The Setting of the Sundial.

CHAPTER III.

The sundial is an interesting device for indicating the solar time of the place, or places other than where fixed. Its construction is founded upon the astronomical theory of the sun's apparent motion; and from these its rules and operations have been deduced by the aid of geometry and trigonometry.

The sundial, at the present time, is made in many forms, the one usually met with being the horizontal form seen on a pedestal in many gardens. The next is the vertical dial to be seen on many old churches and houses. There are also a number of others, such as the hemispherical, cruciform, cylindrical, polygonal, armillary sphere—commonly known as the "globe"—reclining, inclining, and a great variety of pocket dials.

THE HORIZONTAL GARDEN DIAL consists usually of a circular metal plate, divided into five-minute spaces, the hours, compass points, ornamental star, border and motto nicely engraved by hand, and a metal gnomon for casting the shadow to indicate the time of day. The larger dials, from 15 ins. in diameter, are divided to single minutes, but this is not always advisable, especially in low latitudes, as the minute divisions come too close together between the hours of 10 o'clock and 12 o'clock, and from 12 o'clock until 2 o'clock, so that the lines appear almost as one. When making a sundial of this description it is necessary for the maker to know the latitude, or name of the place where the dial is going to be fixed.

THE VERTICAL SUNDIAL, which in construction is similar to a horizontal dial, is for placing in an upright position, such as on the wall of a church or house, or one of the side faces of a tall upright pillar. It should be made for, and fixed on, a wall having a southerly aspect, so as to receive as much sun as possible.

Before constructing a vertical dial it is necessary for the maker to know the declination or true aspect of the wall, expressed in degrees, in addition to the latitude of the place. These figures must be absolutely correct, for the whole accuracy of the dial depends upon the figures given. The makers prefer to ascertain the

declination themselves, for they alone then hold themselves responsible for the dial to indicate correct *solar* time.

There are many ways of measuring the length of a day in use in this country (the British Isles), but not one of them is perfect as a system for universal daily use. The three chief kinds of time used in this country are Greenwich mean time, Solar, or apparent time, and Sidereal, or star time; this latter is the only exact time and is used by astronomers alone. The time varies by several minutes between each of the methods mentioned.

The difference between sundial time and clock time is due partly to the irregular motion of the earth travelling in its path round the sun. Sometimes it travels faster and sometimes slower. It is also due partly to the fact that the time shown by our clocks and watches, called *Greenwich mean time,* is purely artificial and imaginary, not agreeing with any natural time at all, nevertheless for commercial purposes, it answers very well.

The sun crosses the meridian at Greenwich at 12 by the clock upon only four days in the year; on all other days it is either before or after the clock, the difference varying from a few seconds up to as much as a little over 16 minutes.

On looking at the map of England it will be seen that from the extreme east coast (Lowestoft) to the extreme west coast (Land's End) the country extends from Greenwich 1° 45′ on the East 5° 40′ 25″ on the West. Now, as the sun appears to travel from an easterly to a westerly direction each day, and takes four minutes to travel over one degree of longitude, it can be seen that it will take about 30 minutes to travel across the whole country, and the time of all places east of Greenwich is fast, whilst at others west the time is slow. For example, supposing a sundial in position at each of the following places, Lowestoft, Greenwich, and Land's End, and it was noon at Lowestoft by the sundial, the time indicated at the moment by each dial would be as follows: Lowestoft, 12 o'clock; Greenwich, 7 minutes to 12; Land's End, about $22\frac{3}{4}$ minutes to 12. But our watches would have given the time as 12 o'clock at all places at the same moment, so we see that something is required in the way of a table calculated for every day of the year, giving the variations daily between the sundial and the watch.

The following table, called an "Equation Table," gives the difference in minutes, and you will notice that the sundial and clock

both agree on four occasions during the year: 15th April, 14th June, 1st September, 25th December.

EQUATION TABLE.

FAST MEANS THAT THE WATCH SHOULD BE FASTER THAN THE DIAL.

SLOW, SLOWER.

JAN.		FEB.		MARCH.		APRIL.		MAY.		JUNE.	
Days.	Mins.	Days.	Mins.	Days.	Mins.	Days.	Mins.	Days.	Mins.	Days.	Mins.
2 Fast	4	3 Fast	14	4 Fast	12	1 Fast	4	2 Slow	3	4 Slow	2
4	5	20	14	8	11	5	3	15	4	10	1
7	6	27	13	12	10	8	2	28	3	14	0
9	7			16	9	12	1			20 Fast	1
11	8			19	8	15	0			24	2
14	9			23	7	20 Slow	1			29	3
17	10			26	6	25	2				
20	11			29	5						
24	12										
28	13										

JULY.		AUG.		SEPT.		OCT.		NOV.		DEC.	
Days.	Mins.	Days.	Mins.	Days.	Mins	Days.	Mins.	Days.	Mins.	Days.	Mins.
4 Fast	4	4 Fast	6	1	0	1 Slow	10	11 Slow	16	1 Slow	11
10	5	12	5	5 Slow	1	4	11	17	15	4	10
19	6	17	4	8	2	7	12	22	14	6	9
		22	3	11	3	11	13	25	13	6	8
		26	2	13	4	15	14	29	12	11	7
		29	1	16	5	20	15			13	6
				19	6	27	16			15	5
				22	7					17	4
				25	8					19	3
				28	9					21	2
										23	1
										25	0
										27 Fast	1
										29	2
										31	3

The sundial, as already mentioned, shows *solar* time, but by adding or deducting the differences, as shown above, *local mean time* is found, and by again adding or deducting the difference of longitude, *Greenwich mean time* is the result. For instance, a sundial at Wrexham (3° West longitude) on the 11th March indicates 11 o'clock, and we want to find Greenwich mean time. We proceed as follows :—

	H. M.
Wrexham Sundial	11 0
Difference of Equation, *add*	0 10
Local Mean Time	11 10
Difference of Longitude, *add*	0 12
Greenwich Mean Time	11 22

We see by the above, that the watch should be 22 minutes faster than the dial.

A well-made sundial should have engraved upon it an equation table and the longitude of the place where it is fixed, and the consequent allowance of time to be added or substracted to find *Greenwich mean time.*

SUNDIALS SHOULD BE FIXED on a bright, sunny day, a horizontal dial being fixed as follows :—First see that the stone pedestal on which the dial is to be fixed is perfectly rigid, also flat and level on top. Remove with a pair of pinchers or plyers the three button-headed studs that are usually fitted on the back of the dial, then place the dial approximately in position by moving it about until the shadows show the time within a few minutes, and with a pencil, mark the positions of the studs on the stone through the holes in the plate. Remove the dial and replace the studs in the dial; cut the three holes about twice as large as the heads, so that the dial has plenty of play to the right and left to facilitate final adjustment. Mix with water a little Portland cement, which is known as "grouting," damp the holes in the stone and pour the grouting in and place the dial in its place, turning it until it shows correct *solar time* of the place, taking care that the plate is level, and then allow the cement to set. The dial is now fixed, and requires no further refixing at any time.

To ascertain correct *solar time* for fixing purposes proceed as in the example given here, and for the purpose we will take Andover (1½° West) as the place where the dial is about to be fixed on 1st October.

	H. M.
Greenwich Mean Time	10 30
Difference of Longitude, *deduct* ...	0 6
Local Mean Time	10 24
Difference of Equation, *add*	0 10
Andover Solar Time	10 34

So we see that on 1st October the dial must be fixed 4 minutes faster than the watch.

The gnomon of a horizontal sundial is always fixed on the XII. o'clock line, which represents the *true* north and south

meridian, and its edge is elevated above the plane to an angle equal to the latitude of the place. In the northern hemisphere XII. o'clock and the elevated end of the gnomon are always placed towards the north, but in the southern hemisphere the elevated end and XII. o'clock are placed facing the south.

In northern latitudes the sun is always *due south* at XII. o'clock by the sundial throughout the year, and in southern latitudes it is always *due north* at XII. In both hemispheres the sun is always due east at VI. a.m. and due west at VI. p.m.

Sundials can be fixed in dull weather, but a magnetic compass will then have to be employed; and although the fixing is simpler than when the sun is used the result is not so accurate.

The directions are as given here :—

Remove the studs and place the dial on the pedestal; take the compass, which should have a square box with needle, and lay it on the dial plate with the east or west side of the box close against the gnomon, and allow the needle to settle. Then, knowing the "magnetic variation" of the spot—for example, we will take London, which is 16° west of the *true north*—turn the sundial until the north end of the needle coincides with the 16° division west of the N. of compass dial. Take a pencil and mark the holes for studs; cut the holes and fill with grouting; place the dial on the pedestal and finally adjust with the compass before the cement sets.

Sundials can be fixed by the compass, and by the sun, providing the sun is shining on the dial, at any time during the day. To read the time shown by a horizontal sundial, stand facing the sun, and for the morning hours take the right hand edge of the shadow, and for the afternoon hours take the left hand edge.

Sundials of good make have the hour-lines and other divisions radiating from two centres, which are at a distance apart equal to the thickness of the gnomon, consequently there appears to be two hour lines at XII. o'clock, but really it is one, as the shadow at noon fills the space between the two lines.

A sundial cannot be said to be complete without a motto of some description, and by inscribing one on the dial or pedestal it gives a fitting voice to the dignified dial.

F. B. & Sn.