Twentieth-Century Sundials

by LOTHAR M. LOSKE, engineer, Zurich

Fig. 1. — *The largest and most complete modern sundial in the world,* in a public park at Frankfurt. It contains over 19 ½ cwt of copper and is 11 ½ feet in diameter. The shadow thrown on the dial by the single cord serving as a gnomon shows " true solar time ", " mean solar time " and standard time for the place at which it is situated and also for all other places in the world, as well as " world time " in hours.
A special scale running on ball bearings makes it possible to take direct measurements for some 280 towns throughout the world whose names are engraved on it.

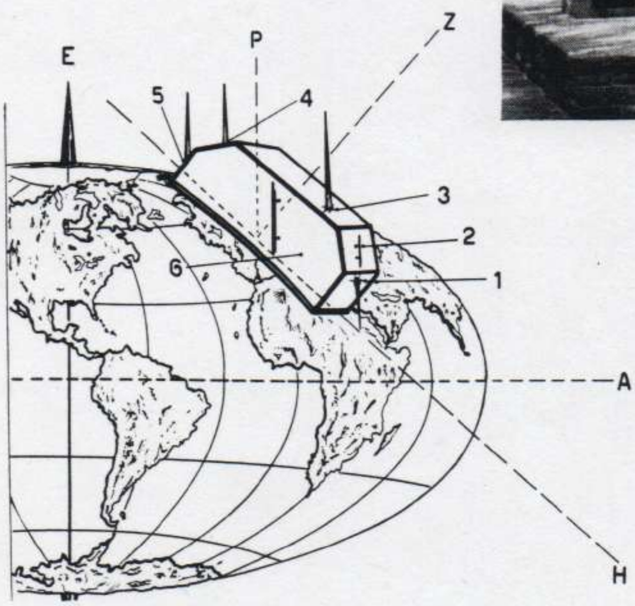

Fig. 2. — *The " sundial-house "* illustrates six of the most common types of sundial with gnomons pointing to the pole and shows their positions in relation to the earth's axis.

The technical development of modern clockmaking and chronometry is largely responsible for the fact that so few people today have any accurate knowledge of the real astronomical and mathematical principles that govern the sundial. Gnomonics, or the theory of sundials, has had a long history, in the course of which it has always been based on serious scientific principles. The ancient laws referred to in the writings of Vitruvius and Ptolemy were superseded by " modern gnomonics ". This science in its turn has undergone many changes extending down to the twentieth century. Thus it is quite possible to design a sundial complying with the modern notions of time that are familiar to us in an age of intercontinental and transpolar air travel, indicating " world time " and " standard time-units ", for instance.

Theoretically, there is no reason why a carefully designed and constructed sundial should not be more accurate than a mechanical clock. Of course, the precision, and therefore the timekeeping properties, of a mechanical clock will depend mainly on its regulating-organ. But all the parts of the latter are subject to manifold influences that may impair the

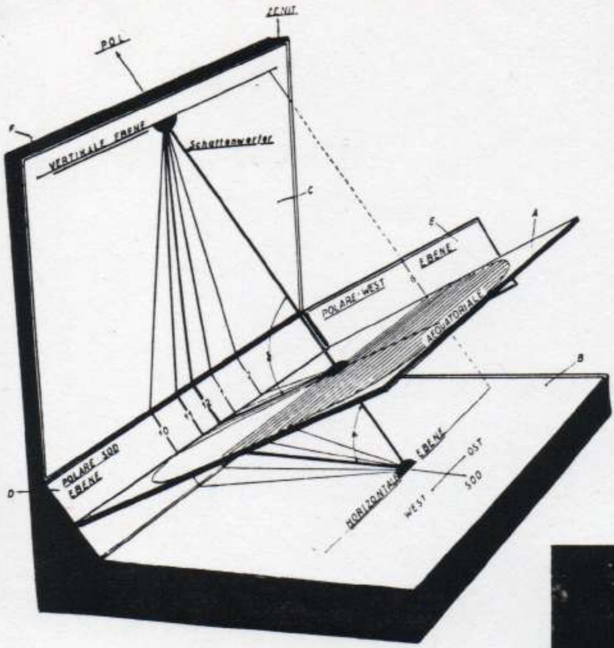

Fig. 3. — *Diagram* showing the line indicating 12 o'clock noon (" true solar time "), as it appears on various surfaces, with a gnomon set at right-angles to the plane of the equator.

Fig. 4

Fig. 4, 5, 6. — *Equatorial sundials* in wrought iron, made to the designs and calculations of L.-M. Loske, 1954. They belong to various private owners and show " true solar time ", " mean solar time ", standard time and the solar calendar.

accuracy of a mechanical clock. The sundial is regulated by the daily rotation of the earth, i. e. the apparent movement of the sun round it. For thousands of years, human measurements have shown that these movements are practically constant ; they have therefore become the world's *standard clock*.

It follows that the first essential in correctly designing and constructing a sundial is an understanding of the motion of the earth and sun. The diagrammatic representation of a so-called " sundial-house " comprises six of the most common types of sundial and shows their positions in relation to the earth's axis. The differences between them are determined according as the plane of the dial, when extended, points to the horizon, the zenith, the pole or the equator.

1. The *south vertical sundial* carries the shadow of the gnomon over the dial as long as the sun's rise and fall from east to west occurs toward the south.

2. The *south polar sundial* has a shadow that is always parallel to the gnomon and to the plane of the dial. It must face due south.

3. The *horizontal sundial* makes it possible to determine the times from sunrise to sunset. It may be observed from any of the four cardinal points and is highly suitable for use on an open lawn.

4. The *equatorial sundial*, like the horizontal type, may be used at any time when the sun is shining. It makes an interesting and attractive ornament for a park or garden (see the illustrations). The gnomon and the plane of the dial are either parallel or at right-angles to each other.

5. The *north vertical sundial* is the counterpart of the south vertical type. Its position is not particularly favourable, and it can only be used if the sun appears to the north of the east-west axis.

Fig. 5

6. The *west polar sundial* gives a shadow parallel to the gnomon and can only be used in the afternoon. The surface on which the shadow falls must face due west. The counterpart to this dial, for use in the morning, would be an *east polar sundial*.

Vertical and even polar sundials may be set up on surfaces that are not exactly at right-angles to the north-south axis. Such *deflected vertical dials* show more of the morning hours

Fig. 6

Fig. 7. — *Equatorial sundial* in a peraluman armillary sphere. *De luxe* construction with enamelled dial-surfaces, made to the designs of L.-M. Loske, 1956. ▷

Fig. 8. — *Small garden sundial*, with equatorial hourdivisions for "mean solar time" on the standard time meridian and time-equation curve. By L.-M. Loske, 1956.

when deflected eastwards and more of the afternoon hours when deflected westwards. As houses are not as a rule placed in accordance with the requirements of a sundial and rarely have a wall facing due south, the deflected mural sundial is to be preferred in many cases.

The "sundial-house" clearly shows the feature that all sundials have in common, viz. gnomons which are all parallel to one another and to the terrestrial or celestial axis. If the "sundial-house" were erected at the north or south pole, all the gnomons would point upwards, forming a right. angle with the plane of the horizon- The names of the various sundials, as given above, would no longer adequately describe their dial-surfaces. For instance, the horizontal sundial would become an equatorial one, while vertical dials would become polar ones, and so on.

If the "sundial-house" were erected on the equator, all the gnomons would be parallel to the plane of the horizon, and the entire system would be changed to such an extent that the names given above would be contradictory. In all latitudes between the poles and the equator, however, the positions of the dials would fully correspond to the names given with the sketch.

A gnomon must always be parallel to the earth's axis, and this position is obtained by raising it above the plane of the horizon, through an angle equal to the geographical latitude at which it is situated. It follows that the angle between the gnomon and the plane of the dial will differ according to the latitude, especially if the sundial is of the horizontal or vertical type.

For instance, the "sundial-house" shown in the sketch is situated at the centre of Geneva, the geographical position being 46° 12' N., 6° 9' E. The angles between the gnomons and the dials are therefore as follows :

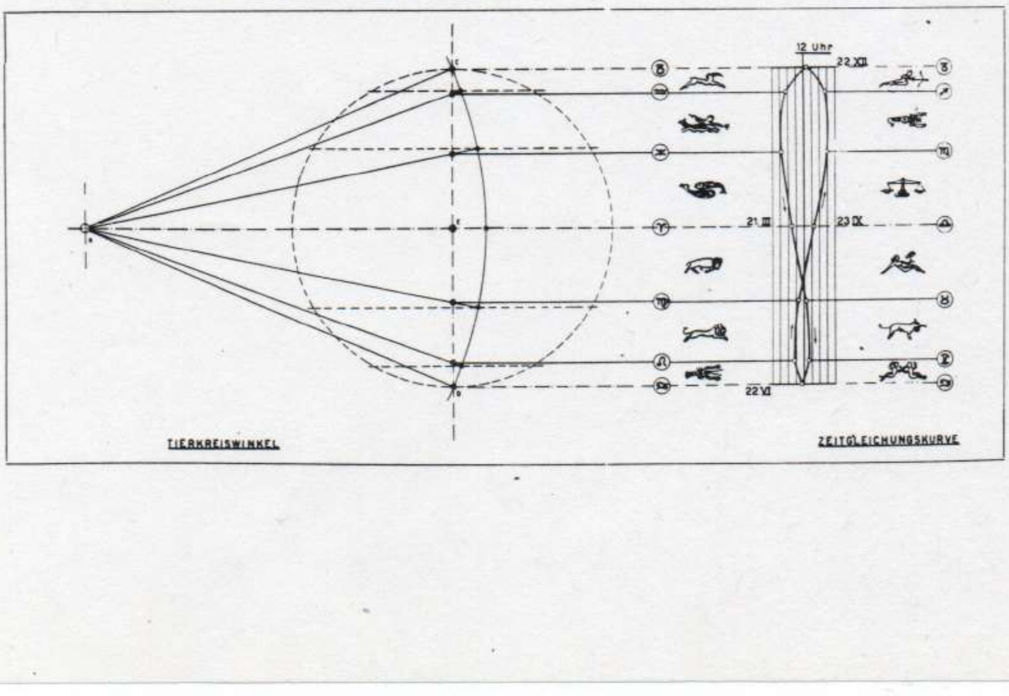

Fig. 9. — Diagram of a zodiac-sector and a time-equation curve for a sundial.

1. The south vertical dial is at right-angles to the plane of the horizon. The angle between the gnomon and the plane of the dial, which faces south, is 90° - 46° 12' = 43° 48'.

2. The south polar sundial requires the angles of the dial-plane and of the gnomon to correspond to the elevation of the pole. Therefore both must be raised southwards above the plane of the horizon parallel to it. As a rule, however, the gnomon is raised southwards through an angle equal to the elevation of the pole, i. e. the geographical latitude.

5. In the case of the north vertical sundial, the gnomon is raised above the plane of the horizon through an angle equal to the elevation of the pole. It is thus in inverse relation to the south vertical sundial.

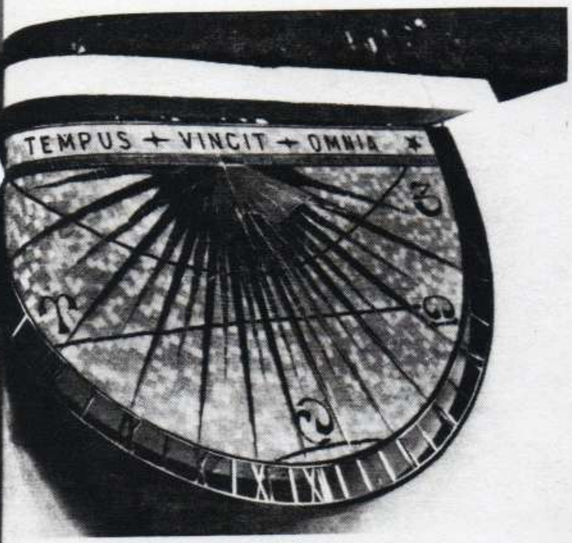

Fig. 10. — *South vertical sundial* in wrought iron, bronze and stained-glass mosaic. The sundial shows " true solar time " taking into account the difference in longitude between the place where it is situated and the standard-time meridian, as well as the paths of the equinoxes and solstices. By L.-M. Loske, 1953.

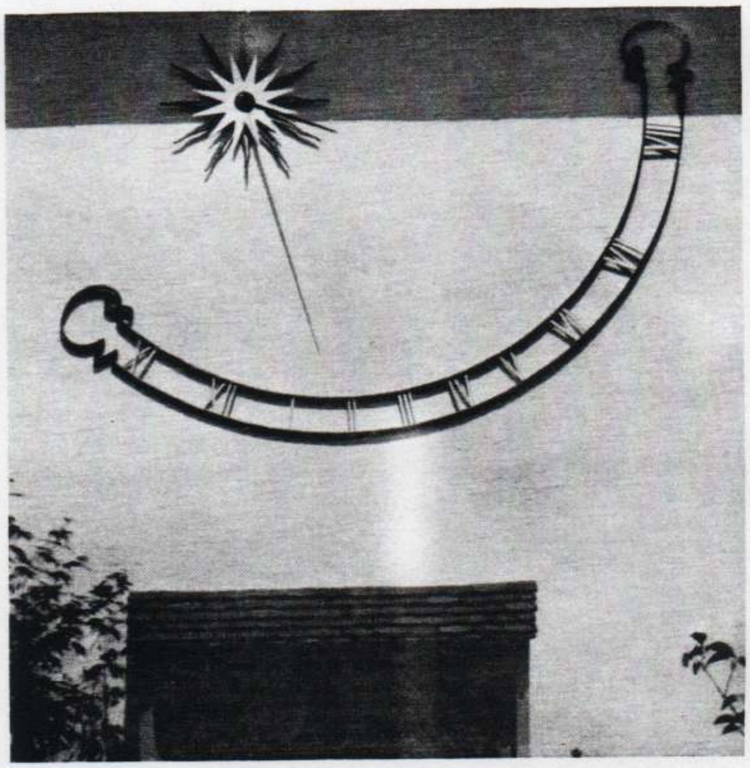

Fig. 11. — *Vertical sundial* as a wall ornament, for " true solar time " duri ng the afternoon. By L.-M. Loske, 1955.

through an angle equal to the geographical latitude, viz. 46° 12'.

3. As its name implies, the horizontal sundial must be exactly on the plane of the horizon. The gnomon must be raised above the plane of the dial through an angle equal to the geographical latitude.

4. The equatorial sundial is exceptional insofar as there are two possibilities as regards the plane of the dial. It may be either at right-angles to the gnomon or

6. The east polar sundial and the west polar sundial on the opposite side are placed vertically, with the gnomons parallel to the vertical walls. The gnomons are set diagonally to the observer. The right-hand end of the gnomon of the east polar sundial is raised above the horizontal plane through an angle equal to the geographical latitude ; in the case of the west polar sundial, the left-hand end of the gnomon must be raised through a similar angle.

The harmony of the hour-lines

There is a uniform geometrical relation between the hour-lines of all types of sundial whose styles point towards the pole (the value of this arrangement has only been recognized since the fifteenth century). The basis of this is always a circle divided into 24 sectors of 15° each. Each of the resulting arcs equals the distance over which the shadow of a gnomon set up at right-angles at the centre travels in a true solar hour, supposing the plane of the arc to be parallel to that of the equator.

Fig. 3 shows a plane of this kind *A*, with a circle set above the horizontal plane *B* at an angle of about 45°. Through the centre, there runs a line drawn parallel to the earth's axis. This may form the gnomon of a sundial. The divisions of the circle, together with the gnomon, form a so-called equatorial dial *A*, on the plane parallel to the equator. The line drawn through the centre to indicate 12 o'clock noon clearly shows the connexion between all other lines indicating 12 o'clock, as well as their harmony. All other hour-lines, whether they lie on the horizontal plane *B*, the vertical plane *C* and *F*, or the polar plane *D* and *E*, have their origin in the centre of the gnomon of the equatorial dial. It is not possible for all the hour-lines extending from the centre to fall on the planes envisaged as dial-surfaces. Thus it is impossible for every type of sundial to show the time throughout the day. It is quite clear that polar dials are especially deficient in this respect, and that equatorial and horizontal dials are the best as regards the distribution of the hour-lines.

" True solar time "

Without exception, the divisions shown diagrammatically in fig. 3 refer however to " true solar time ".

Therefore 12 o' clock noon, as well as the other hours, correspond but rarely to so-called " mean solar time ", not to mention the ordinary standard time used in public life, i. e. the time shown by our mechanical clocks.

Thus it may easily happen that a sundial whose divisions correspond to " true solar time " is thought to be inaccurate. The truth of the matter is, however, that sundials of this type do not divide up time in the same way as our everyday clocks, with which we expect them to agree.

However, the discrepancies between sundials designed to show " true time » and mechanical clocks keeping standard time vary from place to place. They are due only to the technical progress achieved in the nineteenth and twentieth centuries.

Sundials showing standard time and world time.

Most of the ancient sundials on the walls of our old churches or hidden away in castle gardens were set up in an age when " mean time ", " standard time " and " world time " were notions of no importance whatever. Yet this does not mean that the most natural, and probably the oldest, time-measuring instrument known to man — the sundial — is quite unrelated to our modern " artificial " methods of counting the hours.

As a matter of fact, sundials can be designed with a so-called " time-equation table ", which accurately shows the daily difference between " true " and " mean " solar time. The differences between " true " and " mean " time, as noted on the earth in the course of a year, may be ascertained from the time-equation tables given in astronomical almanachs, or from a watchmaker's pocket calendar, if it is a good one. Fig. 9 shows a scale of these differences in the form of a loop-like curve, for an equatorial sundial with a cylindrical dial-plane.

Sundials with curves of this kind require a special type of gnomon. Whereas in simple sundials the gnomon may be a plain rod or a piece of thin sheet metal, a perforated gnomon is required for use with a scale of the kind shown in fig. 9.

The shadow of a thin gnomon will move daily across the entire breadth of the dial, from its westerly to its easterly half, without taking any account of the seasonal inclination of the apparent path

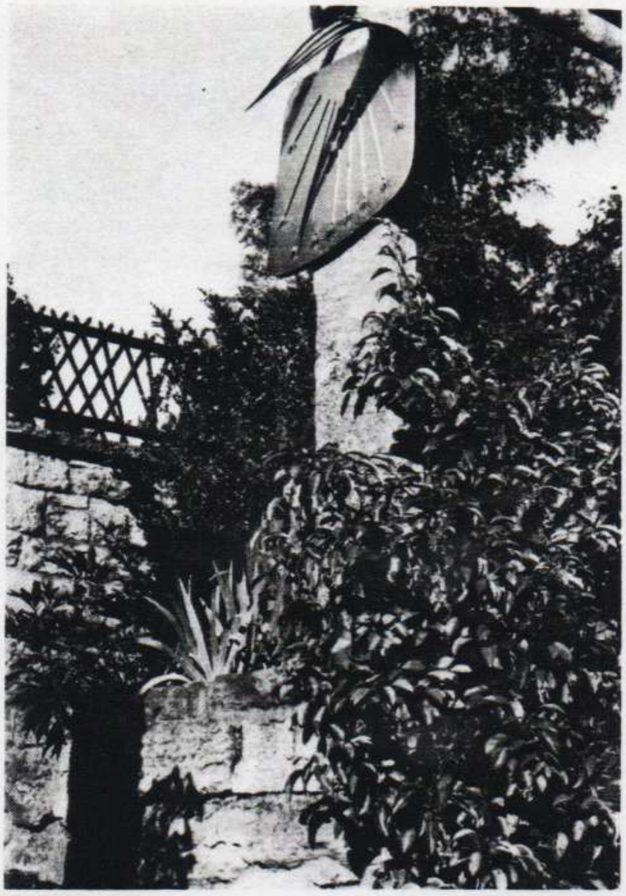

Fig. 12

Fig. 13

Fig. 14

Fig. 12. — *Vertical sundial* in modern style, of hand-beaten aluminium, in three colours. By L.-M. Loske, 1952.

Fig. 13. — *Horizontal sundial* in the form of a flower. A long central pistil acts as a gnomon, and the shorter stamens bear the hour-numbers. According to their width, the petals correspond to the exact hour-divisions of the horizontal sundial showing " true solar time ". The " flower " is made of polychrome anticorodal, beaten by hand. By L.-M. Loske, 1952.

Fig. 14. — *A sundial as a piece of modern sculpture in metal*, in hand-beaten copper and peraluman. The curved metal rod with the " north star " acts as a gnomon. By L.-M. Loske, 1956.

of the sùn. But if the gnomon has a small hole in the middle, its shadow will be broken by a point of light. This point will also move daily across the divisions of the dial from west to east, but never in exactly the same plane as on the previous day. In winter, when the sun is nearest to the horizon, the point of light will move along the top edge of the dial ; in summer, when the sun is highest, it will move along the lower edge of the dial.

This up-and-down movement of the point of light in the shadow of the gnomon provides us at the same with a so-called " solar calendar ", from which we can ascertain the difference between " true " and " mean " time for a given date.

If, as is usually the case, the sundial is not placed exactly on one of the standard time meridians (the one for Central Europe is 15° east of Greenwich), it is essential to shift the divisions of the dial round an axis parallel to that of the earth, so that standard time may be read off directly. This correction is not very complicated to make. For instance, if a sundial is situated 8° east of Greenwich, the geographical difference between " mean noon " at the place in question and " mean noon " at the meridian that determines " Central European Time " (M. E. Z.) amounts to exactly 7°. In relation to the entire circumference of the earth, one degree of longitude corresponds to a period of 4 minutes, so that in this instance the difference is equal to $7 \times 4 =$ 28 minutes. In other words, noon on the 15th degree of longitude east is 28 minutes ahead of noon on the 8th degree of longitude, where the sundial is situated. After the dial has been shifted accordingly, the line indicating noon no longer coincides with that of a normal sundial showing " true time ". The two terms " local time " (i. e. the time according to the actual position of the sun as observed at a given place) and " standard time " (i. e. the time shown by mechanical clocks) become perfectly clear if we construct a sundial with both types of calibration. Thus, even in our technical age the sundial is not only an ornament, but at the same time an instrument that may stimulate experiment and thought. We are confronted with the notion of " true time " — the earliest form of time-measurement known on our planet, with the sun as its point of reference — in the " time-space continuum " of the universe.

Sundials give as an idea of the beauty and grandeur of astronomy and mathematics; they enable us to use the light of the heavenly bodies themselves to count the hours of our existence.

Fig. 15. — *Monumental sundial* in front of the Swiss Trade Fair building at Basle. This exceptionally valuable sundial was presented to the Swiss Trade Fair this year, by Messrs. A. Türler & Co., watch-manufacturers. It shows all time-measurements for Basle, such as " true solar time ", " mean solar time ", standard time and the values of the time-equation and elevations of the sun, with calendar. Designed and calculated by Lothar-M. Loske.