THE CALIBRATION OF A CONSTANT RECORDING ILLUMINOMETER WHEN THE SENSITIVE SAMPLING SURFACE IS HORIZONTAL

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(with two figures)

Introduction

A recent issue of Plant Physiology contained a description of a constant recording potentiometer developed by WALLACE (3), who subsequently suggested its use in conjunction with a Weston Photronic cell for recording sunlight for routine weather records (4). Arrangement and use of the apparatus was discussed in considerable detail, but no thorough attempt at calibration in terms of customary light units was reported. By arrangement with Dr. WALLACE, the instrument was purchased, and has been in intermittent use in this laboratory for considerable periods of time. The object of this brief paper is to report an attempt at calibration of the apparatus in foot-candles by comparison with results obtained with a Macbeth illuminometer and a Weston illuminometer.

This empirical comparison indicates the accuracy obtained under the specific conditions described. As described here, the instrument does not provide a complete record of light energy or its effects on plant functions. It does, however, offer possibilities of data for weather records with an accuracy greater than that from mere visual observation or from intermittent readings with light meters.

Procedure

The recording potentiometer was set with the zero point about eight millimeters from one edge of the paper, at a sensitivity such that the maximum sunlight caused the recorder pen to move about seven inches. It was activated by a Weston Photronic cell, with a ten-ohm shunt across the input terminals of the recorder. This shunt is necessary to secure an approximately linear relationship between foot-candles falling upon the cell and current output over the wide range of light incidence, since, according to the Weston Electrical Instrument Corporation (2) the current output of these cells is much more characteristic of the light intensity than is the voltage generated.

The cell was mounted horizontally on a suitable rubber base, upon a wooden platform built over an unused chimney on the roof of the laboratory. It was covered by an inverted, heavy, white glass, flat-bottomed bowl, which

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rested upon a thick rubber disk. This bowl protected the cell from the weather, absorbed or reflected 75 per cent. of the light falling upon it, and was just large enough to cover the cell. The arrangement of the cell and bowl is shown in figure 1. The bowl was held down level on the rubber disk by suitable clamps, and the interior was connected to a small rubber balloon on the under side of the platform over the chimney. This provided for expansion and contraction of the air under the bowl, as suggested by Prof. C. I. Gunness, of Massachusetts State College. A few pieces of anhydrous calcium chloride were placed under the bowl to maintain low humidity.

The calibration was accomplished by means of foot-candle readings taken simultaneously with a Leeds & Northrup Macbeth illuminometer, equipped with a daylight absorbing screen, and a Weston illuminometer from horizontal reflecting surfaces, at stations within fifty feet from the photoelectric cell. The target of the Weston illuminometer was placed in a horizontal position at the same light station. These readings were plotted against the rise of the pen on the drum of the recorder in millimeters. The observations were made at the same time as the foot-candle readings. Actually about two minutes were required for observations, and care was exercised that the light intensity did not change appreciably during this time. Only clear days when the sky was free from clouds were selected.
Results

Foot-candle readings from both illuminometers were plotted against millimeters rise of pen on drum (fig. 2). This graph shows the agreement which may be expected between the Weston and Macbeth illuminometers. It will be noted that the two instruments agree quite well above 4000 foot-candles, but that below this value the curves separate, and apparently the Weston readings are too low. This may be attributed to the large angle of incidence, measured from the normal, when the sun is low on the horizon, causing reflection from the glass surface over the cell of the Weston illuminometer, and also to the shadow cast by the rim of the case holding the cell. Neither of these factors affects the readings of the Macbeth instrument.

![Graph showing foot-candle readings](image_url)

Fig. 2. Comparison between Macbeth and Weston illuminometers, April 30, 1937.

The graph also shows the desired straight line relationship between foot-candles falling on the cell, rise of pen in millimeters from maximum to minimum readings, and the divergence of the actual observations from this desired straight line. The reading of the pen is a little high throughout the entire range, the greatest divergence being at about 4800 foot-candles. This indicates that the relationship between rise of pen, or cell output, and foot-candles is not exactly a straight line. The maximum error is at 4800 foot-candles, where it is approximately 350 foot-candles or 7.3 per cent. The error decreases on both sides of this value.

Discussion

The resistance across the input terminals of the recorder cannot be reduced much below ten ohms and still have enough potential drop to drive sufficient current through the coil of the galvanometer to move it. Reducing this resistance also reduces sensitivity. The problem becomes one of how much sensitivity can be sacrificed in order to secure as nearly as possible a straight line relationship.
This relationship is important, because it makes possible measurement of the total light upon a surface over a period of time, by integrating the area under the curve drawn by the pen, and expressing the result as foot-candle hours, or in some other convenient unit. A ten-ohm shunt with the thick, white glass, flat-bottomed bowl inverted over the cell, gave better results than several other types of translucent shades that were tried.

Because of changes in the photronic cells, the calibration has not proved permanent, but must be redetermined frequently. Certain of the cells seem much more durable than others. Reduction of sensitivity of a cell may be classed as permanent or temporary. Apparently the cells may be permanently damaged by exposure to the high temperatures of bright summer days. The Weston Electrical Instrument Corporation state that 122° F. (50° C.) is the maximum endurable temperature, beyond which decided changes in sensitivity may be expected. They state also that moisture has a very harmful effect upon the cell (2). These two factors must be guarded against in the assembly of the sampling unit. A temporary failure may be remedied by unscrewing the backs of the cells and inserting small springs, as was done by WALLACE (4) who thoroughly discusses the troublesome weaknesses of the cells. Despite all precautions, however, changes in the relationships between light and the recorded data have occurred.

Conclusions

With a suitable cell mounted horizontally, and covered with a flat, white glass surface capable of removing 75 per cent. of the total light, the recording illuminometer may be calibrated for light falling on a horizontal surface, using either a Weston or a Macbeth illuminometer as a standard.

The maximum error should not be greatly in excess of 7 per cent. The error means variation of observations from the desired straight line relationship for any cause whatever, and does not consider errors in the Weston or Macbeth instruments. The calibration is not permanent, and must be repeated at intervals.

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LITERATURE CITED