SUNDIALS

The Art and Science of Gnomonics

FRANK W. COUSINS

with illustrations by

MALCOLM CHANDLER

Foreword by J. G. Porter

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CORRECTIONS FOR THE EQUATION OF TIME

1. *The Analemma*

We have seen from page 74, FIG. 4 that the equation of time may be readily set out graphically. If now we rearrange it so that the abscissa represents the values for the equation of time plotted against the Sun's declination, then we arrive at curves in the form of a figure of eight which is slightly asymmetrical about the ordinate. Since the declination of the Sun is a function of the date we may insert the dates *on the curve*.

This curve is very similar to the true analemma[1] and we shall use the term hereinafter to signify such a curve. We have seen also that the dial may be provided with a network of lines comprising hour and declination lines such that it may conveniently act as a calendar dial. If now an analemma is constructed on any hour line with due care for the peculiarities of the curve derived from the time distances of the shadow and the position of the shadow at any date, then the said curve may provide a means for converting the local apparent time of the dial face to *local* mean time. A simple analemma for a horizontal and vertical dial is shown in FIGS. 90A and 90B. The enlargement of this idea is well seen in FIG. 91 which shows a vertical dial at the convent of Cimiez-sur-Nice. The skilful designer Père Ildephonse has provided an analemma on each of the hour lines from 7 hours to 17 hours. This shows well the distortions which the analemma suffers from one hour line to another.

If now at the appropriate date the shadow is taken at the appropriate part of the curve then the time will be the *local* mean time. Two superb analemmas drawn by Bedos de Celles are shown in FIGS. 92 and 93. (See Appendix.)

2. *The analemmic style*

A subtle variation of the idea expressed above resides in the analemmic style. In 1892 Major-General John Ryder Oliver was granted British Patent No. 1660 for an open armillary dial

[1] The analemma according to the *Oxford English Dictionary* is a scale of the Sun's daily declination drawn from tropic to tropic on an artificial terrestial globe; an elongated figure of eight.

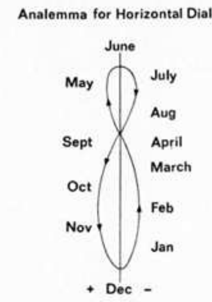


FIG. 90A.

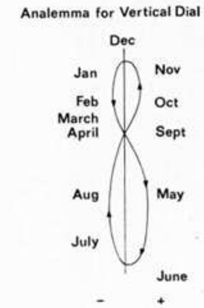
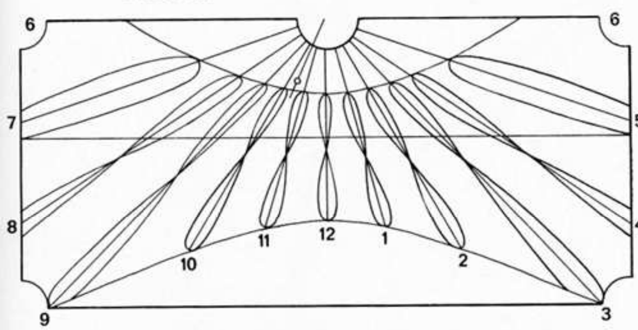


FIG. 90B.



Vertical Dial. Convent. Cimiez-Sur-Nice.
Latitude 43°42′ by Père Ildephonse. c1876.

FIG. 91.

in which the style was of novel design. See FIG. 94. The style carried an analemmic body, the contour of which is the revolution of a curve about a polar axis obtained by setting off along a straight line in both directions from an equatorial zero, series of abscissae, and laying off ordinates at right angles thereto. The abscissae are found for certain dates at given intervals by multiplying the length of the radius of the equatorial arc or circle by the tangent of the Sun's declination (D) for the particular date in question. The ordinates are found by multiplying the same radius by the tangent of the *angular* value of the equation of time (θ). Perfect accuracy demands the use of two distinct styles:

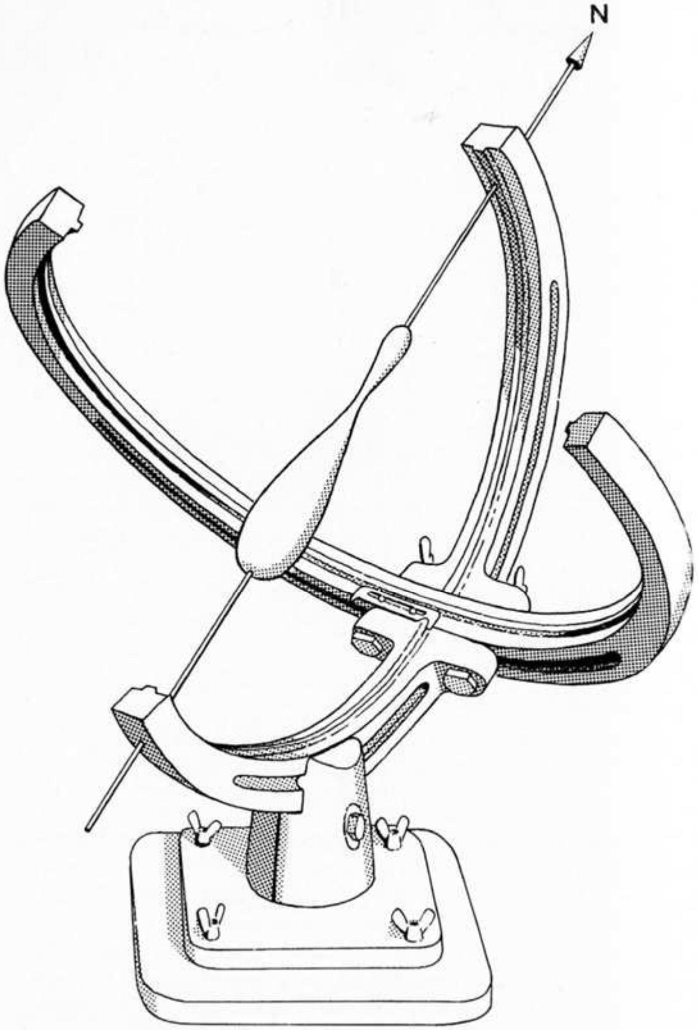


FIG. 94. The Oliver dial with analemmic body on the style.

A large instrument of this type has been erected in Claremont, New Hampshire, U.S.A. It is in Larkin Park, the architects were Criley and McDowell.

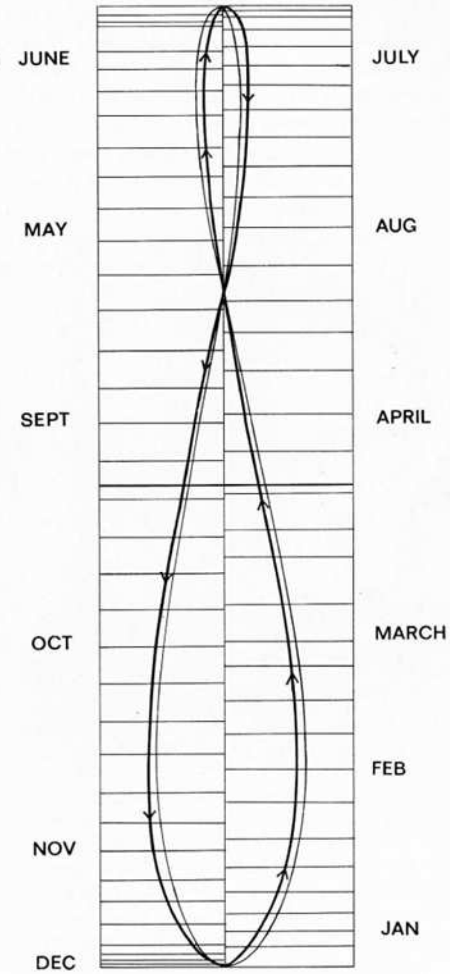


FIG. 95. Actual height $8\frac{11}{16}$ inches.

one for use from the winter to the summer solstice and the other for the following and equal term. A single style of mean contour may be used since the error is inappreciable for small dials. I show my design for an analemmic body for a dial of 10-inch diameter in FIG. 95. The tangent of the Sun's declination and the tangent of the equation of time E are taken at intervals of five days where $\tan E = 0.0000727^s$ where E^s is the equation of time expressed in seconds.

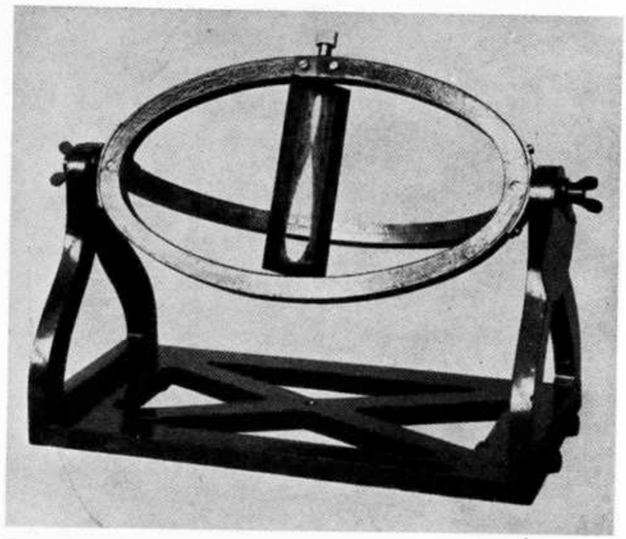


FIG. 96. Sundial capable of showing local mean time. Made by Negretti and Zambra. This sundial is an improvement on the dial patented by Major-General Oliver in 1892. It is designed to indicate local mean time directly, the equation of time being automatically allowed for by the shape of the style that casts the shadow. This style consists of a metal plate from the central part of which a figure of the analemma has been cut out. The time is indicated by the point at which the shadow of the curved edge of the plate intersects the equatorial line on the hour circle, and the plate is marked with the names of the months to show which side of the shadow on the dial plate is to be observed on any given date. The hour circle is engraved with divisions every five minutes, and the instrument can be adjusted for any latitude between 60°N and 60°S.

Major-General Oliver's dial with the solid analemmic body suffers difficulties with the construction of the analemma since the style axis has a finite thickness and the figure of eight cannot pass through zero when the equation of time vanishes as it does four times in each year. He overcomes this objection by a small lateral shift of the dial plate at the appropriate dates.

The British Patent document of 1892 is a model of succinct and accurate description and well worthy of close study. Major-General Oliver developed this idea with a further novel local mean time dial FIG. 96. It will be seen that the improved style has an analemmic aperture instead of a solid body. The aperture allows the equation of time to vanish at the appropriate date; but the style must be rotated to face the Sun.

This fruitful idea reaches its culmination in the elegant design of Mr Richard L. Schmoyer, FIG. 97, in which the style has a slot cut for both the summer and winter curve of the true analemma. The appropriate slot is turned into position and the time is read by adjusting the style for the minimum width of sunlight through the slot. Mr Schmoyer prefers, in making the complex style, to lay out the Sun's declination directly as is seen from his plans for it shown in FIG. 98. The calculations are for a dial plate of radius $6\frac{1}{2}$ inches. The correction of the slot about the gnomon axis obeys the relation

$$\text{Correction} = R \tan \theta^\circ$$

where R is the radius of the dial plate ($6\frac{1}{2}$ inches)
and θ is the equation of time in degrees of arc.

One example will suffice, taken from the gnomon plan:

On Aug 1 Sun's declination $+18^\circ\ 05'$ (D)

Equation of Time 6 min 10 sec (θ)
$\theta^s = 370$ seconds
$\tan \theta^s = 370 \times 0{\cdot}0000727^* = 0{\cdot}02690$
$\text{Correction} = R \tan \theta^s$
$\text{Correction} = 6{\cdot}5 \times 0{\cdot}02690$
$= 0{\cdot}175$ inch

* NOTE. Tan $1^s = 0.0000727$. One can readily use $\tan \theta^s = \theta^s \tan 1^s$ up to 730 seconds of time (3.04 degrees of arc) to an accuracy of four decimal places.

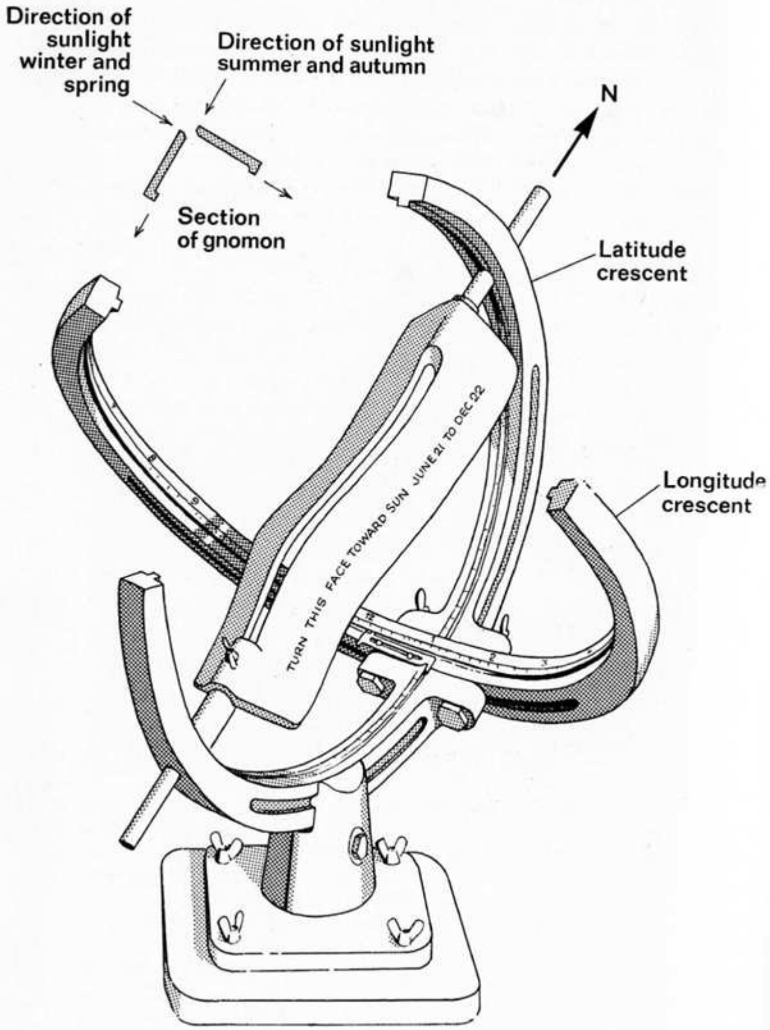


FIG. 97. Sunquest Local Mean Time Dial by R. L. Schmoyer, *c.* 1950.

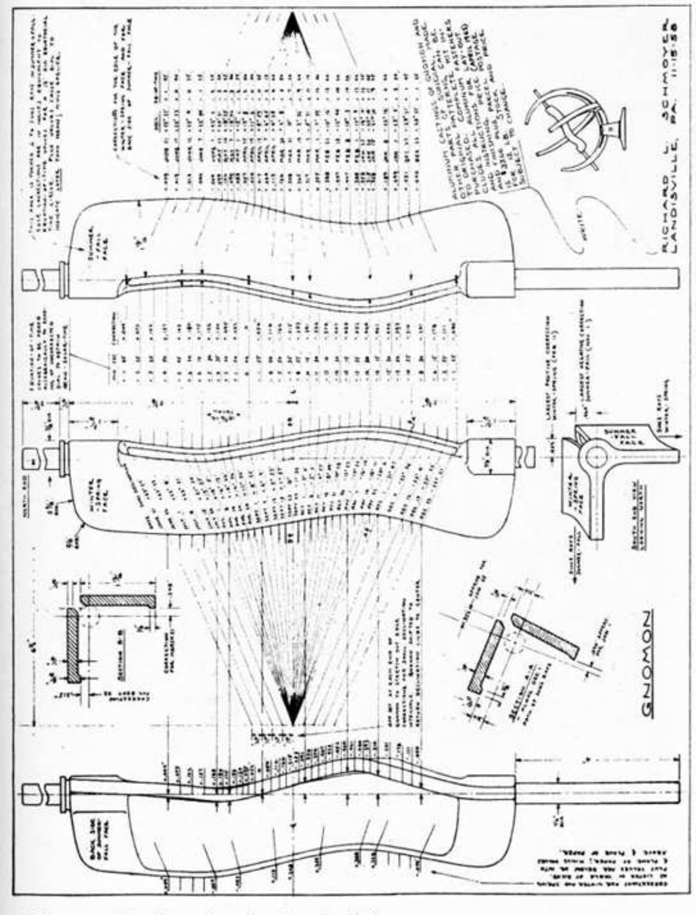


FIG. 98. Working drawing for the Schmoyer gnomon.

Three advanced dials which correct for the equation of time are shown in FIGS. 99, 100 and 101. A refined solar chronometer by Wheatstone is shown on page 67.

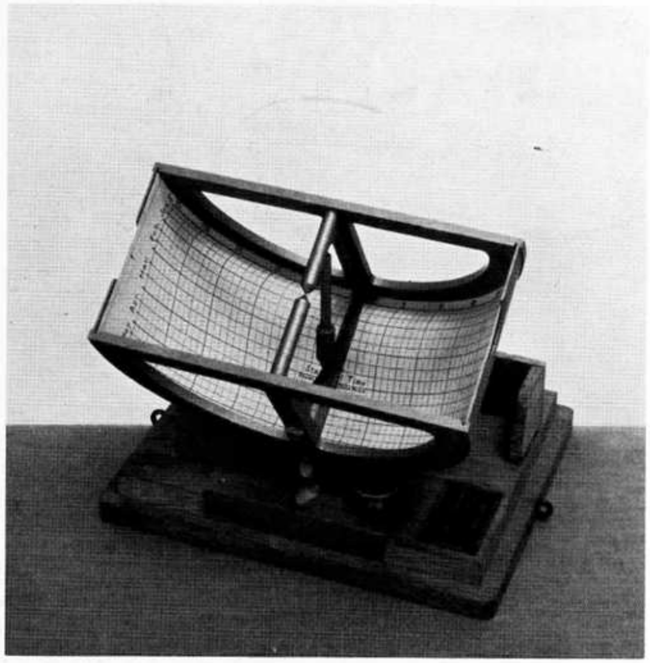


FIG. 99. Ferguson's Solar Chronometer, lent to the Science Museum (London), by Messrs J. H. Steward, Ltd., 406 Strand, W.C.

This is an example of a modern universal sundial arranged to correct for the equation of time.

Two pointed rods parallel to the polar axis, with their points close together, throw a shadow on to a card which is mounted in a frame forming part of a cylinder of which the rods are the axis.

On the card there is a series of curved lines corresponding to the times at which the shadow of the points crosses the lines, and the latter are so shaped as to include corrections for the equation of time. The point on a line where the shadow crosses it on any day depends on the sun's declination and it is necessary to employ two cards, one for use from 22 June to 22 December when the sun is moving south, and one for the other half of the year.

A scale is provided for use in moving the card sideways to correct for longitude and thus obtain standard instead of local time, and the inclination of the instrument can be adjusted for different latitudes by means of a sector and plummet.

Inv. 1922—104.

FIG. 100. Universal Helio-chronometer. Made and lent to the Science Museum (London), by Messrs. Pilkington & Gibbs, Ltd., Preston.

This is a modern equatorial sundial which is arranged to correct for the equation of time and to indicate mean time directly. It is also adjustable to give standard instead of local time.

Mounted on an equatorial disc which turns on a polar axis there is a sighting system consisting of two plates perpendicular to the disc. The disc is turned until light from the sun passes through one or other of two small holes in the first plate on to a line on the other plate and the time is then indicated on the circumference of the disc by a fixed index. To allow for the correction for the equation of time the first sighting plate can be moved sideways by means of a cam which is operated by a second disc mounted on the main disc and bearing a scale of dates.

A quadrant is provided for setting for a change of latitude.

Inv. 1922—156.

FIG. 101. Solar chronometer with vernier scale and analemmic device for the compensation of the equation of time. Bronze. Nineteenth century.

BY COURTESY OF MUSÉE DE LA VIE WALLONNE, LIÈGE

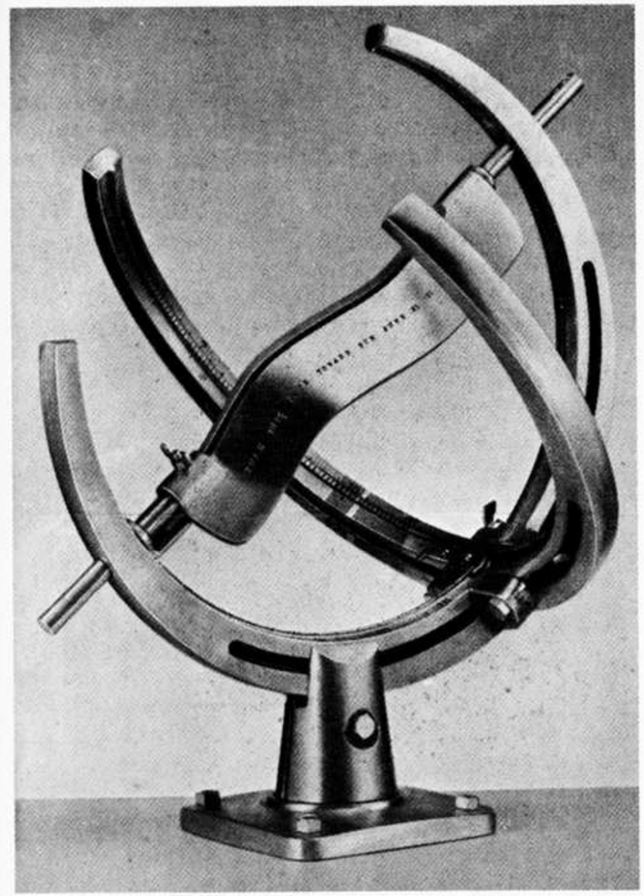


FIG. 102. Example of Sunquest dial in cast aluminium; compare with the drawing, FIG. 97.

3. *The rotation of the dial plate*

In the horizontal and vertical dials the dial plate may be rotated *about the style axis*. This is not usually readily achieved since the dial plate is fixed. To make such an adjustment the style should be extended and provided with suitable journals. If an auxiliary small dial is provided marked in minutes of time correct for the big dial plate ± 15 minutes of a central line and centred on the style axis at the journal then with a simple marker the big dial plate may be set over on any date to compensate for the equation of time without the style being displaced from its alignment with the celestial pole. See FIGS. 103 and 103A.

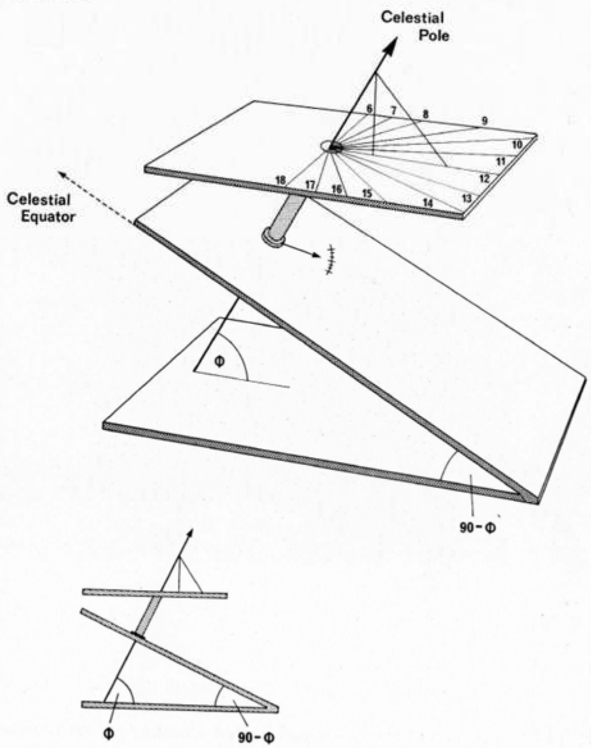


FIG. 103.

CORRECTIONS FOR LONGITUDE DISPLACEMENT FROM THE TIME MERIDIAN

In armillary dials the dial plate may conveniently be shifted bodily to correct for the displacement.

In the dials discussed above the dial plate may be rotated about the style axis. In this way the dial takes up an identical position in space with a similar dial on the time meridian.

Where the displacement is small, vertical and horizontal dials may be marked out to allow for the discrepancy but this is only a palliative and the more desirable course is to correct for the displacement by the continuous application of a constant of correction.

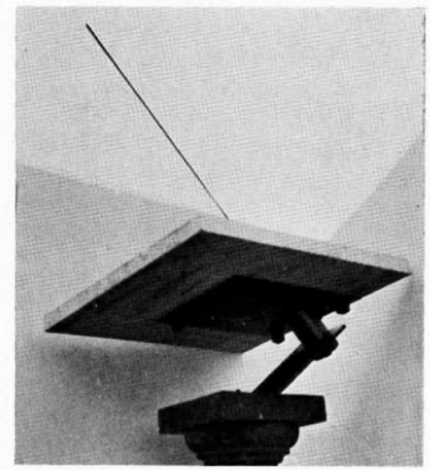


FIG. 103A

This dial, made by the author, is a simple horizontal dial with hour lines marked for latitude 50°48′N. It stands substantially on the Greenwich Meridian. The 'horizontal' plate has been set for the day. (1969 October 25) by rotating it about the Polar (style) axis to compensate for

(i) $+15$m 52s the equation of time for the date.
(ii) The one hour difference between local apparent time and B.S.T.

The dial shadow reads *clock time*. The dial is readily set for any date and gives much satisfaction.