XII

THE HELIOCHRONOMETER

Plates XXXI and XXXII

Early sundials indicated local apparent time. We have shown you how the equation of time may be used to obtain local mean time from the apparent time of the sundial, and how the correction for longitude may be used to obtain standard time from the sundial (Chapter VI). Correction tables made for use with a sundial require some mental calculation. Many dials, both portable and stationary, were made in the 18th and 19th centuries that incorporated the equation of time in their construction. This enabled one to read local mean time directly from the dial. The analemma was the device that made direct reading possible.

When standard time came into use, a further correction was required in the dial's construction if a direct reading instrument was desired. One method was to incorporate the difference in longitude between the place and its standard time meridian into the analemma. Another was to use a standard analemma resulting from the plotting of the equation of time and a dial plate that could be adjusted for the difference in longitude. The latter method is the one we shall describe, for it is the simplest and easiest to construct.

Description (Plate XXXI)

The heliochronometer is just what its name implies—a solar chronometer. Its accuracy is commensurate with its construction. It is not a toy but an instrument for education as well as for timekeeping. We shall use an equatorial dial plate which faces north and lies parallel to the equator.

The heliochronometer consists of four basic parts: base, dial plate, alidade or sighting instrument, and analemma.

The base is fixed in place.

The dial plate is attached to the base so that it may be rotated about its center.

The alidade is attached to the dial plate so that it can be rotated about its center, which is coincident with the center of the dial plate. Consisting of a flat plate, the alidade has two fixed upright arms perpendicular to the dial plate. One arm contains the style or nodus, the other the analemma.

The analemma here is based on the equation of time, when E = A — M (same as the table on page 87 but with reversed signs).

The size of the dial is left for you to decide. We show the construction of the basic elements, and the diagrams are pretty much self-explanatory.

Construction (Plate XXXI)

The base WXYZ (Fig. a) may be a block of wood cut as shown in Fig. b, the angle WZH equal to the co-latitude (90° minus latitude). The bottom of the base is HZ, which must be leveled on a pedestal or other firm support and fixed

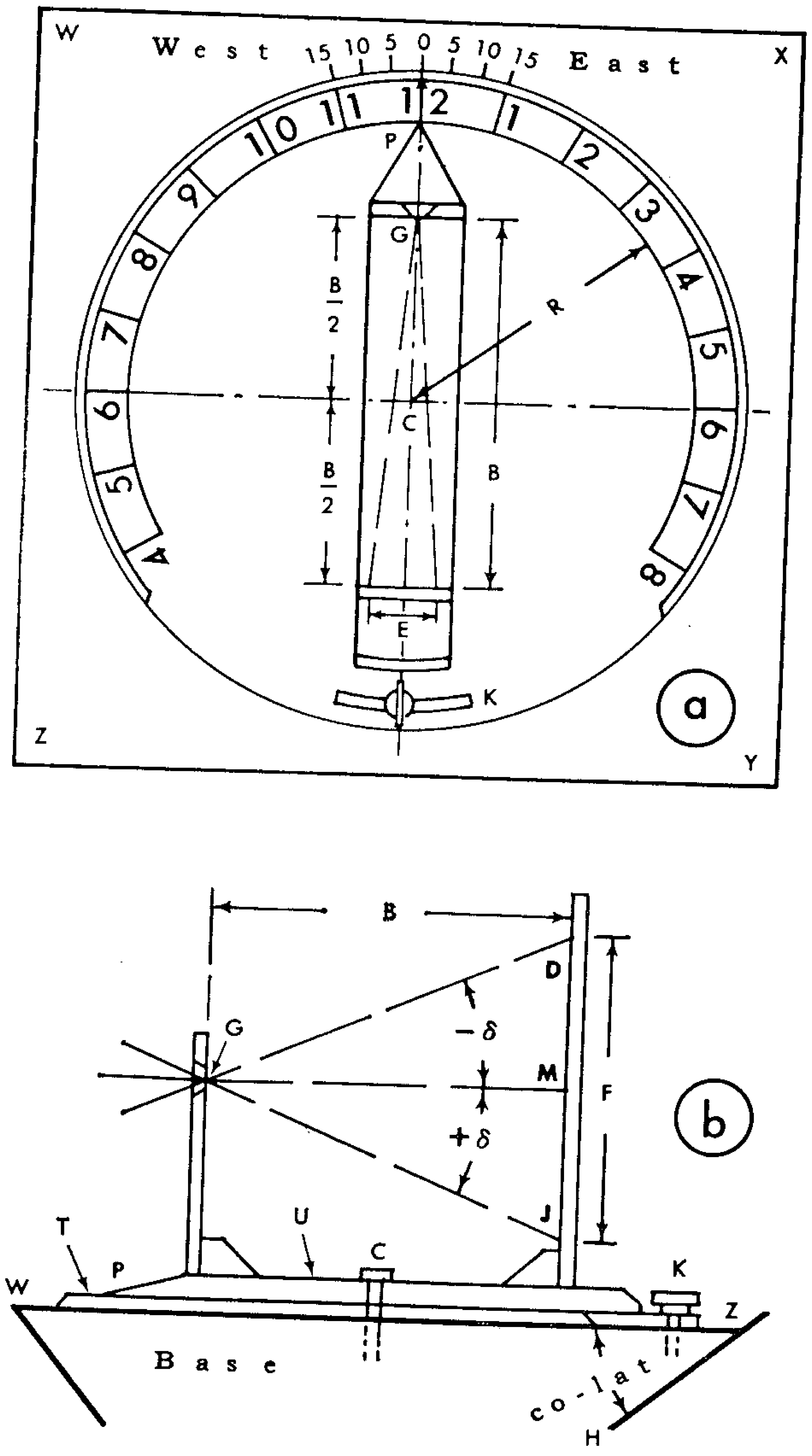


Plate XXXI.

in place. When properly adjusted, WZ will lie parallel to the equator; a perpendicular to WZ, erected at C, will point to the celestial pole; the center line of the face will lie in the plane of the meridian.

Here the base is square and represented by WXYZ. Bisect WX and WZ, and draw lines parallel to the sides, intersecting at C, the exact center. The dial plate and the alidade will rotate about the center C.

The dial plate (Fig. a) is shown as you would see it from directly above. With C as a center and radius R, describe a circle, which is then divided into equal segments of 15° for each of the hours. The number of subdivisions of each hour will depend on the size of the dial. A dial plate having a radius of 6 inches or more may be divided into minutes. The 12 o'clock line, if extended, would intersect the celestial equator at the true south point.

When you have determined the outside diameter of the dial plate, mark a point on the face of the base opposite 12 and label it o, as shown. Then with C as the center and radius Co, describe a 15° arc on each side of o and divide both at intervals of 1°. Mark these divisions East and West as shown. This will be the longitude scale.

The alidade must be proportioned to the dial plate, and centered at C. One end is pointed at P, which indicates the time. The center line of the alidade is its meridian and is coincident with the center line or meridian of the dial plate and base. The distance CG is one-half B.

The width of the arms is determined by the overall width of the analemma, E, which never exceeds plus or minus 16 minutes. Therefore, to be sure to have enough room, provide for 20 minutes or 5° on each side of the center line.

The height of the arms is determined in a similar manner, as shown in (Fig. b), by drawing GM parallel to the dial plate and laying off from G the declination of the sun at the winter and summer solstices. Lines drawn from G through these points will intersect the other arm at D and J. The point G is the style or nodus, and it is located in the south arm. The style or nodus may be a simple pinhole, the intersection of two cross hairs, or a bead centered inside of a small hole.

The line GM represents the path of a ray of light when the sun is on the equator at the equinoxes in March and September; GD at the winter solstice in December; and GJ at the summer solstice in June. The distance B is the same as in (Fig. a), and the distance F is the limit of the path a ray of light will travel during the year. The arms of the alidade must be kept perpendicular to the dial plate T at all times. All that remains to construct is the analemma.

The Analemma (Plate XXXII)

In (Fig. a) the point G represents the style; B the distance between the arms; D, M, and J the positions of the equinoxes and solstices; $\pm\delta$ north and south declinations; $\pm E$ the equation of time; GT the meridian of the dial and the analemma; GM the equator perpendicular to GT. Draw lines through D, M, and J parallel to GM.

Set a protractor on GT centered at G and lay off on each side of GT angles equal to minutes of time — 1° = 4 minutes, 2° = 8 minutes — and draw lines from G through these points to the solstitial line J. We have shown here only the lines representing 10 and 20 minutes (2 1/2° and 5°).

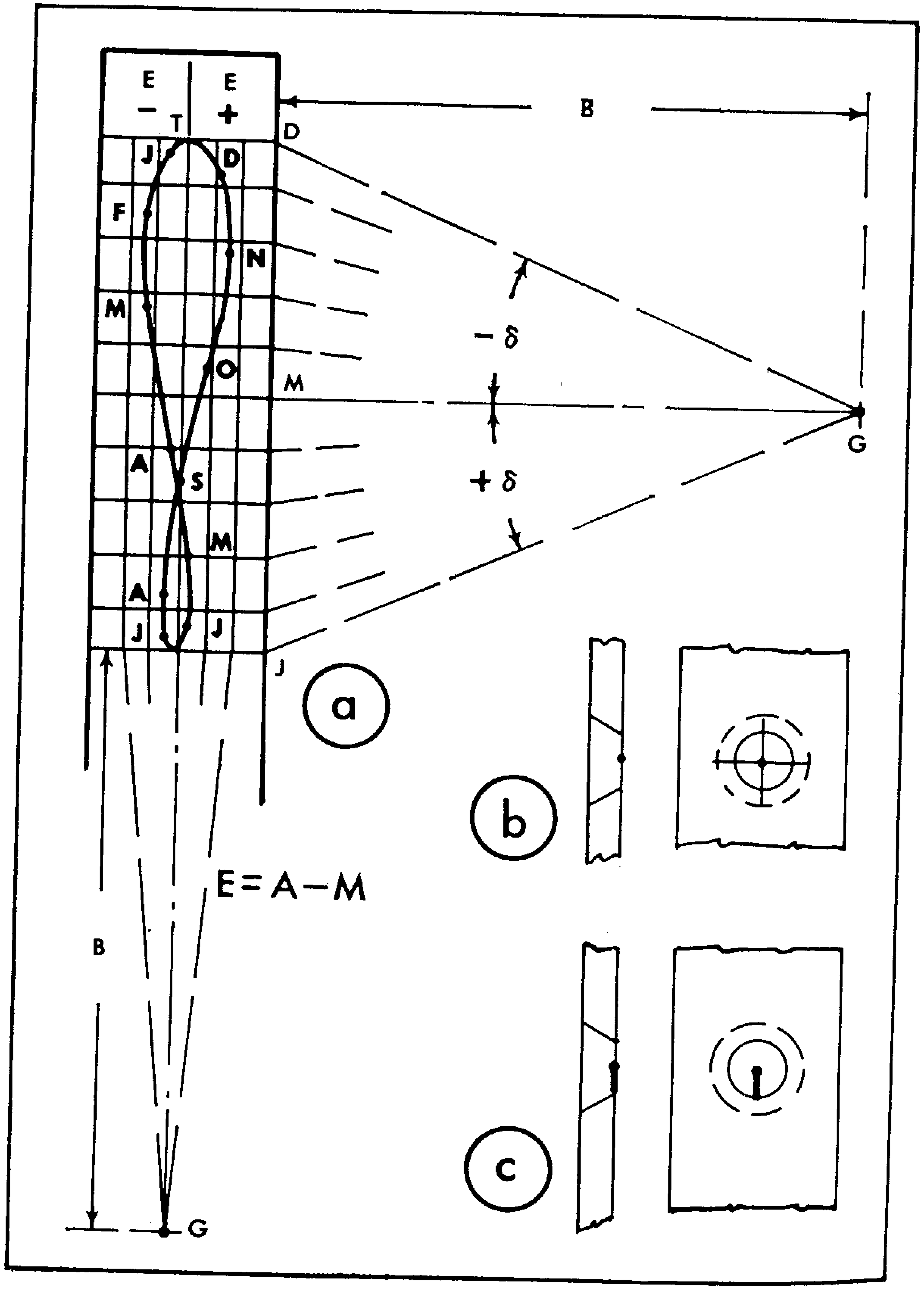


Plate XXXII.

The positive and negative equations must be marked as shown when E = A — M.

Now set a protractor on GM centered at G and lay off on each side of GM angles at 1° intervals. Draw lines from G through these points to the side of the arm DMJ, and through the points on DMJ draw lines parallel to GM. We have shown here only 5° intervals and the declination of the sun at the solstices. North and south declinations must be marked as shown.

This provides you with a grid upon which the equation of time may be plotted easily. The vertical lines are minutes of time, the horizontal lines degrees of declination. Plot as many points as necessary to obtain a smooth curve: the 1st and 15th of each month, the points where the equation is greatest and where it is zero, and the equinoxes and the solstices. As many days as desired can be marked on the curve of the analemma. This completes the dial, except for making a slot in the dial plate at K (Plate XXXI, Fig. a), and fitting it with a thumbscrew or other device by which the dial plate may be locked in place.

Using the Dial

When properly set, the alidade will be in the position shown on Plate XXXI (Fig. a) when it is noon local apparent time; and at four times during the year it will be in this position at noon local mean time.

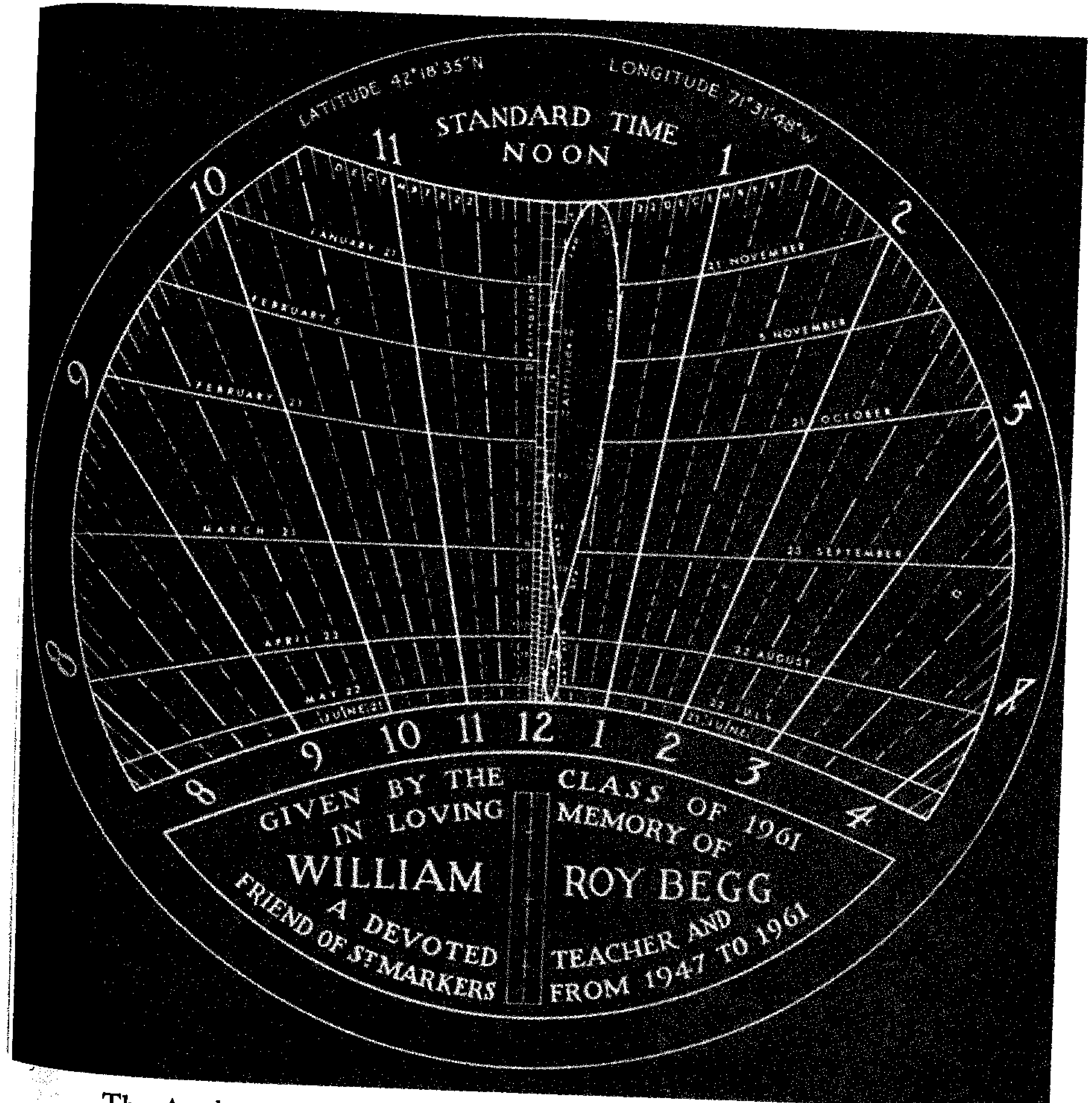
To obtain local mean time at any hour on any day, just turn the alidade until the light passing through the hole at G is centered on that portion of the analemma corresponding to the date. In this position P will indicate local mean time.

To obtain standard time we must adjust the dial plate for the difference in longitude between the place and its standard time meridian. Unloosen the thumbscrew and turn the dial plate until the 12 o'clock line is opposite the number of degrees on the longitude scale equal to the difference between the meridian of the place and the longitude of the standard time meridian. Since this always remains the same, the dial plate may be locked in this position. Then, turn the alidade until the spot of light is centered on the analemma corresponding to the date in question. The pointer P will now indicate standard time.

You can make the dial more interesting if you mark every five days on the analemma and mark the degrees of declination on one side and the degrees of altitude on the other side of the analemma. With this data incorporated, the dial becomes more useful. You can use it to show the declination and altitude of the sun, the day of the year, apparent time, mean time, standard time, and the equation of time.

If you do not wish to use a dial plate that can be set for the difference in longitude, you can incorporate the difference in the analemma. If you are east of the standard meridian, subtract the difference from the equation of time; if west, add the difference. For example, assume a dial on each of three meridians reading $2^h\ 15^m$ p.m. on April 1. The equation of time is $+3^m\ 59^s$, or say $+4^m$. Since the equation here is based on $E = M - A$, the equation is added to the time of the sundial to obtain mean time. Then we can add or subtract the difference in longitude to or from the equation to obtain the total correction to be added to the reading of the dial to obtain standard time, as follows:

If the three dials mentioned above are on the 77th, 75th,



The Analemma permits Local (sundial) Time to be corrected to Standard (watch) Time.

A Wall-type Dial at Rapperswil, Switzerland.

and 72nd meridians, the computation for the corrected analemma is:

77th meridian $= 2°$ long. or 8^m west

$$\text{Cor.} = + 4^m + 8^m = + 12^m$$

75th meridian $= 0°$ long. or 0^m

$$\text{Cor.} = + 4^m + 0^m = + 4^m$$

72nd meridian $= 3°$ long. or 12^m east

$$\text{Cor.} = + 4^m - 12^m = - 8^m$$

The result is the hour angle for the corrected analemma, which is plotted in the same manner as for the standard analemma; but first reverse the + and — signs for E, Plate XXXII, Fig. a. When the corrected analemma is plotted with respect to the meridian of the alidade, the dial plate is set with the 12 o'clock line always opposite 0 on the longitude scale, or in the plane of the meridian.

If you want to make a more accurate dial than can be done by geometric construction, the shape of the analemma may be computed.

Formulas for the Analemma

Trigonometric tables are available with the angles given in hours and minutes. If you do not have such a table, you must first convert the equation of time into degrees and minutes of arc for the number of points desired.

Let

E = horizontal distance from meridian GT, Plate XXXII, Fig. a

D = vertical distance from equator GM, Plate XXXII, Fig. a

B = distance between arms of alidade, Plate XXXI, Fig. b
H = equation of time in hour angle or in degrees
δ = declination of sun

NOTE: On Plate XXXI, Fig. b, the style G and the equator M must be equidistant above the dial plate.

Then

$$D = B \tan \delta$$
$$E = B \tan H$$