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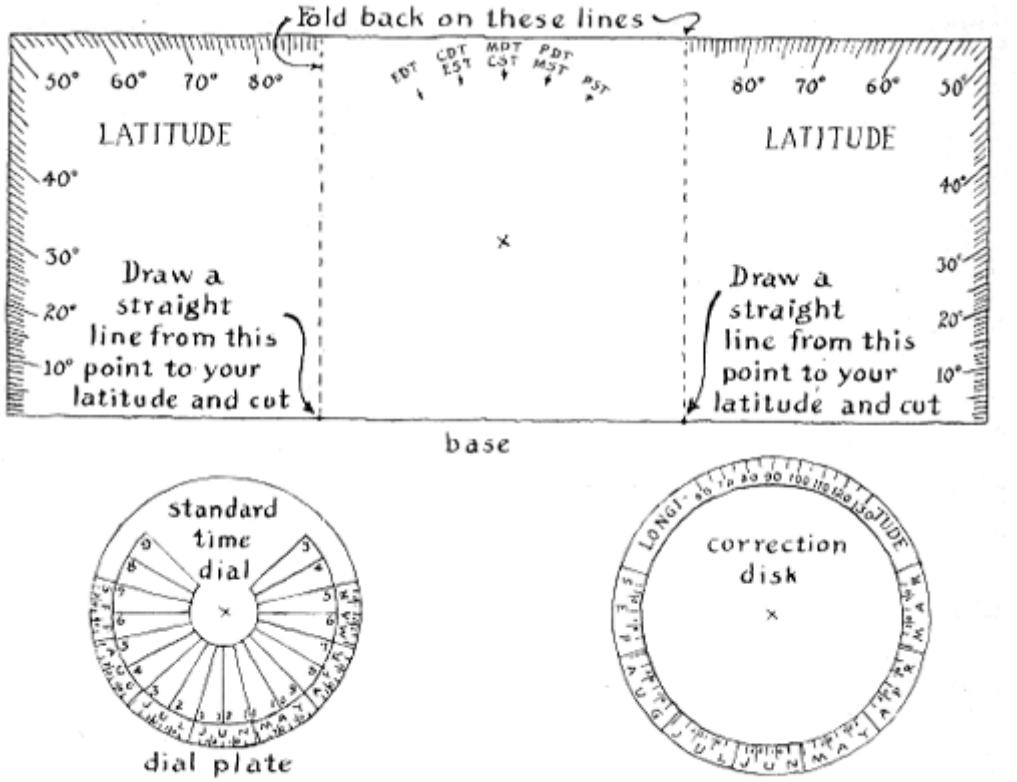
Charles J. Merchant, a mathematician at the University of Arizona, submits the following description of a sundial for indicating standard clock time that can be made in less than an hour. "A sundial," writes Merchant, "even when it is perfectly constructed and correctly installed, generally indicates a time substantially different from standard clock time. This often leads people not familiar with the beautiful intricacies of sun time to the erroneous conclusion that a sundial is an inherently inaccurate device. Sundials that indicate a time correctly to within one minute can be constructed with no great difficulty; with refinements they can be accurate to within a few



seconds.

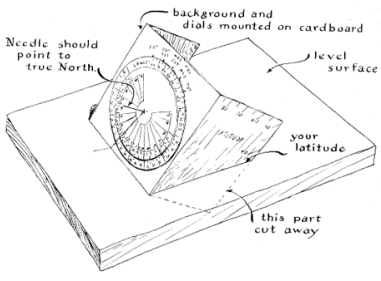


Figure 7: How the sundial is mounted

"The difficulties with sun time versus standard time stem from two sources. The eccentricity of the earth's orbit and the obliquity of the ecliptic cause the sun to gain or lose as much as a minute a day over considerable periods of time, with accumulated inaccuracies of plus or minus 15 minutes at certain times of the year. The correction for this variation is known as the equation of time. When this correction is applied to the reading of a sundial, the result is local mean time. Local mean time, however, is the same as standard time in the U.S. only in those cities whose longitude is 75, 90, 105 and 120 degrees. In all other localities standard time differs from local mean time by a constant amount depending on the longitude of the place. This second cause of a sundial's apparent inaccuracy is known as the longitude correction.

"Two corrections must therefore be applied to the reading of a conventional sundial in order to derive standard time: the equation of time, which varies from day to day, and the longitude correction, which is constant for a given place.

"Numerous methods, some of considerable ingenuity, have been devised for making a sundial indicate standard time directly. My sundial accomplishes this by means of a circular computer. The face of an equatorial-type dial is rotated by various amounts depending on the setting of a pair of disks. When the device is properly adjusted, it indicates standard time correctly to within better than five minutes. It operates only during the spring and summer months, from the vernal equinox to the autumnal equinox; during the other six months of the year the sun lies below the equatorial plane. A set of disks could be calibrated for this interval, but they have not been included with this model.

"The dial was designed to be cut out and mounted on thin cardboard, using a non-wrinkling cement such as Gripit. Rubber cement does an excellent job, but it is not permanent. After they have been mounted on the stiff backing the parts are carefully cut out. The base is then cut off for the latitude of the place where it is to be used and bent at right angles along the broken lines [*see above*]. When properly mounted on a baseboard and placed on a level surface, the face makes an angle with the horizontal equal to the colatitude of the place.

"The disks are then assembled on the face. A needle, pushed through the center mark from below, serves both as the means of assembly and as the gnomon. The gnomon should be as exactly perpendicular to the face as possible!

"The larger of the two disks, the correction disk, is placed face up on the needle first, then the smaller of the disks. Finally a small piece of cardboard, to act as a retaining washer, is pressed down on the needle.

"To operate the sundial the correction disk is first rotated so that the longitude of the place is opposite the arrow on the face that indicates the local time zone. (The abbreviations are self-explanatory: CST means Central Standard Time, MDT means Mountain Daylight Time, and so on.) For example, when the dial is to be used in New York City during the period of Eastern Daylight Time, the correction disk is turned so that 74 degrees, the longitude of New . York City, is at the arrow marked EDT. This disk will require [no] further adjustment. It can be fixed to the base plate with a small piece of drafting tape. The tape must not interfere with the movement of the smaller disk, however. This disk must be adjusted every few days.

"The correction disk carries a date scale that is graduated nonlinearly to correct for the equation of time. The outer edge of the dial plate also carries a date scale, but this scale is graduated linearly. When the dial plate is rotated so that a given date on the dial plate coincides with the same date on the correction disk, the time scale is automatically rotated by the amount necessary to correct for the equation of time on that date.

"Finally, the dial is set on a level surface-in the sun-with the gnomon pointing exactly north. The dial then indicates correct standard or daylight time. For instance, assume that the dial is to be used in New York City on July 10. The latitude of New York City is 41 degrees. The base support should be cut for this angle. The longitude of New York City is 74 degrees. On July 10 Eastern Daylight Time is in effect. The correction disk is therefore rotated so that longitude 74 degrees is at the EDT arrow. The correction disk should be taped to the face plate. The smaller disk is then turned so that July 10 coincides with the July 10 date on the larger disk. The dial is next placed on a level surface in the sun with the gnomon pointing exactly north. The shadow of the gnomon now indicates correct Eastern Daylight Time for New York City.

"It should be noted that this dial will indicate correctly even in those cases where a city operates under an incorrect standard time zone. Certain cities in eastern Indiana and western Ohio, for example, operate on Eastern Standard and Eastern Daylight Time even though they are well within the Central Standard Time zone. In these cities follow the rule of setting the longitude of the city to the arrow representing the time zone under which it operates. The dial will indicate the correct clock time.

"Although the dial is calibrated only for the time zones of the continental U.S., it can be used anywhere in the Northern Hemisphere. Merely add or subtract from the longitude of the place that multiple of 15 degrees which results in a longitude within plus or minus 7.5 degrees of 90 degrees, and then use the resulting longitude with the arrow for CST or CDT, depending on whether standard or daylight time is in use. All longitudes must be converted to longitude west of Greenwich, however. Thus longitudes east of Greenwich should be subtracted from 360 degrees to give west longitude."

Bibliography

SUNDIALS: HOW TO KNOW, USE, AND MAKE THEM. R. Newton Mayall and Margaret L. Mayall. Charles T. Branford Company, Publishers, 1958.