A Photoelectric Sunshine Recorder

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The number of hours the sun is visible each day compared to the number of hours of possible sunshine is of interest to the meteorologist, the climatologist, the horticulturist, the biologist, and even the local Chamber of Commerce. Not only are these people interested in the duration of sunshine, but some are also interested in the exact time of day at which the sun may have been visible at a particular place. For instance, the local courts often call for the Weather Bureau records to substantiate or refute the testimony of a witness as to whether or not the sun was shining at a particular time on a given day.

For more than a half century the Weather Bureau has been obtaining sunshine data at various locations by means of a relatively simple and inexpensive instrument, properly described as the Maring-Marvin thermometric sunshine duration recorder but more commonly known as the Marvin sunshine switch. The sensitive element of this recorder consists of a modified form of the old Leslie differential thermometer. It operates on the principle of differential heating between a blackened and a clear bulb of an air thermometer. The bulbs are connected by means of a straight glass tube partially filled with mercury and alcohol and are protected from the effects of the ambient temperature by being encased in an evacuated clear-glass jacket. When radiation strikes the instrument the air in the black bulb heats more rapidly than the air in the clear bulb. This heated air pushes the mercury up along the connecting tube away from the black bulb to complete the electrical contact between two platinum wires sealed into the glass tube, this in turn, sets a recorder into operation, which remains in operation until the radiation weakens and the mercury again drops below the contacts. The Maring-Marvin switch was first suggested by Mr. D. T. Maring of the U. S. Weather Bureau in 1891 and was later improved somewhat by Prof. Marvin [1][2].

Prior to this date there were two other types of sunshine recorders in use; the photographic and the burning-glass sundial. The photographic type such as the Jordan [3] and the Pers [4] depend, for the record, upon light-sensitive paper such as blueprint paper. The records from such instruments require processing before they are available for study. This and other more serious faults are responsible for the lack of popularity of the photographic recorder. The U. S. Weather Bureau used a modified form of the Jordan recorder from about 1888 to 1897 [1].

The burning glass recorder, in more general use, was invented in England by Campbell in 1853 and improved by Prof. Stokes in 1879 [3]. The basic form of this recorder consists of a polished glass sphere which acts as a burning glass. Under bright sunlight it burns a trace on a chemically treated time card which when properly adjusted shows the duration of bright direct sunlight and the time at which it occurred. A modified form of this instrument is in use today in great Britain and many other countries [4][5].

Both the Campbell-Stokes recorder and the Maring-Marvin recorder have the fault of being relatively insensitive to weak sunlight as encountered near sunrise and sunset, the Campbell-Stokes recorder being somewhat more sensitive than the Maring-Marvin recorder [5]. The Maring-Marvin recorder, however, has the advantage of being able to operate a recording device remotely by means of electrical impulses. This advantage was undoubtedly largely responsible for its adoption by the U. S. Weather Bureau in preference to the Campbell-Stokes recorder.

As has been stated, neither the Campbell-Stokes nor the Maring-Marvin recorder gives an accurate record of the duration of the visibility of the sun's disk. Neither instrument will record when the sun is near the horizon, and the Maring-Marvin recorder is so sluggish in response that even in the brightest sunlight it may take from 5 to 10 minutes, depending on adjustment and light conditions, for it to respond to the appearance or disappearance of the sun.

The users of the Campbell-Stokes recorder make no effort to correct for whatever loss of record may occur, but are content to accept the record as obtained and call it a record of the "duration of bright direct sunshine." The U. S. Weather Bureau, on the other hand, instructs its
Observers to be on the alert to note the periods during which the recorder does not operate when the sun is shining. In this way record discrepancies presumably are noted and corrected for [2].

With the advent of electronics and the photovoltaic cell it would seem a simple matter to develop a sunshine recorder which would follow the appearance and disappearance of the sun’s disk quite accurately. The Instrument Division of the U. S. Weather Bureau has developed such an instrument, although the solution of the problems involved did not prove so simple.

Preliminary work revealed that the problem is more involved than just arranging for a photocell to trip a relay at a certain pre-determined low light level. It can be shown that the light level can be much greater during the middle of the day at the earth’s surface when the sun’s disk is obscured by certain types of clouds than when the sun is visible but near the horizon. In fact it is entirely possible to have a higher light level regardless of the time of day, with the sun obscured than when visible. For these reasons a fixed light-level switch cannot be counted on to do the job.

A sunshine switch to be satisfactory must be insensitive to sky light, no matter how bright, and highly responsive to direct sunshine. This combination of response has been achieved in the new Weather Bureau switch by exposing two photovoltaic cells uniformly to the sky but shielding one of the cells from the direct rays of the sun by means of a shade ring. The cells are connected in opposition electrically so that as long as the sun does not shine, the response, due to sky light, from one cell just balances the response to sky light from the other cell. When the sun’s disk appears, however, the response of the unshielded cell is greatly increased, but because the other cell is shaded, it is unaffected. This results in an electrical unbalance and a flow of current in an external circuit that trips a sensitive relay; this in turn starts a recorder.

Figure 1 shows the photovoltaic sun switch, and the relation of its component parts. An opal glass cylinder, AB, is mounted in the supporting frame D. In each end of the glass cylinder is mounted a hermetically sealed barrier layer self-
generating type selenium photocell. The response from this cell is great enough that it will trip a sensitive relay without the aid of an electronic amplifier. There is a diaphragm located midway of the cylinder to separate optically one cell from the other. A strip of aluminum foil, C, surrounds the central section of the cylinder to limit the area of light pickup by each cell to a cylinder about one inch long respectively. The shade ring E, 2" wide and 10" in diameter, is capable of being moved and set into three different positions depending on the time of the year. The function of the slotted plate F is to protect the photocells from full intensity of the sun when it is high, but at the same time allowing full exposure and maximum sensitivity when the sun is on or near the horizon. Detents G locate the proper position of the shade ring for the various seasons.

In operation the sun switch is mounted with the tube pointing north and at an angle to the horizon equal to the latitude of the location. (See Figure 2.) The shade ring subtends only a small portion of sky close to the sun, and therefore needs to be moved four times a year in order to keep the upper cell continuously shaded at all times from the direct rays of the sun.

Considering the case when the sun is at the equinox the shade ring is centered about the middle of the top cell. When the sun comes above the horizon in the morning, its rays strike the lower cell light-pick-up-cylinder perpendicular for maximum response. Because of the inclination of the axis of the glass cylinder parallel to the earth's axis, the sun's rays remain perpendicular to the lower cell and to the shade ring all day long. As the sun moves north to its summer solstice position the sun's rays become more and more slanting to the surface of the cylinder (up to 23½°) but since the tube is of opal glass the light is so scattered inside the glass that practically no sensitivity is lost even at the solstice position. As soon as the sun moves north to about eight degrees past the equinoxial position, the shade ring because of its width can be shoved up to its summer position where it remains until the sun is again about eight degrees away from the equinox moving south. The ring is then brought back to its middle position until the sun is eight degrees south when the ring is shoved down to the winter position, etc.

The electrical circuit of the sunshine switch is shown in Figure 3. The photocells PC1 and PC2 are connected in opposition through the 500-ohm potentiometer R1. In operation the potentiometer is adjusted until there is no current flowing through the circuit A, when the cells are exposed to uniform skylight such as exists with an overcast sky. When the sun again appears a current develops in this circuit, which when it amounts to about 10 microamperes will trip the sensitive relay K1, this in turn trips the "slave" relay K2 powered by a storage battery or other source of potential E. The recorder can be the Weather-Bureau type "triple register," the Esterline-Angus recorder or any other "operational" type recorder. Figures 4(a) and 4(b) show typical records of both the Maring-Marvin and the photoelectric switch. These records were made on an Esterline-Angus operational recorder.
utilizing three different pens. The middle trace is a time record for comparative purposes. The distance between two consecutive pips represents a time interval of 30 minutes. The upper trace is the record from the Maring-Marvin switch, operating through the triple register time clock. The lower trace is from the photoelectric switch connected directly to the recorder pen. The “off” position of both recorder pens is toward the time line and the “on” position is away from the time line.

The record shown in Figure 4(b) is typical of a clear day. The photoelectric switch shows more than an additional hour of record for the day than the Maring-Marvin switch. The record shown in Figure 4(a) is typical for a day of broken clouds. The photoelectric switch started about 40 minutes before the Maring-Marvin switch in the morning and indicates considerable broken cloud record which the Maring-Marvin switch did not catch, due to its slow response. By the time the sky became completely overcast during the middle of the afternoon, the photoelectric switch had a score of about 2 hours more record for the day than did the Maring-Marvin switch.

Comparative records for the two recorders were kept for several months in this manner at the Weather Bureau in Washington. The Weather Bureau now has a number of the photoelectric recorders in operation in the field and it is planned to replace the Maring-Marvin recorders as fast as the equipment can be made available.

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REFERENCES