before the noonday sun has reached its greatest height. The correlation coefficient for the Macbeth Illuminometer and the radiometer readings is .9498 and for the Weston photoelectric cell and radiometer reading is .9671.

In field studies, the procedure is to take readings in full sunlight, then in the plant communities to be compared and then again in full sunlight. The readings under the plant cover may then be computed in terms of percent of full sunlight based on the average of the two sunlight readings.

Table I — Light and radiant energy readings in percentage of full sunlight

	Radiometer	Weston Photoelectric Cell	Clements Photometer	Macbeth Illuminometer
	Percentage			
Under *Pinus strobus* trees	5.3	3.6	10.0	3.4
Under *Juniperus virginiana* trees	10.7	9.7	15.0	8.2
Greenhouse bench, cloudy day	28.5	30.6	36.6	28.3

In Table I radiometer readings in three different habitats are compared with the readings of the Clements Photometer as well as with those of the Macbeth Illuminometer and the Weston photoelectric cell. By this method of computing results, comparisons can readily be made between the results of various instruments.

The radiometer reading under the white pine stand is slightly higher than is obtained when thermometers graduated to 1/10 degree Centigrade are used. The thermometers used for the results in the table can be read to $\frac{1}{4}$ degree Centigrade and are suitable for most plant communities.

The principal advantages of the use of the radiometer are its simplicity and ease of operation, the fact that it measures radiant energy rather than only the visible spectrum, and the fact that it can be moved back and forth while making the readings in order to get an average reading under mottled shade conditions. It is much more sensitive than thermometer sets which are not enclosed in a partially exhausted tube. Hall (3).

Of all the instruments discussed in the paper, the Clements Photometer is the only one besides the radiometer with which an average reading of uneven light conditions can be made by moving the instrument. However, by using ordinary photographic paper in this instrument, as is usually done, the rays of the visible spectrum which are measured are not those which are considered to be most effective in photosynthesis.

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