Colorado Flower Growers Association, Inc.

IN COOPERATION WITH COLORADO STATE UNIVERSITY
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A SOLAR INTEGRATOR FOR GREENHOUSE USE

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Most instruments that reliably measure solar radiation are expensive. Where it is necessary to find the total accumulated energy over a period of time, the cost becomes higher. There is a need for relatively simple and inexpensive instruments that may be used for measuring total solar radiation received in a greenhouse. At CSU we have made some light measuring devices that might be usable. The instrument shown in Fig. 1 is patterned after the "pyrigrator" designed by Federer and Tanner (1).

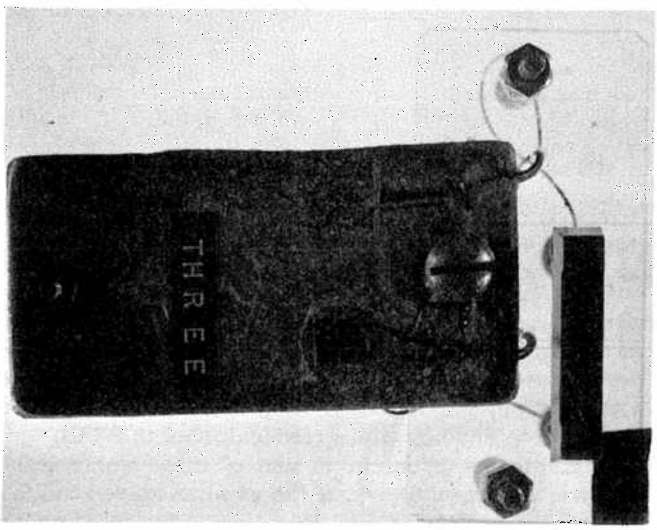

Figure 1: Top view of a homemade radiation measuring device, under $20.00. Silicon cells are attached to a 1/4" thick aluminum plate, the entire instrument supported on 3 adjustable legs for leveling.

Construction

The individual parts are shown in Fig. 2; Fig. 3 is the wiring diagram; and Table 1 contains the parts, sources and approximate costs. The mercury coulometer integrates the current output from the smaller silicon cell over time. The large silicon cell provides a variable bias voltage, improving linearity of the device. The silicon cells we purchased were encapsulated at the factory with leads attached. These were bonded to a heavy piece of aluminum plate, which serves to maintain the cells closer to air temperature. For those with skill and proper tools, the cells may be purchased without epoxy covering and no leads. They are then soldered to a small piece of aluminum or stainless steel, and one lead attached

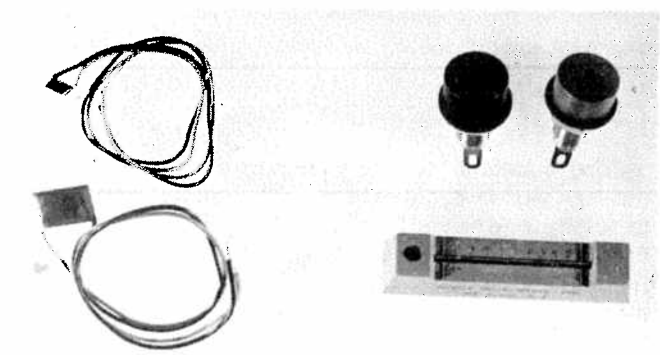

Figure 2: Minimum individual parts required in the solar integrator. Bottom left: mercury coulometer with 1" scale marked in tenths; bottom right: two pin jacks for coulometer mounting; top left: large silicon biasing cell; top right: small silicon measuring cell.

to the base plate. The cell is then bonded to the heavy plate. The other lead is attached and the cell covered with an epoxy for protection. A small circular bubble vial may be mounted in order to level the cells. The pin jacks support the mercury meter. The instruments we constructed were relatively crude, but can supplement more expensive devices when necessary.

As shown in Figures 1 and 2, the mercury coulometer consists of a small capillary tube, filled with mercury parted by an indicating gap of electrolyte. When current is passed through the meter, mercury is electroplated from anode to cathode, moving the gap. The movement of the gap is a function of both time and current. The meter is placed in the pin jack, and a reading taken on the 1 inch scale. After a suitable time interval, a second reading is taken. The distance the gap has moved in the interim is total solar radiation. One end of the coulometer should be marked to indicate the zero end of the scale. When the gap approaches the opposite end, the mercury meter is reversed in the pin jacks and the gap movement is reversed. By making readings on a daily basis, a record may be obtained of daily solar radiation. Location of the gap can be estimated to 0.01 inch. A pocket microscope (Table 1), mounted in a suitable holder, may be used to read the scale with greater precision.

The maximum current that can be passed through the coulometer is 5 milliamperes. If the current is maintained at 5ma for one hour, the gap will move approximately 0.48 inches. This is too fast, and it is customary to reduce the current to a maximum of 1ma under high light conditions by partially covering the small silicon cell with an opaque material in which a hole not more than 1/16th inch square has been cut. An ordinary volt-ohm-milliammeter may be used to measure current, adjusting the aperature over the cell accordingly. Under Colorado conditions during the summer, the meter is usually reversed every other day. It may be desirable, during the winter, to use a second solar integrator having a larger aperature. Or, a second cell may be switched into the circuit when needed. The use of a cell with more surface exposed has the advantage of reducing errors in the system that occur under low light and overcast conditions.

General Problems

The constant for the mercury meter (0.096 " per ma-hr) varies from instrument to instrument. This, in addition to variations that may occur in the aperature over the measuring cell, requires that each instrument be calibrated against some standard if the measurements are to be compared. The device is temperature sensitive, but over a temperature range of 32 to 104°F, the error should not be more than 5%. Other problems may increase the error to 10%. It should be emphasized that silicon cells are more sensitive to certain wavelengths than to others. The cells reach a peak sensitivity in the red region (0.85 microns, cut off at 1.2), and are less responsive to wavelengths in the visible region. Comparisons between silicon cells and other types should be made with caution, particularly when values are converted from one to another (i.e. gram-calories to BTU).

The biggest problem in use of these solar integrators is forgetfulness. If the gap has moved too far toward one end of the capillary tube - due to someone forgetting to reverse it - the cell will be permanently disabled. While $8.00 is not excessive it does not take much carelessness to run up the cost. Therefore, some judgement should be used as to when the meter

Figure 3: Wiring diagram for solar integrator. 1) large biasing cell; 2) small measuring cell; 3) pin jacks; 4) coulometer. Red is positive.

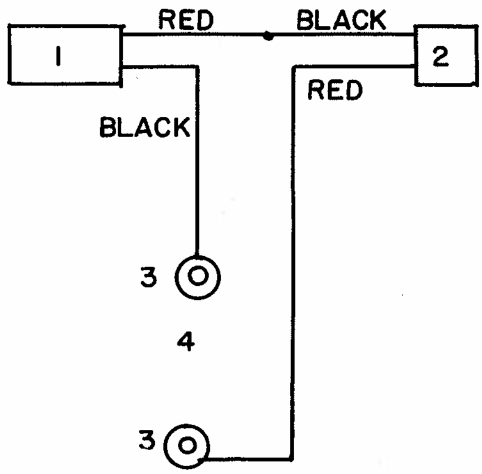

Table 1: List of materials used in construction of solar integrator.[1]

Item	Source	Approximate Cost
1. Mercury coulometer Model 150-SP	Curtis Inst., Inc. 351 Lexington Ave. Mt. Kisco, N.Y.	$ 8.00
2. Silicon cells, epoxy encapsulated with leads attached 110CLV and 58 CLV	Hoffman Semiconductors Hoffman Electronic Park El Monte, Calif.	2.90
3. Insulated tip jacks 43Z885 and 43Z889	Allied Electronics 100 N. Western Ave. Chicago, Ill. 60680	.28
4. Miscellaneous materials for mounting	Local	5.00
	Total cost	$16.18
Optional materials:		
1. Circular level vial No. 40,068	Edmund Scientific Co. Barrington, N.J.	1.70
2. 50X measuring pocket microscope. No. 30,225	Edmund Scientific Co. Barrington, N.J.	7.95

[1]Manufacturers' names are given for convenience and not meant to be a recommendation of their product.

should be read and reversed in the pin jacks. After some experience, an individual can estimate how far the gap may move during the day, and whether it is necessary to reverse it, or read it at a later time, reversing it then.

Literature Cited

1. Federer, C. A. and C. B. Tanner. 1965. A simple integrating pyranometer for measuring daily solar radiation. J. Geophys. Res. 70:2301-2306.