A photographic moonlight recorder

This procedure, which avoids the expense of preparing specimens of exactly equal dimensions, is found to be sufficiently accurate for many cases in practice.

The apparatus may be used for a range of impact stresses by the employment of loads of different weights.

The weight of the load should be such as to require not less than about 10 in. of fall, and under these conditions repeatable results with less than 0·5 per cent. variation have been obtained. It is obvious that the principle of the apparatus may be applied to larger sizes, but the size shown has the advantage of being portable and occupying little space.

A PHOTOGRAPHIC MOONLIGHT RECORDER.

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ABSTRACT. The paper describes a photographic recorder for moonlight. It consists of a cylindrical lens mounted on a light-tight drum which rotates at a speed of one revolution in 24 hours and 50 min., which is the average time of the moon's apparent rotation round the earth. The axis of the drum is set pointing to the pole star and by means of a timing disk the drum is set each afternoon so that the lens follows the position of the moon. Inside the rotating drum is a fixed drum on the outer surface of which is a strip of photographic bromide paper. On this the line image of the moon, produced by the cylindrical lens, is focused. The darkening of the bromide paper gives an indication both of the duration and of the intensity of the moonlight.

In the course of some work on the influence of climatic conditions on insect activity it became necessary to have a record of the duration of moonlight. No instrument appeared to be available to give this information, so that one had to be designed. At first photoelectric methods were considered, but the cost was found to be too high, so that a photographic instrument was finally used.

The difficulties encountered were chiefly due to the rapid changes in position of the moon, which "revolves round the sky" in an average period of 24 hours and 50 min., but may be about 20 min. shorter or longer than this average. It also changes in position from its highest angle at southing to its lowest angle every half lunar month, and is highest in the sky at full moon and lowest at new moon in December and the reverse in June.

Difficulty was originally anticipated in obtaining a photographic paper sensitive to the feeble light of the moon. This, however, was found to be quite a simple matter with the concentration of the light by means of a cylindrical lens.

Principles of the instrument

The instrument finally constructed (Fig. 1) consists in general of a plano-convex cylindrical lens of about 1 in. focal length which is rotated slowly round a fixed drum about 3 in. in diameter so that it produces a line image of the moon on a strip of photographic paper fixed to the outer rim of the drum. The axis of the instrument is directed towards the pole star, and the speed of rotation of the lens is one revolution in 24 hours and 50 min. The position of the lens is arranged each day so as to be exactly directed towards the moon when this is at south. As the total timing error in one rotation is at a maximum 20 min., and as the instrument is seldom used more than 6 hours on either side of southing, that means that the timing error of the lens to the direction of the moon is never more than 5 min., which can be neglected.

A mask is arranged close to the photographic slip so as to allow light only through the centre portion (about 1/3 in.) of the line image when the moon is on a plane at right angles to the polar axis, and the light rays therefore at right angles to the straight front surface of the lens. When the rays become more oblique the line image shifts slightly up or down, but the mask still allows a portion of it to reach the same part of the photographic strip, so that the record does not shift as the moon changes its position relative to the axis of the instrument.

CONSTRUCTION

The apparatus is shown complete (except for a glass cylindrical cover to protect from rain) in Fig. 1 and in diagrammatic cross-section plan and elevation in Figs. 2 and 3. It was made from a standard meteorological one-day clock drum *a* of just over $3\frac{1}{2}$ in. in diameter, the clockwork of which was regulated to rotate at the required speed. The axis *d* was firmly fixed at the bottom to a square stout brass base *e* which can be slipped into a slot in the stand (Fig. 1). At one side of the base is a projecting pointer *f* indicating exact south, which is of course in the middle of the uppermost edge when the instrument is in its inclined position.

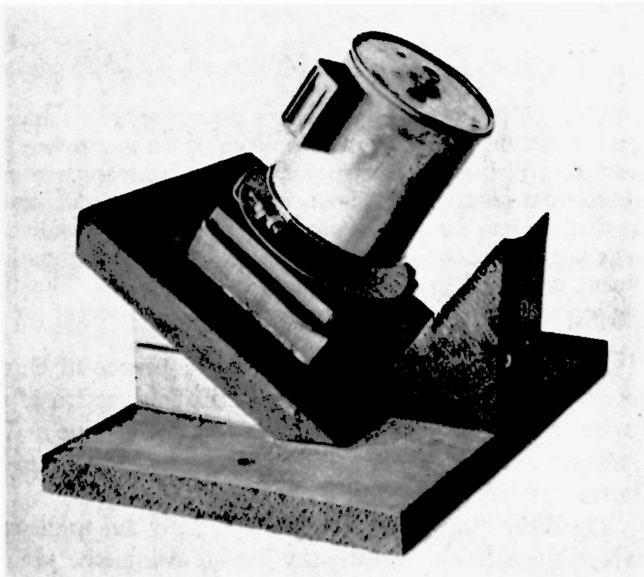

Fig. 1. Photographic moonlight recorder

On the axis just above the base is a disk free to rotate with moderate ease, on which is marked the time scale of rotation *g*. For that portion of the time scale which deals with the middle of the day it is necessary to have two scales, one for the day previous to use, and one for the day following, unless the instrument is always removed before noon and reset after noon. Above this is fixed to the axis the cog wheel *q* round which the drum rotates, and above this the drum itself, free to rotate by its own mechanism. To the upper portion of the drum on one side is attached an oblong projection *i* holding the lens *j* and on the opposite side a counterpoise *l* of equal weight. On the bottom rim of the drum immediately beneath the centre of the lens is a pointer *h* which comes into close proximity to the time scale. When the pointer on the drum is opposite the south indicator on the base, the lens should be facing due south and the image on the photographic strip should be exactly on the south marks on the strip (see below).

Inside the main drum, in the upper portion of it which is free from mechanism, there is fixed to the axis a three-pointed support *m* on which rests a wooden disk or inner drum *o* about $\frac{3}{4}$ in. thick and about $2\frac{7}{8}$ in. in diameter, on the outside of which the strip of photographic paper *p* is fastened. This paper should of course be at the focus of the lens. Between the lens and the inner drum and as near to the latter as possible is the mask *k* to cut out extraneous light and to reduce the length of the image to about one-third of an inch. The side of the inner drum away from the south is cut away so as to allow the ends of the paper strip to be fastened down without anything projecting beyond the outer edge of the drum.

The drum must always be replaced in exactly the same position relative to south and this is arranged by a small projecting peg *n* on one of the arms of the support fitting into a slot on the underside of the inner drum. In addition there are on the edge of the inner drum two very small projecting pin points on the exact south position and one other a little to one side. These pierce the paper strip when it is pressed on to the drum and leave on it a permanent record of the south position of the image and the early and later sections of the record, thereby preventing it from becoming reversed.

Some difficulty was at first experienced in getting the normal push-in joint of the lid of the drum light-tight, but this was finally achieved by lining the inside of the drum and lid with black velvet. All portions of the interior not covered with velvet, including the inner drum itself and the lens holder, are painted dead black.

The instrument when in use is placed on a base of the necessary inclination (equal to the latitude of the locality where used) which is permanently fixed in a position where there will

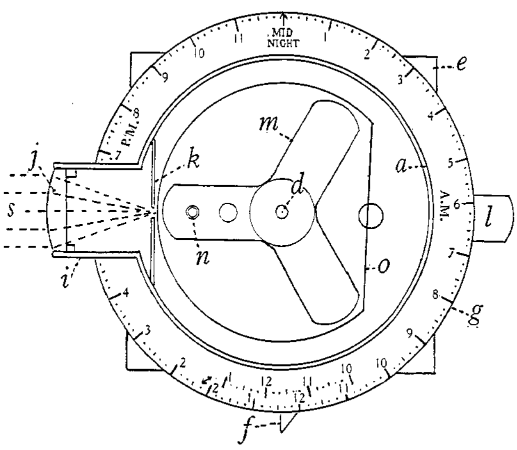

Fig. 2. Plan of moonlight recorder (half size)

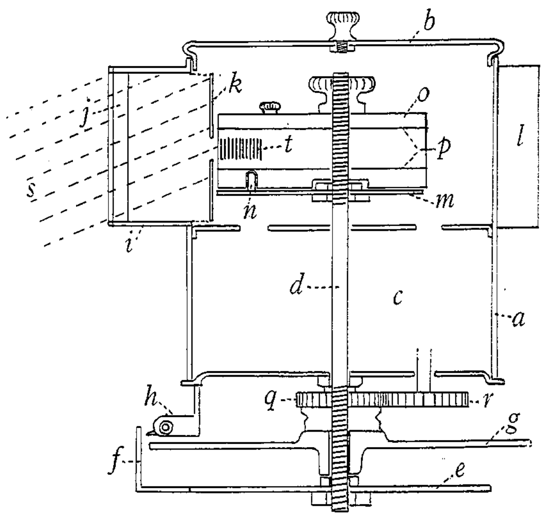

Fig. 3. Cross-sectional elevation of moonlight recorder (half size)

be no obstruction to the free view of the moon from rising to setting. It is further covered with a glass cylinder of about 7 in. diameter with a metal top, to protect it from rain and snow. There is also a small cap to cover the lens which can be put on when moving the instrument.

The photographic paper used at present is Messrs Ilford Ltd.'s normal glossy bromide. It is obtained in sheets $8\frac{1}{2} \times 6\frac{1}{2}$ in. (whole plate), and each sheet is cut longitudinally into about ten strips.

Method of use

The instrument is removed from the fixed stand and taken into a dark room. The inner drum is removed, a strip of photographic paper is fastened round its edge and it is then replaced in its correct position on the support. The lid is replaced on the instrument and the cap put on the lens. The instrument is then replaced on the stand and the timing disk rotated until the time at which the moon will south during the following night is exactly opposite the southing indicator on the base. This "southing time" can be most conveniently obtained from *Whitaker's Almanack*. The drum is next rotated till the pointer beneath the lens points to the actual time at the moment of setting on the time disk. The cap is then removed from the lens and the cover placed over the whole instrument.

On the following day, the pointer should first be inspected to see that it points to the correct time, the cap is then placed on the lens, the instrument slipped from the stand and taken again to the dark room where the photographic strip is developed and dated. A standard strength and time of development should be used so that the darkness of the image may give some indication of the intensity of the moonlight.

After the strip has been fixed, washed and dried it is laid on a time scale with the southing mark (the punctures of the two pins) opposite the correct time, and then the true hours of the night and time of moon rise or moon set, sun rise and sun set can be marked on and all the unnecessary portions trimmed off.

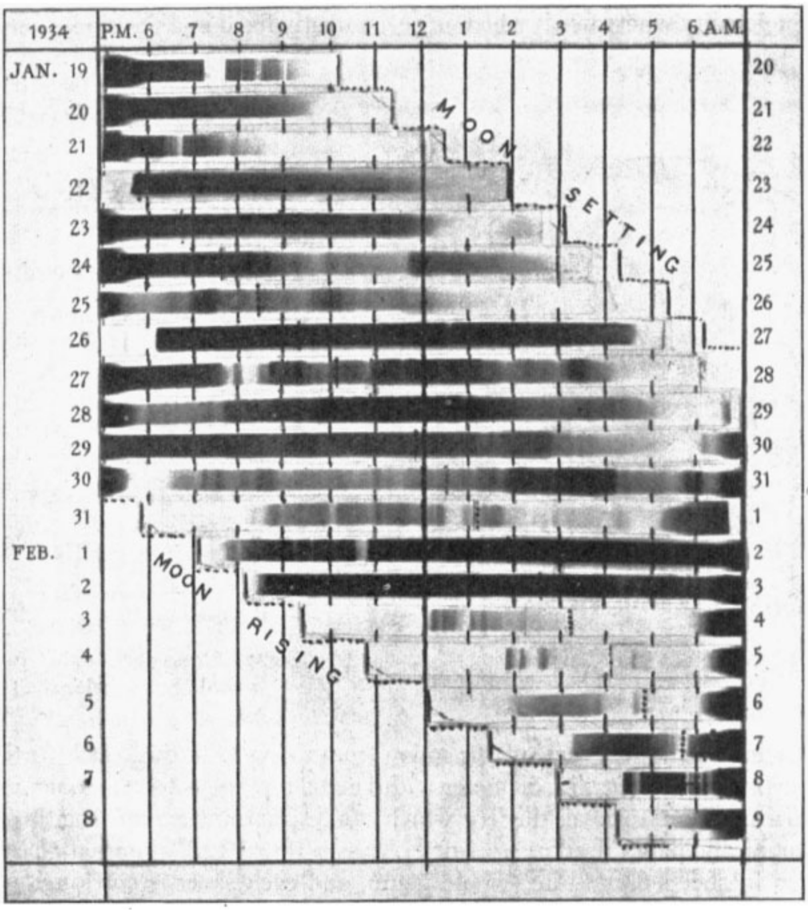

Fig. 4. Specimen records obtained ($\frac{2}{3}$ full size)

As the lens is open during day and night, there is fogging at dusk and dawn which destroys the record for about $1\frac{1}{2}$ hours after sun set and before sun rise, but of this only about $\frac{1}{2}$ hour at each period is really dark enough to be significant. The extent of the fogging is governed by the closeness of the fit of the mask against the paper.

The interpretation of the results largely depends on what use is to be made of them. By a comparison of the charts obtained from this instrument with those from a night sky recorder using the image of the pole star* it is found, as would be expected, that considerable light comes from the moon through thin clouds that obscure the pole star.

* See Introduction to *Greenwich Meteorological Observations*, 1931, pp. E. 8 and 9.

Fig. 4 shows the records obtained during a lunar month in January to February 1934. Within a few days of no moon the records are so faint, and the moon is only above the horizon so near to daylight, that the records are of little value, and the instrument is not now put out during the week of no moon.

From the figure it will be seen that to a certain extent both qualitative and quantitative information can be obtained. Thus on the night of January 19th–20th (first strip, Fig. 4) the sky was clear from 5.30 to 7.15 p.m., heavily clouded from 7.15 to 7.45, and then from 7.45 to 9.15 there were sharp-edged clouds passing across a clear sky giving a series of sharp black line images; the moon set about 10 p.m. On the 20th the sky was clear till 9 p.m. then gradually clouded over and was continuously cloudy till the moon set at 11.20. On the 21st the sky was clear with a few clouds till between 7 and 8 p.m. and then became cloudy till midnight. Other examples show that the sky was quite clear on January 26th and February 2nd; almost clear on January 28th and February 1st; there were thin clouds reducing the intensity and definition of the image on January 25th and 27th; while on February 3rd, 4th and 5th there was heavy cloud except for a few short intervals.

The instrument as described has been in use for just over one year and is sufficiently sensitive to record the light of a lamp of about 300 candle-power at a distance of over 300 yards. It has worked well enough to supply all the information that we desired, but it is possible that a larger drum might be more useful for more accurate work.

The instrument cost £2. 5*s.* 0*d.* for the clockwork drum and about 10*s.* for the lens; the rest of the work was done in our own workshops. The photographic paper is 2*s.* 7*d.* per dozen sheets, so that the cost is below ¼*d.* per night.

Use as sunlight recorder

It has been found by small experiments that the instrument will work equally well as a sunlight recorder, although no continuous use has been made of it in this way. For this purpose the fast bromide paper is replaced by a slow daylight printing paper; the clock adjusted so as to make one revolution in 24 hours, and the time disk must be similarly graduated and permanently fixed with the 12 noon towards the south. There is then no need for the south indicator on the base.

AMPLIFICATION OF A GALVANOMETER DEFLECTION BY RETROACTION WITH A PHOTOCELL.

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ABSTRACT. A method of increasing the sensitivity of a mirror galvanometer is described, in which the light beam falls on to a photocell unit, the current from which is passed through the galvanometer to give an increased deflection, or otherwise to modify the effective galvanometer constants. An experimental assembly is described in detail and curves are given showing its performance. A mathematical treatment is given in an appendix.

Until the use of the photocell was first suggested for this purpose, the production of galvanometers of great sensitivity was accomplished by paying careful attention to their design with the object of increasing the torque on the moving element and reducing the restoring force upon it at any given deflection. Recent developments with the moving coil have made it equal to the moving magnet, except of course, that its characteristics cannot be varied in a given instrument. The present device is useful in that it allows the characteristics of a moving coil galvanometer also to be varied.