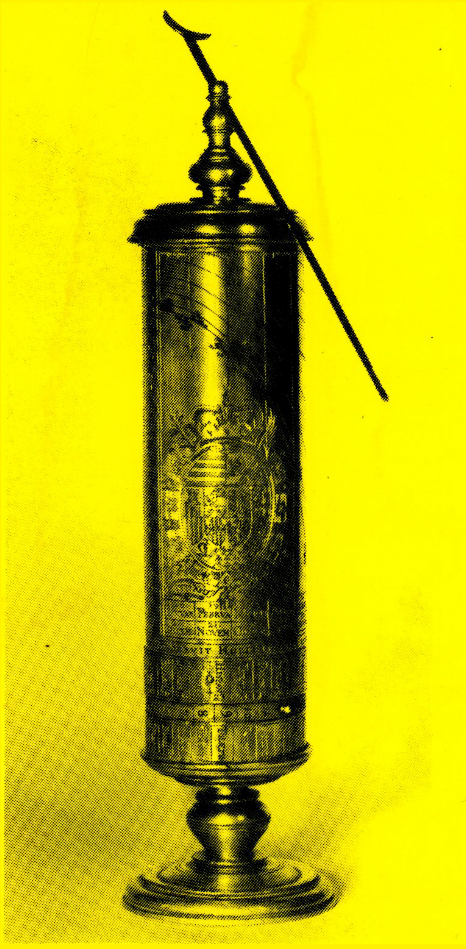
The British Sundial Society



BULLETIN

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HONORARY OFFICIALS OF THE BRITISH SUNDIAL SOCIETY

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Cover Illustration - Column dial engraved with the arms of the Austrian Archduke, Innsbruck 1548. This sundial is exhibited in the Kunsthistoriches Museum, Vienna.

DIALOGUE

LA BUSCA DE PAPER

This, to remind BSS members, is the official bulletin of the Catalan Society of Gnomonics. In issue No. 8, under the title of "20th Century Sundial Makers", the first article deals with the analemmatic sundial adorning the centre of the Primer de Miag Square, in the city of Sabadell, inaugurated 1st May 1986 to mark the 25th anniversary of the founding of the Astronomical Society of Sabadell. It is 12 metres in diameter and was designed by the President of the Catalan Society, Mr. Eduard Farré i Olivé, the artistic design is by Mr. Joseph Domènech, Director of the School of Fine Arts in Sabadell. Two similar but slightly smaller dials are in the Astronomical Observatory in Cárceres and the Fene School in A Corũna. Other dials by the same designer are quoted.

Another article of interest is "Latitude and Longitude in detailed geographical maps". It outlines the problems encountered by map makers in attempting to represent the curved surface of the world on the plane surfaces of maps. The Universal Transverse Mercator [UTM] representation introduced by Gauss in 1827 is discussed. A computer programme (Basic) is given to allow conversion of UTM coordinates to latitude and longitude.

The rest of the bulletin is taken up with "Time to think about Time - if you have the time" by E. D. Cammins. It is a gnomonics problem and quite cleverly wrapped up in the guise of a story woven around the person of Friar Janot who listens open-mouthed to the adventures recounted by an old military friend.

In issue No. 9, the opening article is "Towns and Sundials" which deals with seven sundials in the town of Corró d'Amunt, a few kilometers north of Barcelona. Evidently there are seven others but these are not in good condition. Rafael Soler I Gayà has an article "Adapting a horizontal sundial for use at different latitudes". This is based upon the fact that a horizontal sundial will give the same readings anywhere providing its plane is parallel to that when in use at the site for which it was intended [limited of course by the hours of useful illumination by the sun at the new site].

There is an analytical review of the Book *Bizcaiko Equzki-Eriojuak*, written by three authors, including our BSS member José Luis Basanta Campos. It sounds a most welcome addition to dialling literature and will be reviewed in the BSS *Bulletin* as soon as a copy can be obtained. The answer to the problem in the previous issue has not been included, perhaps the pressure on space was too great to include the solution.

Issue No. 10 commences with another article in the series "20th Century Diallers". It is about the owner of a villa in Sant Miquel d'Olèrdola who wished to brighten up the main facade and thought of installing a sundial. He did not know whom to ask, nor did he know anything of the subject, however, on going into a bookshop one day he found the book *Rellotges de Sol* [Sundials] by Miquel Palau and became interested in the subject. Eventually, after many experiments, he produced his sundial with a calendar. On the Holy Friday of 1983 he had an early breakfast and set about constructing his sundial and expected that with his son-in-law's help, he would finish it in the afternoon. Alas, at midday, when just about to start the work he dropped dead. It was not until a year and a half later that his son-in-law, Antoni Gil i Querol, made the dream come true, and the result may be seen on the facade of the house just as its late owner dreamed of for so many years.

A review is given of the book written by the President of the Catalan Dialling Society, Eduard Farré i Olivé -*Los Canteiros y el Relog de Sol,* which roughly translates as "Stonecarvers and Sundials". It includes the history of time measurement and sundials from antiquity, and thirty dials are illustrated, with the last few pages devoted to inscriptions. The book is only forty pages long but is praised as a "small work of Art" by the reviewer.

On page 6 of the Bulletin a map is given showing the distribution of sundials in Catalonia, drawn from the listings made by Mr. Jordi Nogué i Màs, there are several hundred examples. Mention is made of the new society founded in Madrid, with their journal *Analemma.*

The solution to the problem in issue No. 8 is given in this issue. These Bulletins must give great pleasure to the members of the Catalonian Society.

ÖSTEREICH ASTRONOMISHER VEREIN - SUNDIAL GROUP

Issue No. 3 contains an article by Lajos Bartha of Budapest which outlines the ancient mass dials still extant in Hungary. This has been translated by Mr. E.J. Tyler and is included in this Bulletin, see page 2.

L'ASTROFILO

This is the Bulletin of the Unione Astrofilo Bresciani published by the Civic Museum of Natural Science of Brescia, Italy. Supplement 16, published in 1990, is devoted almost completely to the astronomical quadrant of the church of Santa Maria Novella in Florence. This was the subject of an article, by the same author - Giovanni Paltrinieri, BSS *Bulletin* 91.2, July 1991, pages 15-19; but this little treatise of 34 pages was not mentioned.

The treatment covers the life of Egnazio Danti, the quadrant of Santa Maria Novella, the equinoctial armillary of C. Tolemeo, and the tracings of the delineations of the sundials. Had the booklet been at hand when the article was published, these would have been included to help clarify the details.

For those who can read Italian, this booklet amplifies the BSS *Bulletin* article, if the Editor can get round to translating it, it may be included in a future issue of the BSS *Bulletin,* S. Paltriniera has already given his permission.

S. Paltrinieri would like to correspond with English gnomonists, his address is: Via G. Dozza n. 3, 40139 -BOLOGNA, ITALY. Tel. No. (051) 46 76 80. He has just written a new book on sundials which will be ready next November, details of his book and a review will be given as soon as a copy is received.

DE ZONNEWIJZERKRING

Bulletin 92.2 for March 1992 contains details of the Summer excursion which will be on 20 June in Zwolle. A total of eight major articles is included, unfortunately this issue is rather more difficult than usual to extract the information by an English reader. This is a pity since the articles presented are of fundamental importance to diallists. The normal inclusion of dialling literature is absent in this issue. If any BSS member would like to volunteer to review this journal on a regular basis, the Editor would be pleased to hear from him/her. A useful inclusion is a summary of the contents of the Bulletin issues 84.2 to 91.3, and a glance at this shows the great diversity of the areas of dialling which are covered with great authority.

ERRATA

It is regretted that errors crept into the article "Sundial Alignment by the use of the Pole Star" included in Bulletin 92.1, the main one being that the author is Mr. C. M. Lowne and not "Lowe". Unfortunately the Editor did not see the final proof because of family committments taking him away from home. In line 9 delete the words 'and also of the sky' so it reads '... true pole of the sky and also of the position angle ...'; in line 29, insert 'aligned' after 'approximately' within the parenthesis. The Editor has already apologised personally to the author.

A TIDAL DIAL

Concluded from page 40.

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THE OLDEST FIXED DIALS IN HUNGARY

BY LAJOS BARTHA

In Hungary very few medieval sundials remain. The reasons are wars and the rebuilding of many Middle Age churches and castles. Characteristic of the period were the canonical sundials used for determining of the times of religious services, and therefore hours of prayer.

Canonical sundials were first merely divided into four equal parts, later the four sectors were halved and so the eight-division of dials came into existence. The equal-angle divisions naturally represent unequal time intervals. The gnomon was horizontally placed with respect to the vertical dial. In the early period of the Renaissance, these canonical dials were displaced by dials showing canonical hours.

At present I know of only four canonical dials with primitive divisions in the whole of Hungary. The single eight-division canonical dial dates from an earlier period than those with divisions into twelve parts, and one assumes that the period of use of primitive and more modern types of dial overlapped.

The oldest, and also the most problematical medieval sundial is found in the church of Mátraverabély (in Konitat Nógrád, North Hungary). This twelve-division dial is of about 50cm diameter (20 inches) and was scratched into the stone of the church wall, it is not fixed into the inner wall of the sacristy. The present outer wall and the sacristy were built some time after 1380, the age of the dial is estimated between 1250 and 1350.

A Gothic sundial is to be found on the tower pillar of the castle church of Szentendre (Komitat Post-Pils, Donaukniegebiet). The shield-shaped dial is about 35cm in height, the location is not original. The dial is divided into 12 so as to indicate "hours". Over the horizontal rising-and-setting of the sun line are two other lines. The angles of division are not equal, however it does not indicate equinoctial hours. The dial is probably a transitional form between the equal angle division and the modern dials, and dates presumably from the rebuilding of the church in 1310.

The Gothic sundial in Köszeg (Jurisiah pl 14) is found in the inner courtyard of the so-called Ambrózy or Szovjáh House. It has been studied by Ernö Vértes. The 45cm diameter half circle cut in stone could have been inscribed at the same time as the other gothic elements of the building which were incorporated in the late 14th or early 15th century. The dial has often been modified and the original division is no longer visible. It is the sole example of a medieval sundial remaining in Hungary which is not placed on a church or public building.

The dial of St. Nicholas church in Rudabánya (Komitat Borsod Abanj NO Hungary) is the only one with a real religious character. The supporting pillar on which the engraved dial stands was made in the second half or end of the 14th century. The 24cm circular dial is divided in the lower part into eight parts, further halved by the other lines. The inner circle is very exactly engraved and surrounded by a large outer ring. This sundial marks the times of prayer.

From about the middle of the fifteenth century, vertical sundials marked with equinonoctial hour divisions and utilizing polar gnomons were introduced and soon ousted the older inaccurate dials. This development was connected with the work of the savant Regiomontanus (Johann Müller from Könysberg, Transconia).

THE SUNDIAL AT SEA:
SOME PRACTICAL ASPECTS OF 16th & 17th CENTURY NAVIGATION
A lecture read at the BSS Seminar 11th April, 1992
BY CHRISTOPHER St. J. H. DANIEL

In the year 1593 the first book in the English language, devoted entirely to sundials and their construction, was published in London. It owed much to an earlier treatise on the subject, in Latin, by Hermann Witekind, Professor of Mathematics at the University of Heidelberg, Germany, which had been published in 1576. The English treatise, entitled *Horologiographia: The Art of Dialling,* was the work of Thomas Fale, a Cambridge mathematician. On the title-page the author expresses the view that his work will be 'Of speciall use and delight not onely for Students of the Arts Mathematicall, but also for divers Artificers, Architects, Surveyors of buildings, free-Masons, Saylors and others'.

Eight years earlier, in 1585, another English mathematician, John Blagrave, a gentleman of Reading and a contemporary of Fale, had also had a work published, entitled *The Mathematical Jewel,* to accompany and explain the use of an astrolabe which he had 'invented'. On the title-page of his book, he states that his work is published 'for the furtherance, as well of Gentlemen and others desirous of speculative knowledge, and private practice: as also for the furnishing of such worthy minds, Navigators, and traveylers, that pretend long voyages or new discoveries'. The 6th book of the treatise on his instrument is concerned with the construction of sundials 'by the onely helpe of this Mathematicall Jewell'. In chapter 1 of the book he observes that "The travailer by land is not a little comforted, when he may with a small toy see how the day goeth away before him: and also may see to what place he may reach before nyght overtake him. The Seaman with dials, or such like instruments to know their houres and times, coulde not travaile at all".

These two 16th century works on the construction of sundials both make the crucial point that the seaman (by which term it may be inferred that the reference is made in respect to the pilots or navigators of deep-sea or ocean-going vessels) required sundials or "such-like instruments" to determine the time. The determination of time at sea was and is essential to the safe navigation of a ship from one place to another, especially when out of sight of land, or in strange, uncharted waters. The accurate determination of the time, and the accurate means of comparing the time between one place and another, has always been the vital factor in accurately determining the position of the ship at sea, especially in respect to the longitude.

A ship's position is given in terms of the co-ordinates of latitude and longitude. The latitude is the angular distance of the vessel, measured in degrees north or south of the equator, and may be obtained by an observation of the Sun at noon, or of other celestial bodies, when visible. The longitude is the angular distance, measured in degrees, east or west from the Greenwich meridian, (or from any other meridian, as deemed to be the prime meridian, prior to the Washington conference agreement in 1884). The longitude may be deduced from the difference in time between the prime meridian and the meridian passing through the ship, at the time of observation. In the 16th century, the principles of determining the longitude were known, but the instruments available at the time were unable to provide the seaman with accurate results. Consequently, the navigation of a ship in those days was very much a matter of 'by guess and by God'.

In the time of Columbus and Drake, when the exploration of the world was the equivalent of modern space-travel, it must be remembered that the ships engaged in such ventures were powered by the wind, and occasionally by oars. When under sail alone, the seaman relied on the wind, especially a 'fair' wind.

In a storm, his ship could be driven before the wind for days on end, helpless and at the mercy of the elements. Many were wrecked or were lost at sea without trace. But for those who survived the perils of the tempest, - the uncharted shoals, the teeth of jagged rocks foaming in the sea, and the appalling terror of being driven ashore, to crash against the wave-lashed cliffs of a hostile coast, - when the wind abated and the storm-clouds gave way to sunshine, there was the ever pressing need to know the exact position of the ship and the best course for a safe anchorage.

The most pressing need, however, was to know how much water there was under the keel, that is to say, the depth of the water to the sea-bed. Whenever the vessel was in confined waters, in the vicinity of land, especially when closing with the land and approaching unknown shores, it was of paramount importance to take soundings. This was done by means of a sea-lead or sounding-lead, a narrow cone-shaped lead weight, usually of 7, 14 or 28lbs, attached to a sounding line. The line was marked in fathoms (ie. at intervals of 6 feet) by pieces of leather and coloured cloth. A seaman or leadsman, standing out on the side of the ship, would swing the lead, at the end of the lead-line, and let it plummet to the sea-bed at regular intervals. At the instant that he felt the sounding line go slack, he would note the distinctive marker nearest to the water line and would call out the number of fathoms that this indicated, to the ship's master or pilot. The bottom of the lead itself had a depression in it which was 'armed' (to use the seafaring term) with tallow. When the lead struck the bottom, samples of sand, shells, mud or other evidence of the sea-bed would be stuck to the tallow. This information, together with the depth of the water, would enable the experienced pilot, in familiar waters, to gauge the approximate location of the ship.

Of course, such information was not of much use in fixing the ship's position without the aid of a map or sea-chart of the area in question. In the 16th century, charts of England and English waters were not perhaps difficult to obtain; but they were crude by modern standards and far from being accurate. Nevertheless, they showed coastlines and the names of individual places, and they are marked with the depths in fathoms and the state of the sea-bed. The construction of the chart enabled the skilled mariner to determine the direction and approximate distance of one place to another by means of a lattice-work of so-called 'rhumb' lines, emanating from an arrangement of 16-point wind-roses or compass-roses. By laying his ruler between his place of departure and his intended destination, he had only to identify the nearest parallel line and trace it back to the parent compass-rose to give him the required bearing or course to sail. With a pair of dividers (or compasses) he then measured off the distance against a scale of leagues or nautical miles.

In setting sail, it was a fundamental requirement for the mariner to know that, in fact, his ship was being steered in the right direction. To this end he would carry a magnetic sea-compass. The compass comprised a magnetized iron needle, mounted on a card and pivoted at the centre, such that the needle was free to point to magnetic north. This varied from the direction of true north by an amount known as the 'magnetic variation', the value of which varied from one part of the world to another and which, in a particular place, changed over a period of time. Nevertheless, this information was a valuable factor in an ocean pilot's sea-route, especially in unfamiliar waters. It could be checked, however, by celestial observations.

When travelling on land, unless in a familiar locality, it is usually necessary to consult a map end and to obtain some directions. In the same way, making a sea-voyage is no exception. Many of Francis Drake's most prized possessions would have been the sailing directions, route-maps (or 'rutters', as they were called) and sea-charts, which he had acquired or seized from the various foreign pilots whom he had captured. The sailing directions were compiled by individual pilots and included everything of importance, from information on ocean currents and local currents, likely to affect the passage of the ship, to the direction of the tides and the rate of their ebb and flow, especially in the vicinity of the land, in a channel or in the approaches to a harbour. Also included would be details of the coast-line, prominent features that would aid the mariner in knowing his position, and known dangers to be avoided. Safe anchorages, rivers, harbours, places where fresh-water could be obtained, and whether or not the natives were friendly, all such information could be of extreme importance, and, indeed, the difference between life and death. Consequently, a pilot's sailing-directions were his most jealously-guarded secrets.

In his great circumnavigation of the globe (1577/78-1580), Drake may well have carried with him a copy of the world map of 1570 by the great Flemish cartographer Abraham Ortelius, (reduced from Gerard Mercator's great 'world-map'), which might account for the fact that, when the Golden Hinde was off the coast of Chile, Drake twice set a course north-west for Peru. The Ortelius map shows a bulge on the western coast of South America, which might well have caused Drake some concern and prompted him to alter course to run parallel to the strange mythical coast-line. As it happened, Drake had acquired a foreign pilot sometime earlier, with knowledge of these waters. Thus, his caution, in endeavouring to keep his ship from running aground on an unknown and hostile shore, did not drive him out into the Pacific, as might otherwise have been the case, perhaps never to have returned to England. The error in the Ortelius map was no doubt due to lack of knowledge of the change in the longitude of places on the Chilean coast, in relation to the latitude, drawn by the cartographer as best he could from the information available at the time. Such information was scarce however, since it was the deliberate policy of Spain and Portugal, in protecting their overseas interests, to prevent the use of their maps and sailing directions to other nations. A comparison between the 1570 world map or Ortelius and the map published over twenty years earlier in 1548, in the Spanish edition of the 'Cosmographia' by Peter Apianus, will suffice to show that the Spanish succeeded remarkably well in keeping their secrets from the rest of the European world.

Having set his course on an ocean passage, as the land and the familiar land-marks fell away astern of his ship, to sink below the horizon, the mariner needed to keep track of the direction and distance that the vessel sailed. Ships at sea have traditionally kept 'watches' of four hours on duty and four or eight hours off duty, depending on the circumstances. During his watch, the pilot made use of a 'traverse' board, a wooden board marked out with a series of equidistant pin-holes or peg-holes, radiating out on 32 compass points, indicating the course sailed by the ship for every half-hour or hour of the watch. Thus, the number of 'pins' placed on any one compass point gave the time sailed on each track or course. Likewise, a second series of pin-holes gave the estimated speed or distance sailed on each course during the watch. At the end of the watch, the pilot could deduce the mean estimated course and distance made good. With this information he could plot the reckoned position on his chart and make a written record in his 'log'-book. An entry in the log-book of one of Drake's ship's masters reads: "At none tyme the board was clered as folowithe: 16 pinns southwest... hir way sowth west 6 leagues".

To estimate the speed of the ship through the water and the distance sailed, a piece of wood might be thrown over the side, at the bow, and the time that was taken for it to pass the stern of the ship estimated by pacing it along the deck. Other methods of counting this distance were used as well; but, in due course, a wooden 'chip' or 'log', with a line attached, was used for this purpose, the line having a number of knots in it, tied at specific intervals. The drag of the log in the water would cause the line to run through the mariner's hands. Thus, by counting the number of knots that passed out astern, in a given time, he could gauge the speed of the vessel in nautical miles per hour. By association, the speed of a ship is reckoned in terms of 'so many knots'.

To estimate the ship's speed and hence the distance sailed, as well as for the purposes of watch-keeping, the pilot used a sand-glass or running-glass to measure the passage of time. These glasses were made to measure both large and small periods of time, usually in half-hour, one-hour and four-hour intervals, for watch-keeping requirements; and measuring very small intervals for such needs as timing the log. (In the 18th century, 28-second glasses and 14-second glasses were used for this purpose, these intervals giving a direct reading of the ship's speed. The 14 second glass was used with a fast-sailing ship, where the ship's speed exceeded 8 knots.) At the turn of the half-hour glass, at the moment when the sand ran out, the ship's bell would be sounded, one bell for as many times as the glass had been turned from the start of the watch. Thus, 8 bells signified the end of the four-hour watch, (and the beginning of the next watch).

Sand-glasses, however, served much the same function as clocks and watches: they did not determine time and they were susceptible to human error through constant handling. For the purposes of determining the time at sea, portable sundials were carried aboard ship, developed for use in any latitude, to indicate local time by the Sun, of which the 'astronomical ring', described by Gemma Frisius in the 1530's, was the most practical. From this device, about the year 1600, William Oughtred, the English mathematician, perfected the universal equinoctial ring-dial, which proved to be a useful and popular instrument with the mariner for some two hundred years. Various other dials were also seemingly used at sea, such as the common ring and the horizontal; but, being dependent on the latitude for which they were constructed, they would have served no real purpose, except when the mariner's vessel was in home waters.

On the title-page of Thomas Fale's *Horologiographia: The Art of Dialling,* there is a wood-cut device of a nocturnal dial. The 'nocturnal', as it was called and as the term suggests, was an instrument which was used at night. With this dial, the pilot could deduce the time from the position of the stars, known as the 'pointers' or the 'guards' of the constellation of Ursa Major, the 'Great Bear', in relationship to Polaris, the pole-star. By setting the instrument to the desired date, sighting the pole-star through the hole in the centre of the instrument, and aligning the 'arm' of the nocturnal with these stars, the time may be read off against an hour-scale.

However, the time was principally determined, and used for governing the time-keeping of the ship, from the moment of noon, (ie. mid-day), when the Sun reaches its

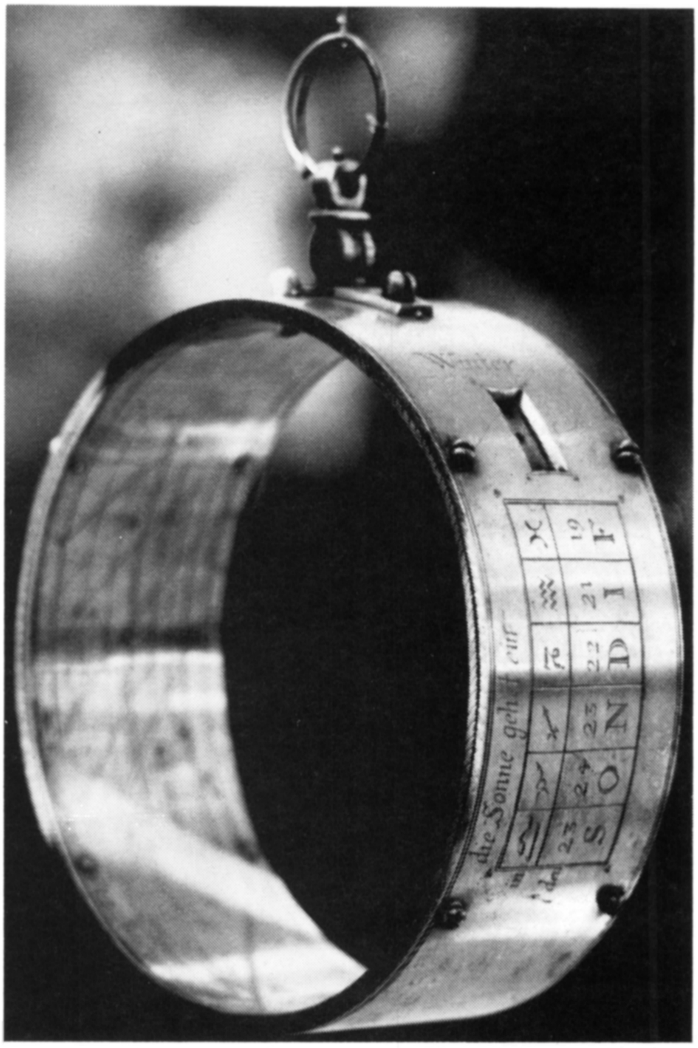


FIGURE 1: 'Common Ring Dial'

Fo.62.

Vso del Anillo Astronomico compuesto por Gemma Frisio.

Capitulo primero, que contiene la declaracion delas partes.

FIGURE 2: 'Astronomical Ring Dial'
Spanish Edition 1548

maximum altitude, or angular height above the horizon, (when it is on the meridian of the observer, due south, or due north, depending on whether the ship is in northern or southern latitudes). At this moment, with the requisite tables for the declination of the Sun, giving its angular distance north or south of the equator for the date in question, the latitude of the vessel may also be deduced by measuring the meridian altitude of the Sun. Various instruments were employed for this purpose, such as the simple quadrant (with a plumb-line), the mariner's astrolabe or the cross-staff (or fore-staff).

The quadrant required the use of a plumb-line, weighted with a lead plumb-bob. Holding the instrument aloft, the method of observation was to align the Sun or the pole-star in the sights, set on the upper edge of the quadrant, and then to clamp the plumb-line against the degree scale engraved around the circumference of the instrument. This would give a direct reading of the altitude of the body, assuming that the plumb-line remained steadily suspended in the vertical during the observation. A slight breeze or the movement of the ship could be enough to cause a considerable error.

The mariner's astrolabe, as the name implies, was intended for use in measuring the altitude or height of the pole-star at night; but it was a difficult instrument to use aboard ship in conditions of darkness, especially on the deck of a vessel which might be pitching or rolling in a seaway. Holding the astrolabe aloft in one's hand, even

FIGURE 3: 'Universal Equinoctial Ring Dial'

with the aid of a line suspending it from the rigging and supporting much of the weight, and endeavouring to align the pole-star in the sights of the instrument, is no easy matter in such circumstances. Furthermore, in windy conditions, which is more often the case than not, a fresh breeze may bring a sudden gust, which blows the astrolabe momentarily out of alignment. On the other hand, the mariner's astrolabe was a proficient and comfortable instrument to use during the daytime, in determining the height of the Sun at noon. Suspending the instrument, with the finger or thumb, by the small ring designed for this purpose, the astrolabe is allowed to hang in the vertical plane. Then it is simply turned and adjusted, such that the 'alidade' or sighting-arm is aligned with the Sun. At this moment, the two lugs or sightings 'vanes' on the alidade will be in such a position that the shadow of the upper vane will be cast exactly onto the surface of the lower vane. At the same moment, a small pin-hole, at the centre of the upper vane, will project the Sun's rays, as a pin-point of light, onto the centre of the lower vane. Observing this instant, the angle of the alidade from the horizontal (or the vertical) may be read off against a scale of degrees on the circumference of the astrolabe. Thus, at the moment of noon, the time may be determined and the latitude deduced.

The cross-staff, as the name suggests, is a graduated wooden staff, (about 3 feet in length), which is held to the eye, such that the observer may measure the angle between two objects by moving a cross-piece or vane towards or away from the eye, and noting the value of the angle on the graduated scale. The nearer the vane is to the eye, the greater will be the angle subtended at the eye; the further away the vane, the smaller will be the angle. The instrument usually had three such vanes, (not all used together, as some engravings might imply), each one serving either for a large angle, a medium angle or a small angle. The instrument was used with some difficulty in measuring the altitude of the noon-day Sun in low latitudes; but, with a smoked glass shade, it served its purpose quite well when the Sun was not too high in the heavens. Conversely, the cross-staff succeeded at night, where the astrolable failed, in measuring the height of the pole-star.

With such instruments, the 16th and 17th century navigator was able to find the latitude of his ship, from day to day, by noon-day observations of the Sun and night-time observations of the pole-star. However, he was obliged to deduce his longitude from his estimated courses and distances sailed in an east-west direction or vice versa. It was not until the 18th century that an accurate marine time-keeper resolved this problem. Thus, the prudent mariner would endeavour to sail north or south until he reached his desired latitude, when he would 'run-down the latitude' until he made his hoped for landfall or, at least, sighted land. To this end, a fundamental requirement aboard ship, which still applies today, is the necessity to keep a sharp lookout. Men would be posted as lookouts on the upper yards or at the masthead, not so much for reporting other shipping; but for the paramount and necessarily vigilant duties of sighting reefs, shoals, rocks and land, in good time to avoid disaster.

The earlier voyages of exploration were hazardous, to say the least, and even with the knowledge gained through such ventures, the 16th century mariner was not much better off in uncharted waters. Thus, Francis Drake's circumnavigation of the world, through unknown oceans and the treacherous seas of Indonesia, -where he nearly lost his ship, his crew and his life, - is an achievement which may now be hard to properly appreciate. One must admire his personal endeavour, his qualities of leadership, his remarkable seamanship and

FIGURE 4: 'Mariner's Astrolabe'
In use aboard the Golden Hinde

his skills in navigation, which brought the Golden Hinde around the world, to a safe anchorage in Plymouth sound over 400 years ago. The gold, the silver, the treasure and the treaty, which Drake had obtained for England in the rich spice trade, were, in this context, insignificant in the light of the voyage itself. The success of this remarkable voyage owed much to the foreign pilots, whose instruments, knowledge and expertise Drake was fortunate enough to have acquired on the way. It owed much also to seamanship and to the skills of navigation, to the instruments which enabled Drake to calculate the position of the Golden Hinde, and, perhaps, (who knows?), to the sundial, which may well have been carried aboard. After all, as Blagrave wrote: "The Seaman without dials, or such like instruments to know their houres and times, coulde not travaile at all".

FIGURE 5: The Golden Hinde at sea off the West Coast of America

THE SECRETARY'S NOTEBOOK

THE 'COUNCIL'

The word 'council' brings a picture to my mind of a gathering around a large polished table of grim-faced men in grey suits in a smoked-filled room. The British Sundial Society Council is not at all like that! Our late Chairman, Andrew Somerville was determined to keep our discussions serious but light-hearted, and I am pleased to say that this dictum has been followed to the present time, and long may it continue. We endeavour to promote this light-heartedness in all our meetings and conferences, for surely it is a pleasure to meet for mutual discussion with others having similar interests. The sundial itself, when well designed and functional is a joy to be behold, it is a pleasure when having actually made a simple dial, to observe the shadow of the gnomon progressing to fall on the inscribed hour lines at the correct moment in time. Doubtless the mathematicians amongst us get a similar feeling of elation after solving a complex problem in spherical trigonometry, a subject that not many of us have had to deal with since our schooldays. Now for the commercial break - **book now** for the September conference at the fair city of Bath to prove the pleasure of participating for yourself.

THE AGM

Members will know that the 1992 Annual General Meeting was successfully held on 11th April aboard HQS Wellington by kind permission of the Honourable Company of Master Mariners. We have gained some 'new blood' on the Council. Mr. R.A. Nicholls from Sherborne, Dorset, is our new Treasurer; Mr. Robert Sylvester from Kirby-in-Furness, Cumbria, has taken on the onerous post of Membership Secretary; and Mr. P. Nicholson of Epsom, Surrey, and Dr. I.D.P. Wooton of Goring-on-Thames, Oxfordshire have joined the Council. Whilst welcoming these new members to the Council, I have also to thank the three retiring members who put in a considerable amount of time and effort for the Society during their two years in office. Richard and Janet Thorne have had to put up with very long journeys to attend meetings from their home in far-away Plymouth, and having left both membership and finances at record levels, will now take a well-earned break, (I won't say rest as they are heavily involved in other projects). Michael Cowham has left to concentrate on his business and other interests for a while, he organised the successful Edinburgh and Cambridge conferences in spite of his committments. All three, will of course, remain members of the Society, and may be persuaded to do another stint in the future!

JODRELL BANK

The Society has had two generous offers of sundials for Jodrell Bank one, from our member Silas Higgon of Connoisseur Sundials and also a smaller replica of the well-known 'Dolphin' sundial by Mrs. Margaret Ta'Bois. We thank both these members. Mrs. Anne Somerville, who acts as our liaison officer with Jodrell Bank, has now taken on an additional task for the Society, that of sales. Details of what is on offer is given below.

SALES

The first three Bulletins issued by the Society are not now available but it is hoped to bring these out as one combined issue in the future. The following back numbers can still be supplied at £5 each.

90.2 June 1990
90.3 October 1990
91.1 February 1991
91.2 July 1991
91.3 October 1991
92.1 February 1992

England and Wales Dial Listing 1992	£3.00
Scotland Dial Listing 1991	£2.00
BSS Ties, dark blue with symbols	£8.00
Lapel badges, available July	£3.50

All prices include postage and packing.

Orders to: Mrs. Anne Somerville, Mendota, Middlewood Road, Higher Poynton, Cheshire, SK12 1TX. Do not include other items of correspondence intended for the BSS with your order.

CHEQUES PAYABLE TO:
THE BRITISH SUNDIAL SOCIETY - PLEASE.

NEW DIAL LISTINGS

A second edition of the summary of our sundial records for England and Wales will be ready shortly. It includes a further 500 dials and includes their location, type, date and maker where known, plus a brief note of any special interest. Those who have contributed in the past year will receive a free copy, but any member can obtain a copy for £3 post free. See the sales box above.

WANTED

A number of our members regularly give lectures and talks at our meetings, and very good they are too, but we are always looking out for new faces and new subjects (with some bearing on sundials, of course). If you feel you can give a short/long talk, or a slide show which would intrest other members, I would be pleased to hear from you.

SCRATCH OR MASS DIALS

The Scratch Dial workshop at the Cambridge Conference attracted a lot of interest, and although I submitted a report for the last Bulletin, there was no room to spare for it. So, better late than never, it is given overleaf.

In view of the accelerated damage by modern atmospheric pollution, it is all the more important that all remaining scratch dials should be identified and recorded as soon as possible. The scratch or mass dial is one of the endangered species of the genus "sundial", and very few are protected from the weather or vandals.

See also Book Review page 41/42.

CLACTON CLOCK FAIR

Mr. Clive Osborne, a very well known figure in the antiquarian clock world, arranged a one-day Clock Fair held at Clacton-on-Sea in May 1992. The British Sundial Society was offered a free stand, so the Secretary Mr. D.A. Young and the Editor Mr. C.K. Aked took along items to form a display. Mrs. Margaret Ta'Bois volunteered to come along to provide assistance, and this proved most useful in allowing each exhibitor the opportunity to have the occasional welcome break.

Actually the Society was given three separate tables, fortunately enough things had been taken to fill the space available. Mr. Young displayed his panels of sundial cigarette cards, these evoked a lot of interest, plus bringing along the whole range of British Sundial Society literature for sale.

An item which attracted a lot of attention was the Singleton helical dial, in fact the local press photographer insisted upon photographs of this with the BSS officials shown dutifully admiring it. In fact the Singleton dial could have been sold for twice the price charged by the makers (to BSS members), fortunately the enquirers were told to contact the Singletons directly, and so were not over-charged in error. (Having had several of these sundials personally, the writer recommends them as a good buy to BSS members.)

The Fair was officially opened by Lord Middleton, who is in charge of the fine Gershom Parkington Collection at Bury St Edmunds, and this contains a number of early portable sundials. He was introduced by the Lady Mayor, who after inspecting the BSS display, invited the participants to the Mayor's Parlour for refreshments and expressed her interest in the subject of dialling.

Although attendance was affected by the brilliant sunny weather of the day, the effort of attending the fair was rewarded by the considerable interest shown by the public, most of whom had no idea that sundials were of any importance at all in today's world.

Thanks are expressed to Mr. Clive Osborne for not only providing exhibition space free of charge, but also free refreshments to the BSS exhibitors, and also giving the BSS a proportion of the attendance money to help BSS funds. It was a long journey and a long day but quite enjoyable, and it helped to demonstrate just how little is known about sundials by the general public and the need for publicity to make the subject of dialling better known.

CHARLES K. AKED

SCRATCH DIALS WORKSHOP CAMBRIDGE 1991

The following members attended:

Charles K. Aked, Richard Andrewes, Aylmer Astbury, Frank Evans, Marinus Hagen, Antoinette Hanekuijk, George Hesketh, Tom Hughes, John Ingram, Donald Rodger-Brown, Margaret Ta'Bois, Walter Wells, David Young (in the chair).

Other members who have expressed interest are: David Brown, Neville Rodber, Margaret Stanier, Robert Sylvester.

The meeting commenced with a short talk by Walter Wells, followed by a most interesting general discussion primarily concerned with the origin and early history of these fascinating dials. Many members indicated that the dials originated from Norman times but that they were certainly found on much later churches. Various members pointed out the enormous variation of these dials, both in style and number throughout the country, with the concentration in certain counties in the south and the very few found north of the Midlands. Our Dutch friends mentioned that they knew of one only existing in the Netherlands, however it was generally agreed that there were a great many in the north of France and in Germany. It was obvious that in some areas the quality of the building stone used affected the longevity of the dials, and in other areas flint walls and timber porches would not prove a good surface for their inscription in the first place. However this could not account for the vast variation in numbers throughout England, and indeed in Europe.

Suggestions were made that in the past, edicts had been issued by church authorities to the effect that all churches should have a dial so as to regulate the time of the Mass and other services. This could well have been more strictly observed in some ecclesiastical regions than others, but their real origin and how they spread is a mystery.

It was agreed an overall map of the country detailing all dials existent and known to have existed would be useful, expecially if other European countries could be persuaded to do similarly - it might then be possible to trace the spread of the scratch dial across the Continent.

Many records of dials in different parts of England have been published, by individuals working more or less on their own. The Society has copies of most of these listings. Through the great generosity of Margaret Ta'Bois, we have a very fine collection of photographs and records collected in the early eighties by the late Noel Ta'Bois. These, together with some records in the existing dial survey would make an excellent start for a detailed National Record. However it was considered that the present general sundial recording form was not suitable for scratch dials, most of it would be left blank and some useful information was not asked for. Using the suggestions proposed by Dom Ethelbert Horne as long ago as 1929 as a basis, a discussion took place on the best layout of a specialist form for recording scratch dials. It was agreed that a sample form should be circulated to all those interested in the project so that comments could be returned.

Other members who are interested in this subject may indicate this by writing to me, the early questionnaires returned in 1989 did not indicate much interest by members in scratch dials but the Society has grown so rapidly that circumstances have changed.

DAVID YOUNG,
SECRETARY

THE MONUMENTAL SUNDIAL IN THE QUIRINALE GARDENS IN ROME

BY VICE-ADMIRAL (Rtd) GIROLAMO FANTONI (ITALY)

The peak of activity with sundials (or Science of Gnomonics), not so much for precision as for the splendour of its realisation, was certainly reached in the seventeenth and eighteenth centuries, the "golden centuries" of the sundial.

Among the documentation of this period, the description of a noteworthy sundial situated in the Quirinale Gardens in Rome is worthy of attention and is dated 1628[1]. This sundial is not well known, not even among the "devotees" of these devices, and therefore it is thought to be well worth the effort to present a brief description.

The uniqueness of this instrument is that it is a sundial of cubical cylindrical form of large dimensions, fixed permanently to the ground, whereas instruments of this type are normally small and portable. This sundial is of monumental proportions, 2.70 metres high and constructed of white marble. The block containing the dials is placed upon a cylindrical column ornamented with swags of fruit, dolphins, and peacocks. All the inscriptions and indications inscribed on the sundial are in Latin.

QUADRANTS

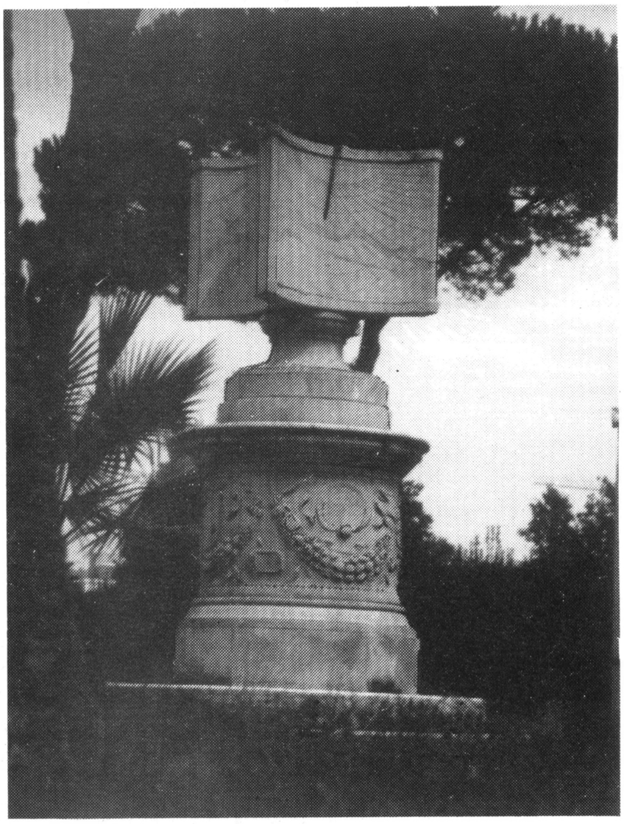
The arrangement of the sundial consists of four vertical concave cylindrical quadrants, 83cm in height and 98cm in width, oriented exactly to the four cardinal points. The concavity of the quadrants is an artifice to avoid the shadow of the styles going to infinity when the sun's rays reach the entrance and exit of the dials. It is necessary to point out that this geometrical disposition was not much used in the past, probably because of the increased complexity of drawing the lines on the cylindrical surfaces compared with plane surfaces.

Figure 6 shows the quadrant block through a horizontal section. From a functional point of view, the four quadrants are paired, the east-west pair give "civil time" or astronomical time; whilst the north-south pair provide "Italian time". Thus substantially the instrument consists of two complete but different sundials, each functioning with its own system of time keeping. In fact, since in the course of each day the sun illuminates each quadrant for some hours only, and for the remaining hours illuminates the opposite quadrant, each pair of opposing quadrants furnishes the time for the whole day; the civil hours on one sundial, and the Italian hours on the other sundial.

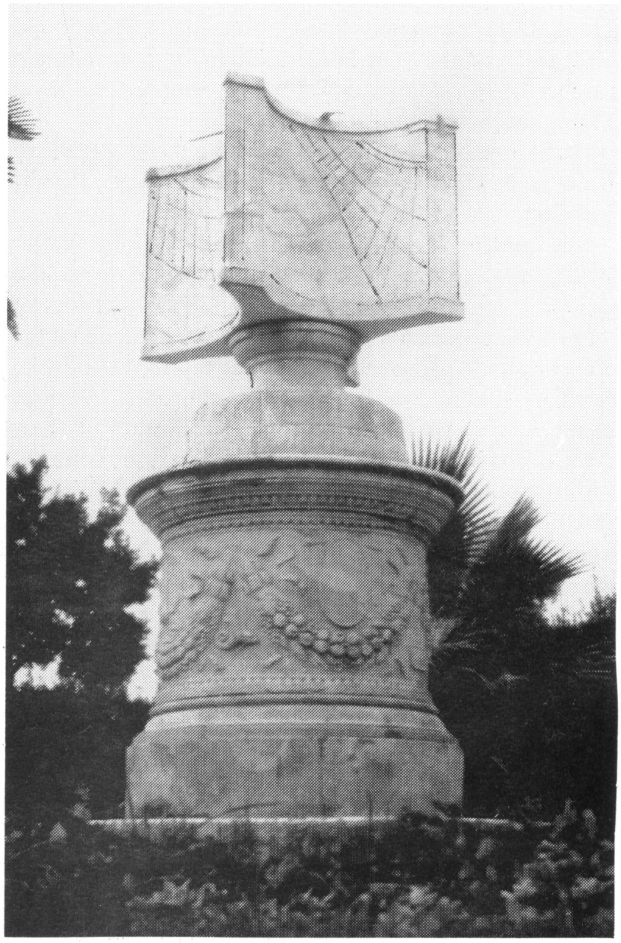
The four styles are arranged, one for each quadrant in the upper part, in approximately horizontal positions. With such an arrangement, the only useful point of the styles is the terminal point, as always occurs in Italian sundials.

THE TIME SYSTEMS

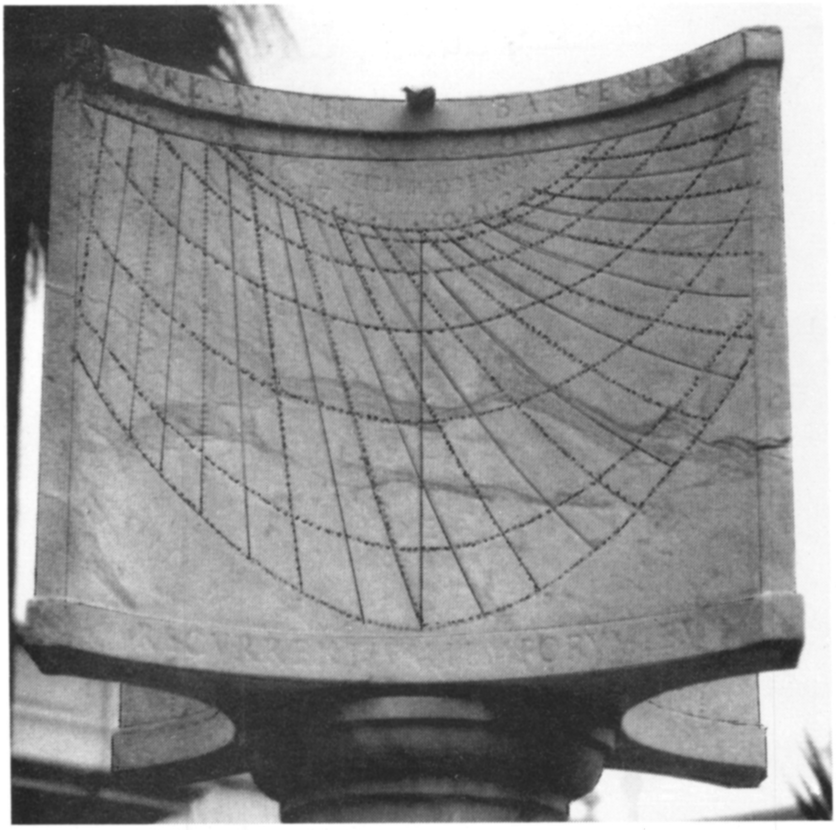
The civil or astronomical time indicated by the east-west pair of quadrants, derives from the system of time measurement which divides the day into 24 equal hours beginning at midnight, as we also do today. This time system, which now seems instinctive to us, has not been the only one used in human history. It was invented by the Arabs circa 1000 BC and was not an immediate easy success, it only became widespread in civilised countries when the introduction of the mechanical clock necessitated an equal division of all hours. The "Italian



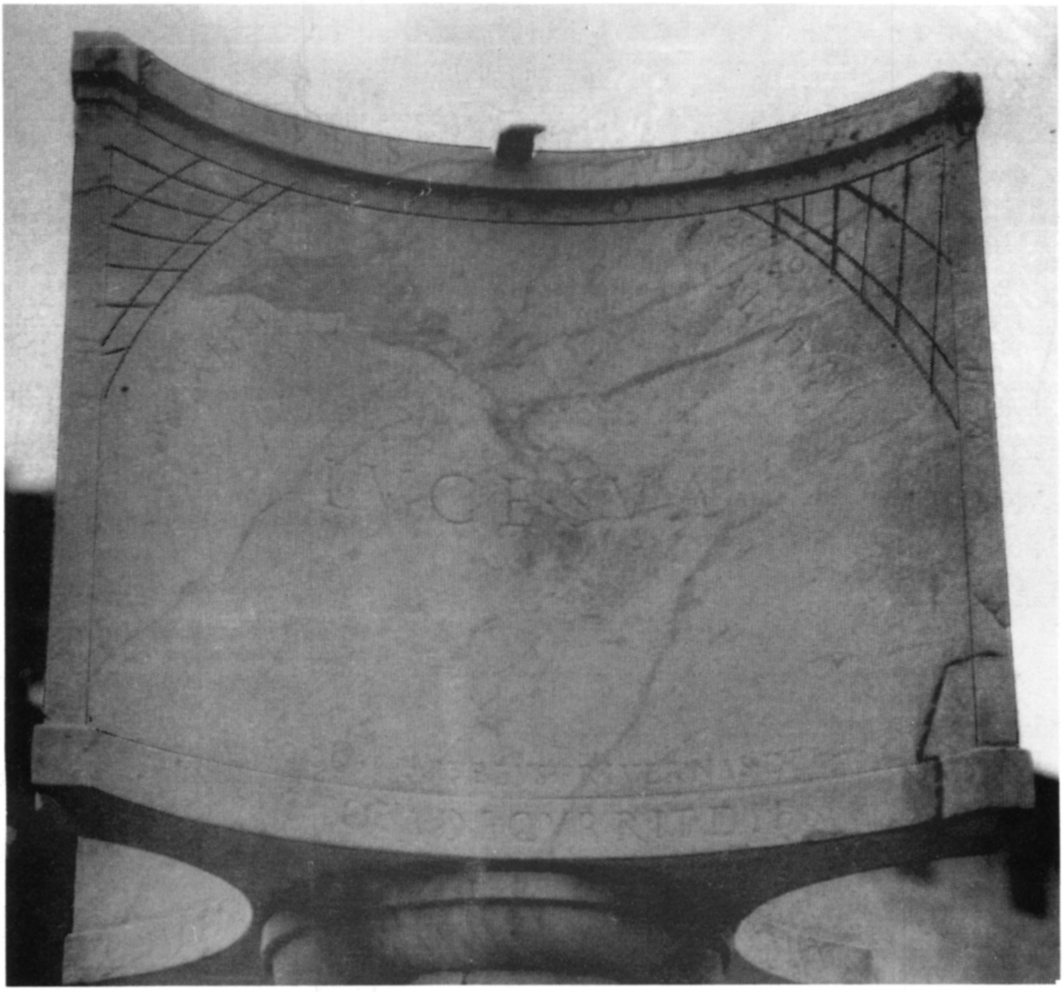
1. The Quirinale sundial viewed slightly west of south, showing the south-facing quandrant in full



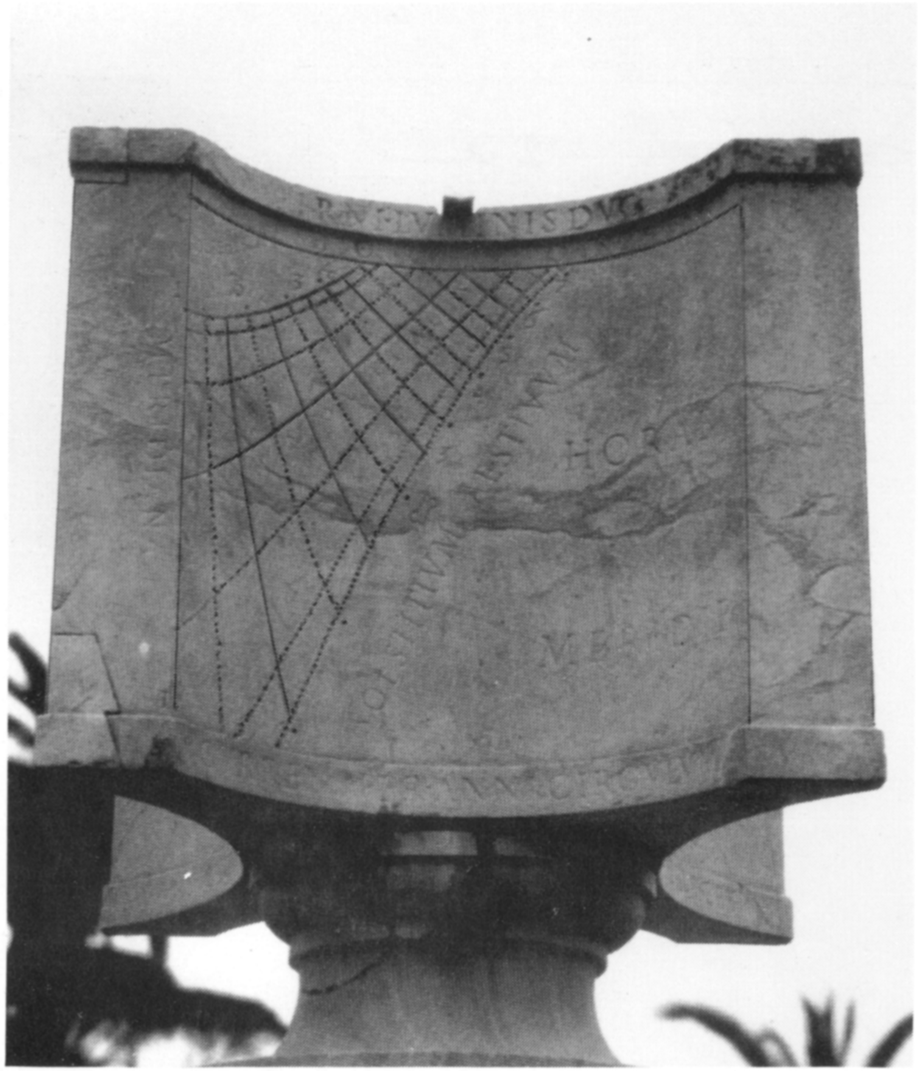
2. The Quirinale sundial viewed from the east



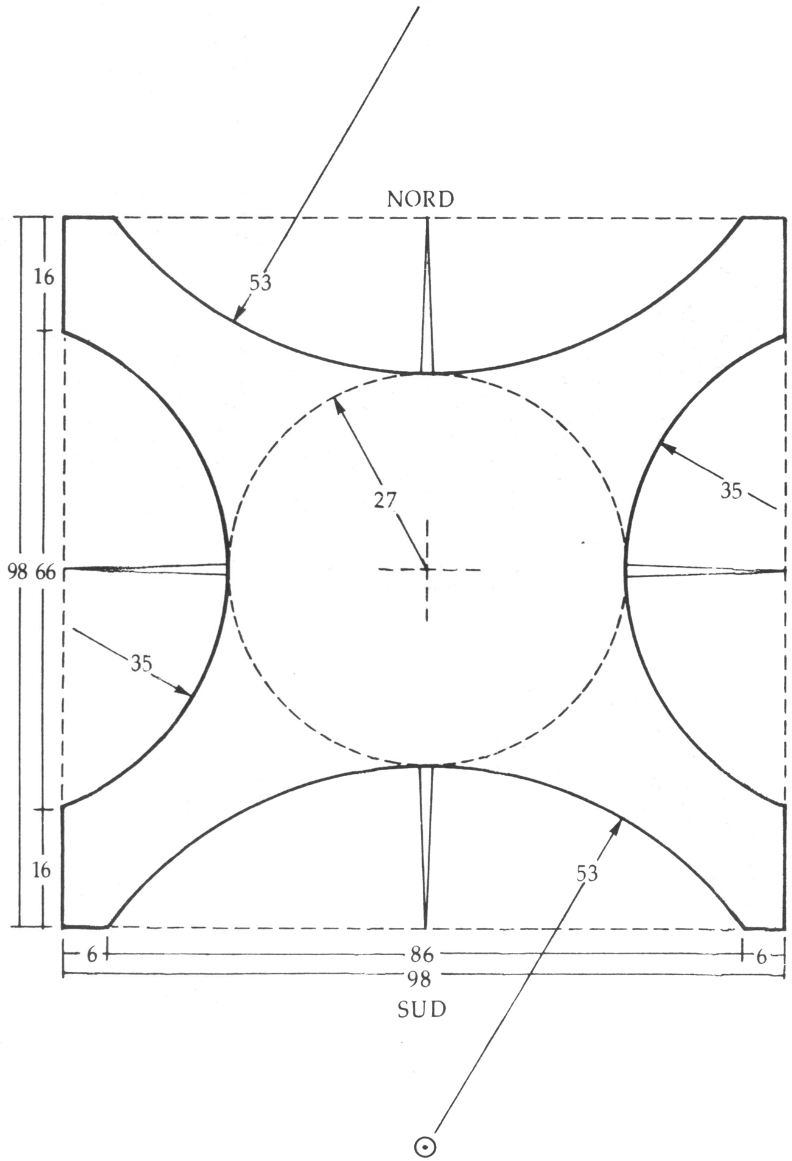
3. The south quadrant dial of the Quirinale Sundial



4. The north quadrant dial of the Quirinale Sundial



5. The west quadrant dial of the Quirinale Sundial



6. Horizontal section through the block inscribed with the four dials

Hour" is derived from this time system and divides the day into 24 equal hours commencing at sunset, or the beginning of the onset of night, or *Ave Maria* which is the moment half an hour following sunset. This system is now obsolete, but in Italy, for example, it was in use until quite recent times, thus many sundials, including the ancient examples which are still conspicuous on the walls of ancestral houses, bell towers, churches, towers, etc, are still found faithfully indicating the time according to Italian hours; it can be said that in some regions our grandfathers and great-grandfathers continued to use this type of time measurement.

At the time of construction of the Quirinale sundial both systems were in use, a fashion which spread more or less in the region of the Popes, and which explains the double time system used by the instrument[2]. Of course in 1628, the present-day mean solar time system indicated by mechanical clocks was not in force, therefore the time furnished by the east-west quadrant pair is true local solar time.

The four inscribed quadrants present the time curves in half-hour divisions, the time is designated on each line with the hour number at the extremity; the half hours are indicated with dotted lines.

The succession of the hours on each quadrant proceeds in the following fashion:

EAST With the inscription ***HORAE A MEDIA NOCTE*** (hours from midnight): civil time from 5 to 12 am.

WEST With the inscription ***HORAE A MERIDIE*** (hours from midday): civil time from 12 to 7 pm.

SOUTH Without inscription: Italian hours from 12 to 24.

NORTH With the inscription ***LUCE SUA*** (By its light): Italian hours from 21 to 24 and from 9 to 12.

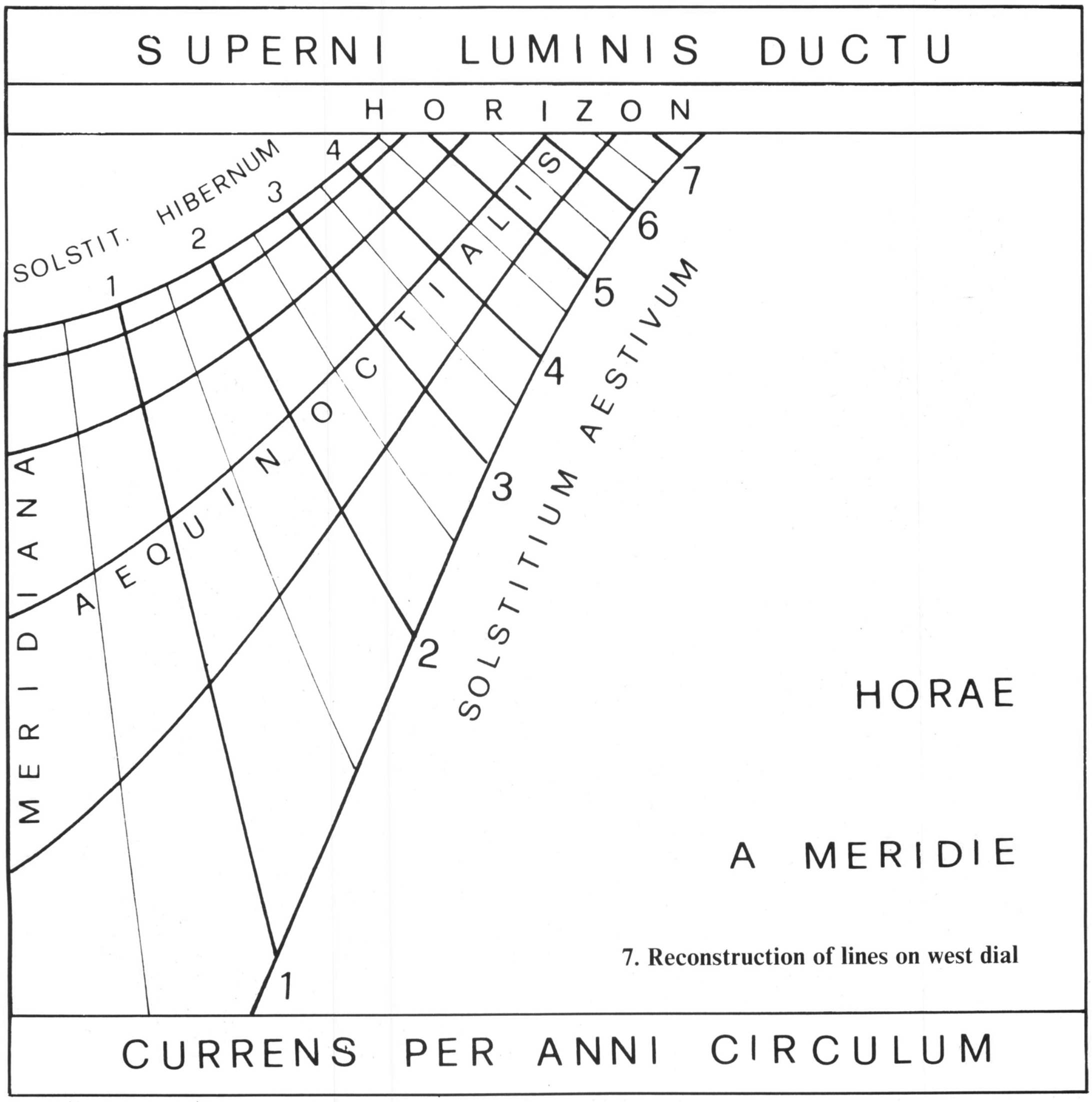
THE CALENDAR

In accordance with the almost universal practice with sundials of this age, the declination lines are represented by the seven "zodiacal curves", inscribed with dotted lines corresponding to the days marking entry into the zodiacal signs[3]. Each of these lines is marked with the corresponding pair of zodiacal signs at the margins of the quadrant, in accordance with the iconography of the period.

Latin inscriptions identify the three principal curves:

SOLSTITIUM HIBERNUM (Winter Solstice), above, marked with the symbol of Capricorn.

EQUINOCTIALIS (Equinoctial), centre indicated with the symbols of Aries and Libra, the only curve drawn with a full line.



7. Reconstruction of lines on west dial

SOLSTITIUM AESTIVUM (Summer Solstice), below, marked with the symbol of Cancer.

Whilst it is true that this family of curves can be used as a calendar, it is necessary to point out that 30 days are crowded between two adjacent curves, therefore in this sundial the calendar approximations are rather modest, as in all gnomonic instruments; so in reality with these calendar curves, rather than read the exact date, the most we can obtain in practice is to follow the change of the months and seasons[4].

AUTHOR, PATRON AND INSCRIPTIONS

The author of this beautiful sundial is clearly indicated on the north quadrant with the inscription ***THEODOSIUS RUBEUS PRIVERVERNAS DEL*** (Designed by Theodosius of Priverno). Unfortunately we have no information on this learned astronomer who drew, inscribed and installed this most invaluable monumental sundial. His name is without mention in the vast gnomonic literature to my knowledge.

The patron of this work is also clearly indicated on the monument, in fact on the upper part of the quadrants and the lower cornice is circumscribed the Latin inscription.

(SUP)ERNI LUMINIS DUCTU - URBANI VIII BARBERINI - PONT. MAX. AN. SEXTO - SALUTIS MDCXXVIII - CURRENS PER ANNI CIRCULUM - RECURRENTIUM TEMPORUM LEX - A LUCE PRIMA IN VESPERAM - SIC TOTA DECURRIT DIES.

(By order of Urbano VIII Barberini in the sixth year of the Pontificate 1628 of the Salvation, the law of time passes on the circle of the year from dawn to sunset during each day).

Maffeo Barberini was Pope from 1623 to 1644, with the name of Urbano VIII, and 1628 was the sixth year of his reign of office.

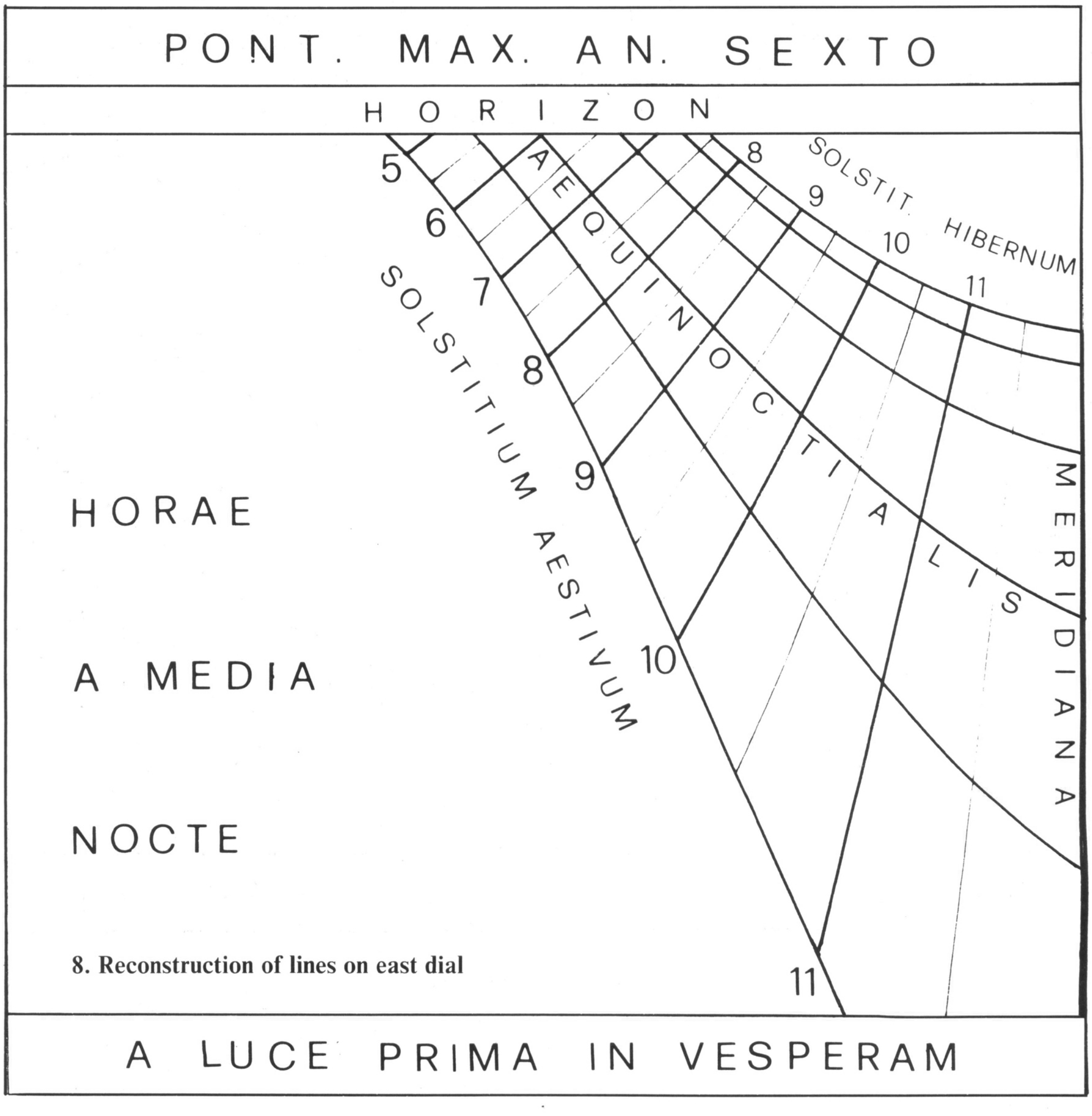
On the periphery of the base of the quadrants as a motto, is an inscription recalling a famous phrase of Virgil (*Georgiche,* Book VI, 165):

SUNT QUIBUS AD PORTAS CECIDIT CUSTODIA SORTIT (To someone Fate has given the task of standing guard at the Doors).

In addition the following inscriptions appear on the quadrants:

MERIDIANA (Meridian), traced on the middle part of the southern quadrant, on the exit vertical margin of the east quadrant and on the entry vertical margin of the west quadrant; this line corresponds precisely to the time of local noon.

HORIZON (Horizontal) on the upper horizontal line of all the quadrants: these represent the horizontal line and at this level are the points of the style extremities which form the indicating shadow.



8. Reconstruction of lines on east dial

TECHNICAL AND ARTISTIC EVALUATION

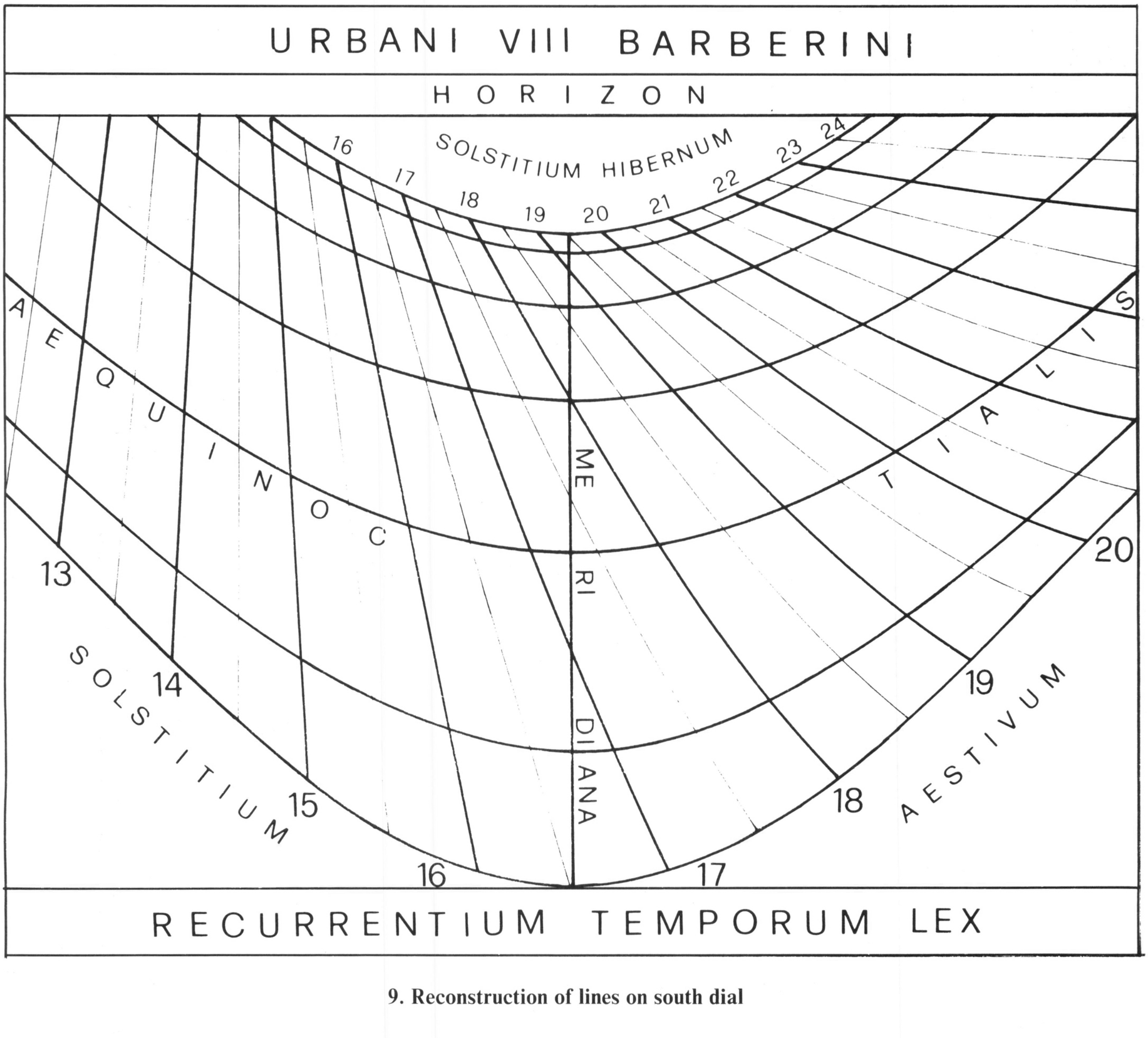
On both technical and artistic grounds, it may be affirmed that the work is of quite exceptional merit, it is a truly remarkable monument and it can be said that it is unique: at no other place is it possible to find a sundial of such large dimensions which embellishes a park or garden in so harmonious and effective a fashion. From the purely technical point of view, this sundial is a masterpiece of gnomonics in every aspect; this work, produced at the culmination of the golden period of gnomonics is perfect in its conception and realization, yet it is not at all widely known. This monument reflects great credit to the astronomical scientist who planned it, and to the sculptor who carved the dials and inscribed the lines on the marble faces, (possibly the same person).

* * *

FOOTNOTES

1. The Quirinale Palace, which today is the official residence of the President of the Republic, was formerly the Summer residence of the Popes from 1592 (the date of its construction), until 1870.
2. For those interested, Italian hours can be converted to civil time by the following simple rule: "Civil time = [Italian time - the semi-nocturnal arc]", where the semi-nocturnal arc is half of the duration of the night on a given date.
3. It is necessary to point out that the zodiacal signs have fallen into disrepute and are reduced to the miserable level of astrology today, but in the past these were basic elements of astronomical science and played a most important role in the measurement of time.
4. In order to present a reasonable calendar indication, the sundial would have to be of enormous proportions. The most effective calendar was the ancient sundial of Augustus at Camp Marzio in Rome, in which the distance between the course of the shadow on two consecutive days could be as much as 60 cm.

* * *



9. Reconstruction of lines on south dial

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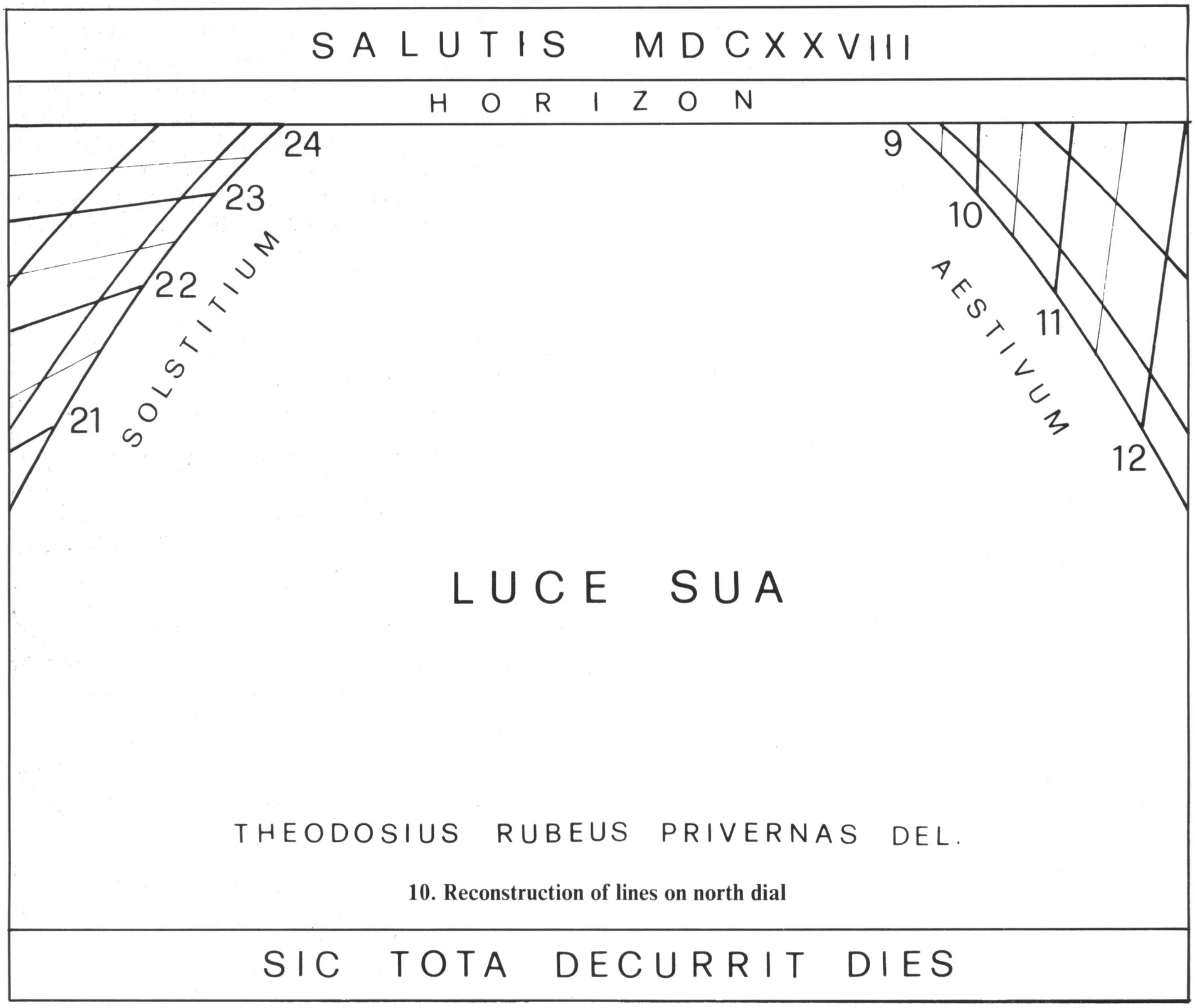
Fantoni, G. *OROLOGI SOLARI* (Sundials), Ed, Technimedia, 1989, Rome. [A full review of this excellent dialling book was given in *BSS Bulletin* 91.3, October 1991.

Fantoni, G. "La meridiana nei giardini del Quirinale", dalla rivista *Orologi,* November 1987, Rome. (The sundial in the garden of the Quirinale, from the magazine *Orologi*).

EDITOR: Grateful thanks are expressed to our Italian author for bringing such a beautiful example of the gnomonic art to the attention of BSS members, and the enriching of our knowledge of the noble art of dialling. The Italian text was translated by Mr. Ron Satchwell, to whom thanks are also expressed.



10. Reconstruction of lines on north dial

Concluded from page 23

The declination of the sun does, of course, vary in the course of the year from + 23½° to - 23½° either side of the celestial equator. Therefore the shadow boundary will not in general be exactly at right angles to the edge of the strip, requiring the hour markings to be made as spots along the central axis on both sides.

If the helix is mounted on a stub axle that is a friction fit in its socket (as in Figure 6) then the entire sundial may be rotated on this axis to allow for Summer Time or the longitude correction for Standard time.

Ingenious as it is, the Piet Hein design is not particularly precise as a timeteller for the separation between hour marks is set by the pitch of the helix, and the 'lever arm' (the distance between gnomon and hour mark) is very short. The more accurate members of the family detailed above increase the physical separation between the gnomon and the shadow-receiving helical surface.

NOTES AND REFERENCES

1. F.W. Cousins, *Sundials* Baker, London, 1969.
2. M.S. Gatty, revised Eden & Lloyd, *The Book of Sundials* London, 1900, is a well-known example.
3. H. Schumacher, *Sonnenuhren* Vols. I, II and III Callwey, Munich, 1973, 1978 and 1984 respectively. The Lérida sundial is illustrated in Vol. I p. 80 and Vol. III pp. 26 and 75.
4. A.A. Mills, 'Super-Eggs and Sundials: Some Examples of the Work of Piet Hein', *Bulletin of the Scientific Instrument Society* 1992 No. 32 pp. 7-10.

PORTABLE DIALS - AN INTRODUCTION

BY JOHN MOORE

Most portable dials are known to us from the many fine examples which may be seen in our technical museums[1] and in specialist literature[2].

They have been made in a wide range of styles and designs, the variety only being limited by human imagination and ingenuity. Most portable dials were intended to be carried in the pocket and were the early versions of the pocket watch. This does not mean to say that watches were not available at this period, but those watches that were in use were considerably more expensive and somewhat unreliable in their timekeeping. The pocket dials, of course, were only of use when the sun was shining, and, generally, were most popular in the sunnier countries of Europe.

Other forms of portable dials were designed for surveyors and sailors, or to be used in the house in a more or less permanent position. Some of these were large and elaborate and can hardly be considered as portable. Due to their size and weight they would probably be placed just inside a south facing window of a country manor house or in a gentleman's private observatory. The majority of portable dials were made to travel, and to this end many were made universal ie. they could simply be adjusted to cover a range of latitudes. Most were finally engraved or stamped with lists of towns and their latitudes to enable the dial to be correctly set. These lists of towns generally cover a wide geographical area. The towns of London, Paris and Rome, always popular destinations for the gentleman traveller, appear on most in addition to those in the owner's local area, Fig. 3.

With the simpler versions of these dials accuracy, at best, could only be to the nearest half hour, but as dial making progressed, accuracy improved and some of the later dials were even engraved with the equation of time to achieve the most precise readings. A small handful were made which could be read to the nearest minute by employing mechanical means to expand their scales.

Various means were used to correctly align the dials to achieve the highest accuracies. Some had spirit levels or plumb bobs to set them horizontally, sometimes with the aid of three levellings screws. Others were self aligning, being mounted on gimbals, or with the gnomon and hour scale mounted on the compass card. The commonest and most important alignment aid which was on the majority of dials was the magnetic compass used to enable the dial to be orientated to face exactly south. The compass, which was usually built in as part of the dial would only point to the local magnetic north, which, as today, was not the true north but somewhere in that general direction. Magnetic north changes with time and in the period covered by the manufacture of these dials the variation in northern Europe has changed from a few degrees east, through zero around 1660, to a maximum of 24.5° west in 1815 and is now again approaching zero for some time around the year 2030. A useful way of confirming the dates of dials is to check the variation as marked in the compass bowl and compare it with historical records for the appropriate city[3]. With care a very accurate date check can be achieved. Many portable dials had folding gnomons, plumb bobs, scales etc. and to protect them in the pocket they were fitted into a custom

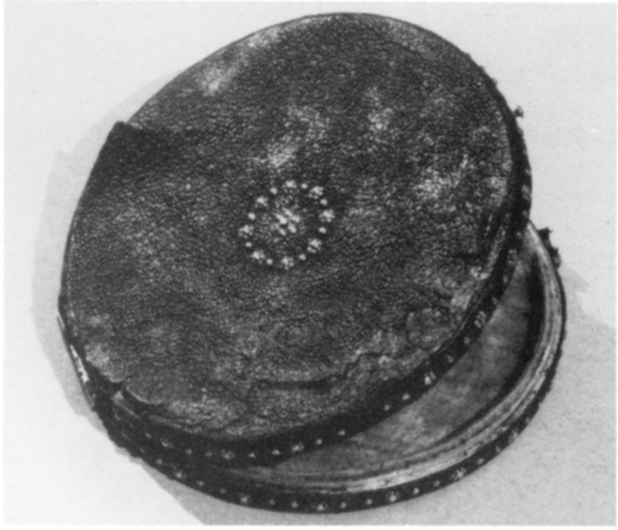


FIGURE 1: Black fishskin carrying case, decorated with silver clusters, interior lined with velvet for silver ring dial, edges of metal gilt, circa 1690. 80 mm. diamter. Possibly of German manufacture.

designed carrying case, most of which were made of leather or fish skin. Some of these were elaborately decorated to suit their owner's wishes, (Figs. 1 and 5). Dials, such as the ivory diptych did not need a protective case as once the two halves were folded together and safely latched they were generally self protecting.

The majority of dials with which we are familiar were made in just five locations. Each of these centres were active at different periods and the following list attempts to give these with approximate dates for peak activity, styles and materials used.

LONDON — A wide variety of designs by numerous makers. The predominant material was brass. 1600-1850.

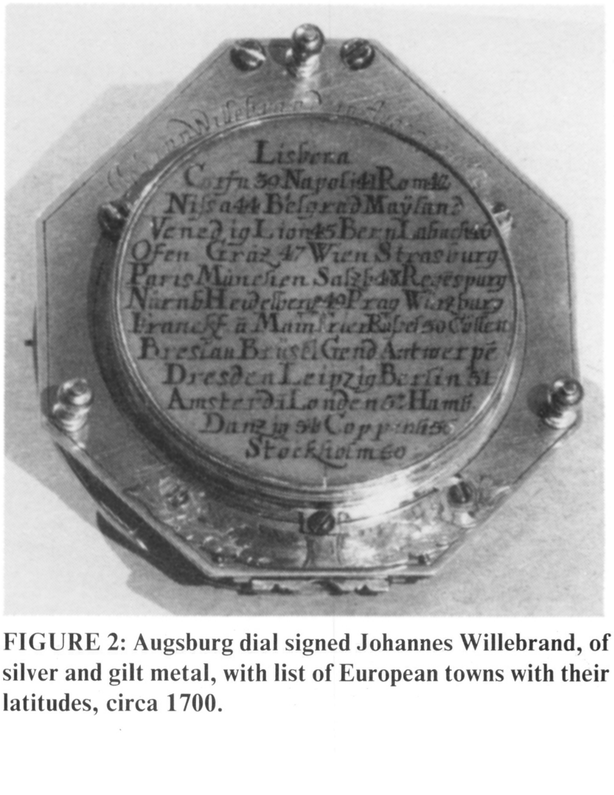


FIGURE 2: Augsburg dial signed Johannes Willebrand, of silver and gilt metal, with list of European towns with their latitudes, circa 1700.

FIGURE 3: Universal inclining dial by Edward Culpeper, London, brass, circa 1700. With list of European towns and their latitudes.

PARIS	Most dials were in the so called 'Butterfield' style, and were made by a large number of workers. They were commonly made in silver, but a few also in brass. 1680-1800.
DIEPPE	Mostly diptych in ivory. Two or three standard patterns, but the majority were in the style normally attributed to Charles Bloud and made by a very small number of makers. 1650-1700.
AUGSBURG	A particular style was developed, mostly in brass, but with a few in silver and occasional gilding. They were made in large quantities by a relatively small number of workshops. 1720-1800.
NUREMBURG	These workshops concentrated on the ivory diptych dials which were attractive and of good quality. Size and decoration differed widely. Large quantities were made by a small number of workshops. 1580-1700.

Portable dials were obviously made in many other parts of Europe, and occasionally further afield, but generally the outputs from these areas were small in comparison to those detailed.

In later articles it is hoped to illustrate and detail the various styles of dial, with their methods of use, development, refinement, and of course listing the more famous makers.

REFERENCE 1: SOME SUNDIAL COLLECTIONS

ENGLAND	
Bury St. Edmunds, Suffolk	The Gershom Parkington Collection. (The Clock Museum).
Cambridge	The Whipple Museum
Greenwich	The Old Royal Observatory of the National Maritime Museum
London	The British Museum The Science Museum
Oxford	The Museum of the History of Science
SCOTLAND	
Edinburgh	The Royal Scottish Museum, Chambers Street
BELGIUM	
Liege	Musée de la Vie Wallone
CZECHOSLOVAKIA	
Prague	National Technical Museum
FRANCE	
Paris	Conservatoire des Arts et Métiers
GERMANY	
Bielefeld	Kunstgewerbesammlung Stiftung Huelsmann
Dresden	Staatlischer Mathematisch-Physikalischer Salon in Swinger
Munich	Deutches Museum
ITALY	
Florence	Il Museo di Storia Della Scienza
SWITZERLAND	
Geneva	Musée de l'Histoire des Sciences
U.S.A.	
Chicago Il	The Adler Planetarium
Rockford Il	The Time Museum
Washington DC DC	Smithsonian Institute. National Museum of History and Technology

FIGURE 4: 'Butterfield' style dial by Le Maire et Fils, brass, circa 1730. Made for the Arabic market with a list of towns and their latitudes.

REFERENCE 2: SOME BOOKS ABOUT PORTABLE DIALS

DAVID BRYDEN. Whipple Museum Catalogue. 'Sundials and Related Instruments'

PAUL DANBLON. 'La Measure de Temps dans les Collections Belges' (French) (Also a Dutch version)

PENELOPE GOUK. 'The Ivory Sundials of Nuremberg. 1500-1700'

JIŘI LENFELD. 'Slunecni Hodiny ze sbirek UPM v Praze' (Czech - some English)

HENRI MICHEL. 'Catalogue de Cadrans Solaires du Musée de la Vie Wallonné. (French)

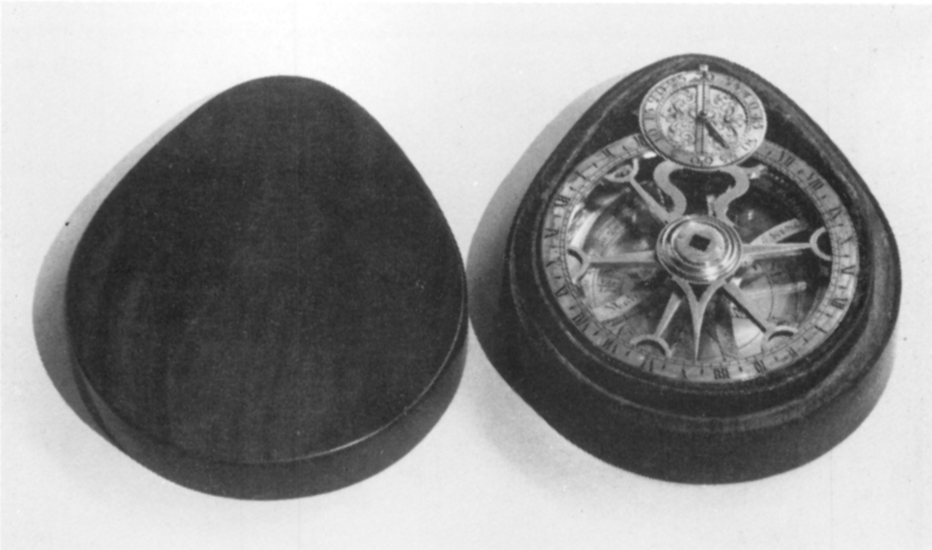


FIGURE 5: Universal Equinoctial mechanical dial by Thomas Wright, London, 'Instrument maker to y^e King', with purpose built wooden case lined with velvet. First half of 18th century.

HENRI MICHEL. 'Les Cadrans solaires Max Elskamp' (French)

RENÉ R.-J. ROHR. 'Les Cadrans Solaires' (French) and 'Die Sonnenuhr' (German)

DIRK SYNDRAM. 'Wissenschaftliche Instrumente und Sonnenuhren' (German)

ANTHONY TURNER. 'Ritmi del Cielo e Misura del Tempo' (Italian and English texts)

Catalogues for the main auction houses, such as Christies' and Sotherby's contain many examples. In particular Christies' sale of 'Time Measuring Instruments from the Time Museum' 14th April 1988.

Most of these books are available from specialist booksellers. Two of these are:

Rogers Turner Books Ltd., 22 Nelson Road, Greenwich, LONDON, SE10.

Rita Shenton, 148 Percy Road, Twickenham, LONDON, TW2 6JG.

REFERENCE 3: MAGNETIC VARIATION

The Editor has compiled a brief item on the estimation of the date of a portable sundial by the magnetic variation marked on the compass bowl, to supplement the remarks made by Mr. Moore in his text, see following article.

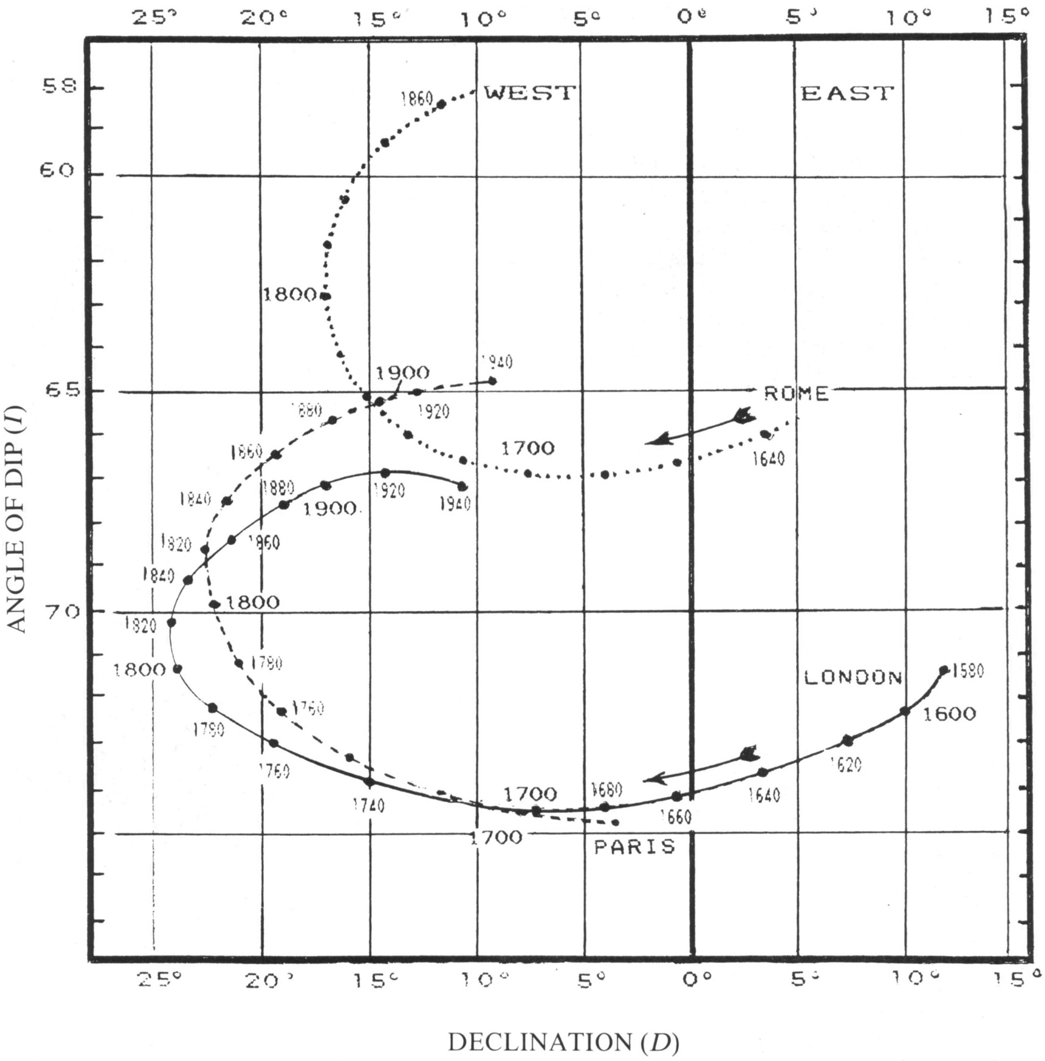
ESTIMATION OF COMPASS DATE BY MAGNETIC VARIATION

BY CHARLES K. AKED

Under the impression that the Earth's magnetic poles were fixed in position, the early diallists made use of magnetic compasses for setting the sundial on the meridian. For the same purpose, magnetic compasses were incorporated into portable dials at an early date. In actual fact there is no one spot on earth to which either the North or South pole can be said to be situated, the approximate positions are changing slightly daily, plus longer term variations, combined with a cyclic return over several centuries. It was not long before sundial makers became aware of these variations, the magnetic anomalies occuring in sea voyages had been known much earlier and at one time these variations were considered as a means of identifying a vessel's position at sea.

Observations of the magnetic variations have been observed over several centuries in many locations, mainly for navigational purposes, thus allowing the date of manufacture of a compass to be ascertained from the deviation marked on it, knowing the place of manufacture, and comparing it with the chart shown here. However it is possible that the sundial compass may have been rectified at a later date when the variation datum line was seriously in error, the old line being deleted and a new one inscribed for the current magnetic variation. Therefore the style of the compass and the dial itself must be taken into account to arrive at a suitable assessment, bearing in mind that the compass may itself have been replaced at a later date because of some accident to the original one. The earliest compass needles were by no means permanent and have even been known to reverse in magnetism by such means as a nearby stroke of lightning.

The accumulated knowledge of terrestial magnetism is very great and complex. Deviation of the magnetic field from true north is affected by local conditions such as metallic ores below the surface, and in modern times by the buried material which may contain concentrated magnetic sources such as magnets for various purposes such as small motors or loudspeakers, or merely large sections of iron or steel piping. The passage of an electric current, either by leakage or by natural means, will also greatly affect the local magnetic field. Thus the use of a compass for setting a dial is, at best, very approximate and merely an aid to get the dial orientation into the correct region before applying a more accurate method such as the Polar star and its known deviation. With a portable dial, the scale is of small proportions and thus limits the accuracy of reading anyway, so a compass set portable dial may well be adequately aligned to the local meridian for the temporary determination of solar time.



DATING BY DEVIATION MARKED ON MAGNETIC COMPASS

Because extensive records of the variation of the Earth's Magnetic Poles exist, it is possible to know the deviation at a particular spot at any time in the last four centuries. The chart shown here unfortunately does not indicate that for Nuremberg, the sundial manufacturing centre which first introduced the use of the magnetic compass for setting portable dials; and probably responsible for the making of most of the remaining specimens existing today. The better class of portable dial incorporated a means of adjusting for the magnetic variation but not for the variation in dip, so this latter is another means of identifying the correct period. The needle must be made lighter on the northseeking side to allow the needle to assume a true horizontal position at the time of making (in the Northern hemisphere although it is doubtful if any were made for the Southern hemisphere). This balance is upset when the dip varies from the initial value when the compass was made. This effect will be completely masked if the needle has been allowed to rust at some time in its lifetime. Carbon dating of the needle material is another possibility but is not very accurate.

Brief remarks on magnetic compasses will be found in *The Ivory Sundials of Nuremburg* 1500-1700 by Dr. Penelope Gouk, published 1988; on pages 9, 23, 46, 111; and on magnetic needles on pages 9, 14-15, 58, 66, 69, 73, 78-80, 87 and 116; plus pages 14-15, 84, 87, 106 and 116 on magnetic variation. Perhaps some budding author would like to submit an article to the Editor on this quite complex and relatively little discussed subject. The groundwork has already been covered in discussions on the magnetic compasses used by the Mercantile and Royal Navies in that fine treatise *The Art of Navigation in England in Elizabethan and Early Stuart Times,* 1958, by Lieutenant-Commander David W. Waters, which contains many references to the subject. E.G.R. Taylor's *The Mathematical Practitioners ...* also contains references to magnetic variation, including a biography of Henry Gellibrand who established the secular variation of the compass-needle from his observations when he, Henry Briggs, Edmund Gunter, and several mathematicians visited John Wells, at his Deptford home to measure the variation in Wells's garden from dials precisely set in 1612, 1633 and 1634, using a magnetic compass, to set the dial orientation on the local meridian.

ACKNOWLEDGEMENTS

The chart illustrated here is based on one supplied by a BSS member to the writer.

HELICAL SUNDIALS

BY ALLAN MILLS

INTRODUCTION

One of the simplest of sundials to understand is the equatorial dial, where a cylindrical surface co-axial with the pole-directed gnomon acts as the receiving surface for its shadow, and so gives rise to uniformly spaced hour markings at 15° intervals. For this reason the equatorial dial is treated as the basic pattern in a well-known textbook[1], and a number of actual examples may be found in descriptive and collective works on sundials[2]. An instrument of this form is shown in Figure 1.

FIGURE 1: An equatorial dial by Ralph Jefferson, 1985.

However, in spite of the diversity associated with vertical and horizontal planar dials, it is most unusual to find any variation of the equatorial dial. One possibility is to replace the usual dial band oriented at 90° to the gnomon with a receiving surface also extending axially, so giving rise to the family of helical sundials.

HELICAL SUNDIALS

The Simple Helix

If the dial of the basic equatorial form is imagined to be drawn out uniformly parallel to the gnomon we obtain a single-turn helix of constant diameter and pitch. Like any screw, it could be right or left-handed.

A prototype of this pattern, designed by John Singleton was exhibited at the Inaugural Conference of the British Sundial Society, held in Oxford in March 1990. Illustrated here as Figure 2, it will soon be on show at the Sundial Collection being assembled at Jodrell Bank Science Centre. The rod-gnomon is supported at both ends by an outer arc, adjustable in elevation so that the instrument may be set to the latitude of its site. The calibrated helical dial is in turn supported by the gnomon, with provision for rotational adjustment to allow for the longitudinal displacement from the appropriate standard time meridian as well as for any temporary 'Summer Time' that may be imposed.

FIGURE 2: Helical sundial produced by the Singleton brothers. (Photo courtesy of John Singleton)

A monumental dial of the same basic form is included by Heinz Schumacher in his book on sundials[3]. Designed by J. Masuet, it is to be found at Lérida in Spain. (The town of Lérida lies about half-way between Barcelona and Zaragoza.) It is shown here as Figure 3. Some 2 metres high, its sloping gnomon has a graceful tapering form, producing a resemblance to an embedded javelin. The helical dial enfolding it is cast from a decorative reinforced concrete ('Betonwerkstein'), and although of constant internal diameter appears to diminish in thickness as it ascends.

Irregular Helices

There is, of course, no reason why the diameter or pitch of the helix should be constant, apart from the non-linearity of the hour scale that such variations would

FIGURE 3: Helical sundial by J. Masuet, 1974, at Lérida in Spain. (After Schumacher[3])

induce. (Non-linearity is happily accepted in planar sundials.) It would, for example, be possible to inscribe a dial upon the interior surface of a metal 'ribbon' flying from the tail of a Lérida - like javelin embedded at the polar elevation. I am not aware of the existence of any such dials.

The Piet Hein Helical Sundial

The Danish scientist-poet Piet Hein is perhaps best known for his epigrams ('Grooke') and for his promotion of the fractional exponent 'superellipse' as a curve mediating between the circle and the square, or the ellipse and the rectangle[4]. However, his inventiveness is again apparent in his design of a helical sundial combining gnomon and dial in a single twisted strip of thin metal pointing at the celestial pole. The original is to be seen in the beautiful gardens surrounding Egeskov Castle, near Kvaerndrup on the island of Funen, Denmark. (Claimed to be the best-preserved Renaissance moated castle in Europe, the house, gardens and veteran car museum are open daily from May to September.)

The entire Piet Hein sundial is shown in Figure 4: with its supporting column it reaches a height of 9 metres. A closer view is given in Figure 5, from which it may be seen that the ends of the helix are fixed in the plane of the meridian, and so its centre (180° away) will also be in this vertical plane. It will therefore be apparent that the rays from the noon sun at the equinoxes will illuminate one half of the helix, leaving the other half in shadow. However, it will also be appreciated that both edges (acting as gnomons) and both sides of the strip (acting as receiving surfaces for the shadows) are operative, although light and dark zones are interchanged on the two sides. Their boundary marks the time of day.

This may be clearer in Figure 6, which shows a similar helical sundial made by the author: both photographs were taken at 2 p.m. As the day advances so the light/dark boundary rises at 15° of pitch per hour: knowing this length enables the 'screw' to be calibrated in hours. It is necessary to graduate only the six hours (± 90°) either side of noon, for a summer sun leaving the upper graduated section at 6 p.m. will immediately give rise to a shadow boundary climbing the lower section; so that '7' for example can denote both 7 a.m. and 7 p.m. Piet Hein has chosen a left-handed helix, but a right-handed version would exhibit similar behaviour with light and dark areas interchanged.

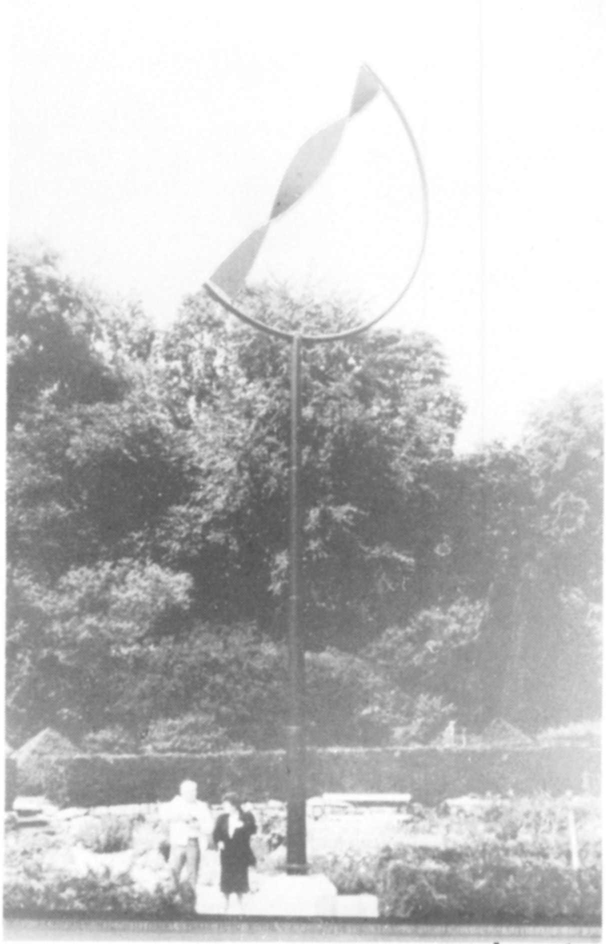


FIGURE 4: The Piet Hein sundial in the grounds of Egeskov Castle, Funen, Denmark. (Photo by H. Andersen)

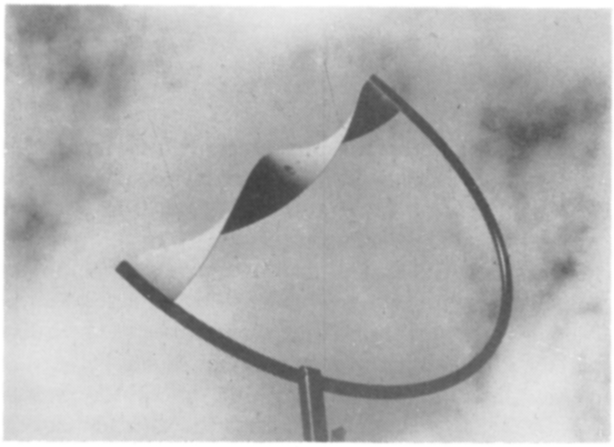
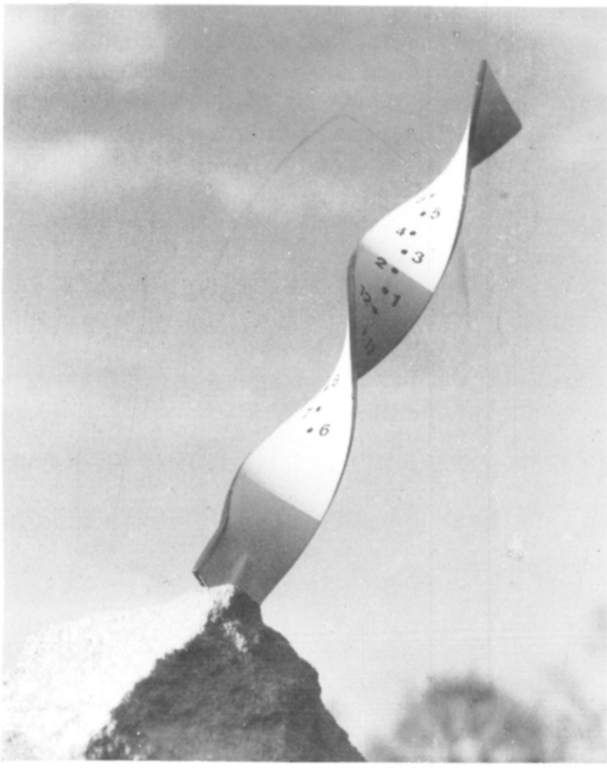


FIGURE 5:

Here is Time
in heavenly grace,
Hither brought
from outer space,
Helios
uncomplicated
In a helix
concentrated.
Piet Hein



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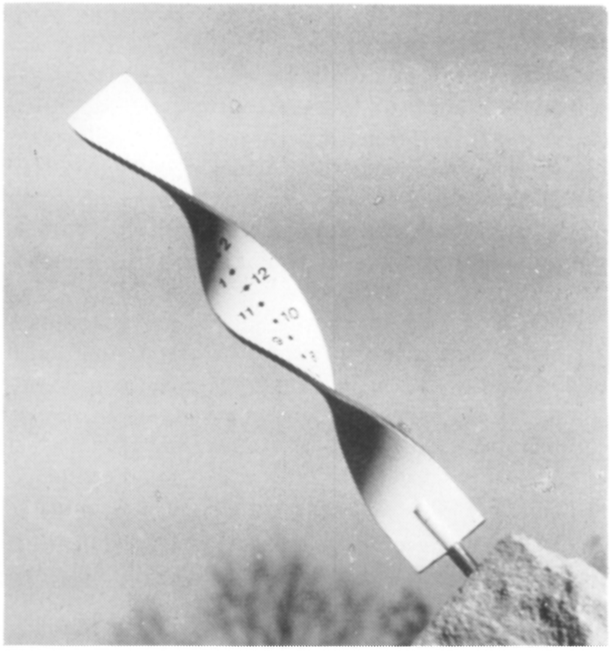


b

FIGURE 6: A small sundial based on the Piet Hein design. Twisted from mild steel, the helix is 300mm long, 40mm wide, and has a pitch of 285mm. (a) and (b) are views from east and west at the same time of day: note the inversion of the shadow zones.

Continued on page 16

THE PHOEBOSCOPE
BY H. CHRISTOPHER H. ARMSTEAD

RECIPROCALITY OF SUNDIALS AND SUN COMPASSES

A sundial can perform its time-keeping function (within its limitations) only if it is correctly aligned to the meridian. It is therefore necessary to enlist the help of a compass when it is set up. Likewise a sun compass can perform its meridian-finding function only if operated in conjunction with a time-keeper. Thus the solar time-keeper is dependent upon the direction of the meridian and the solar meridian-finder is dependent upon the time. Neither instrument in simple form can therefore be self-reliant as each requires information that can, in theory at least, be supplied by the other. If, however, either instrument can so be made as to be capable also of detecting the solar declination, then a single self-sufficient instrument could be devised capable of detecting both the time and the meridian without the aid of any other instrument. The ship-wrecked mariner, armed with such an instrument, would be self-reliant for time-keeping and direction-finding, provided he knew his position. Solar declination is of course dependent upon the date. So if the instrument were calibrated to show the correlationship between the date and solar declination, a nautical almanack could be dispensed with. Our ship-wrecked mariner would then even be provided with a calendar.

The phoeboscope is such an instrument, capable of functioning with accuracy anywhere in the world where the sun shines, from the Arctic to the Antarctic.

EVOLUTION OF THE PHOEBOSCOPE

During the second world war sun-compasses were extensively used by the army for navigating the North African desert. This was because magnetic compasses would have been useless in vehicles of iron and steel. The sun on the other hand was nearly always shining by day and it could be depended upon to behave consistently regardless of the materials of which war vehicles were made. It was the use of sun compasses during the second world war that was ultimately responsible for the evolution of the phoeboscope, but it took many years to hatch. This is how it happened.

In 1941 I was in charge of certain government departments in an Indian princely state and had fairly extensive workshop facilities at my disposal. The general commanding the nearby garrison asked me one day if I could produce sun-compasses, twenty thousand of which were urgently needed for the North African campaign. When he produced a sample army issue sun-compass I looked at it critically, for I had learned the rudiments of navigation as a naval cadet many years earlier and had also learned to apply elementary astronomy to surveying when I had later been an engineering student. I decided then and there that I could do better than produce more such instruments: I could improve upon the design. From the practical point of view I did not like the frail gnomon which looked like a defenceless steel knitting needle sticking vertically up from a circular shadow-plate, scarcely robust enough to resist the rigours of a campaign. Secondly, the vicissitudes of varying latitude, longitude and solar declination were crudely allowed for by the use of charts that had to be slipped over the gnomon and changed every two weeks. And thirdly, for deducing the direction of the meridian the instrument relied upon solar azimuth, a complex variable, whereas hour-angle would have been so much simpler.

Within two or three weeks I had completed a new design and had a working model made. This new instrument needed no charts, made full allowance for the observer's latitude, longitude and for the equation of time, and was universal in that it could be used anywhere in the world in either hemisphere. The model was sent to the Director of Armaments in Simla in August, 1941, together with a brochure of instructions. For sixteen months it was lost in the maw of bureacracy. At one stage a friend of mine discovered it in some official's office in Calcutta unopened.

Then in December, 1942, I was asked to demonstrate my sun-compass in the presence of a new general who had come to command the local garrison, and his Chief Royal Engineer Officer. It was somewhat disconcerting to discover that not only the general and his CRE but also a whole posse of brass-hats had assembled for the demonstration. Feeling like a salesman of vacuum-cleaners, I put the instrument through its paces and concluded with the words 'And that, gentlemen, is the true north'. Half a minute's total silence followed, ultimately broken by a much bemedalled brigadier who said 'Too damned high-brow for me to understand'. The general thanked me and the party broke up. However, the CRE stayed behind and assured me that he had understood the instrument and appreciated its advantages: he promised to take it to Poona for a proper trial. This he did, and two weeks later he wrote to say that 'although the superiority of your instrument was recognised' it was regrettably too late for anything to be done as the Lybian campaign was over and there would be little demand for sun-compasses in future. The most unkindest cut of all was contained in another letter I received from the general, who said 'The time for it (the instrument) to have been shown would have been about a year ago'. That, after sixteen and a half months from when I had first submitted the instrument!

That I was not alone in experiencing frustration at the hands of bureaucratic procedure is well borne out by the experience of Mr. O.M. Meares, who was unknown to me at the time when I was fighting my 'battle of the sun-compass' but who later became a close colleague of mine in England. Unknown to me, Meares too was taking an interest in sun-compasses at the same time as I was, but he approached the problem from a different angle. Whereas accuracy had been my primary aim, extreme cheapness had been his: and he designed an ingenious and simple device that could have been mass-produced at very low cost. He offered his brain-child to the Supply Development Committee of India. After a six weeks' gestation period he received a reply pointing out, among other things, that 'the policy laid down regarding the use of sun-compasses was such that calculations must be done on charts'. The Meares compass, like mine, dispensed with charts altogether. He offered a proposal to his committee for overcoming this regrettable omission to the effect that 365 blank charts could be provided, and that it should be arranged at the next Hague Convention that if war should be fought during a leap-year then February 29th should be internationally recognised as a day of truce! Needless to say, the Meares compass also failed to get off the ground.

My model sun-compass was never returned to me. After the war when I was again in England, I had another model made by a firm of qualified instrument-makers. It embodied a few minor improvements and was exhibited at the Physical and Optical Society Exhibition in April, 1947, where it attracted the attention of an official of the Admiralty Gunnery Establishment at Teddington. In

The first three of these factors can be allowed for quite simply by tilting and biassing the gnomon in ways that will be described below, but the fourth one varies from day to day and requires a more subtle solution. In place of a shadow-casting gnomon, the phoeboscope uses a lens that brings to a sharp focus the sun's rays onto the shadow-plate. (A purist might argue that a plate that receives a bright sun spot should not be called a 'shadow-plate'; but the name is convenient and it does in fact bear the shadow of the gnomon plate in which the lens is fixed.) Engraved on the shadow-plate is a figure-of-eight analemma (Fig. 1) that marks the locus of the sun spot's movement throughout the year as the equation of time and the solar declination continuously change. This is the design feature that enables the instrument to detect the

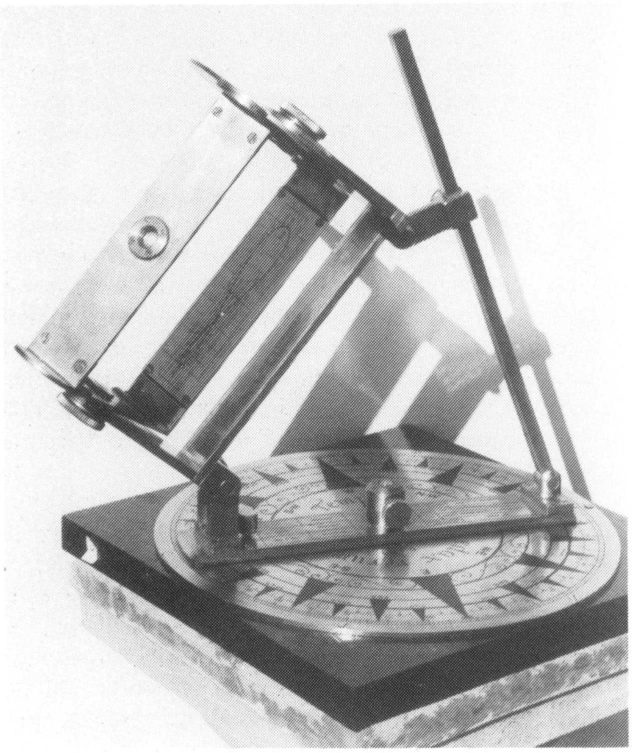


PLATE 1: General view of the Phoeboscope taken at the moment of observation

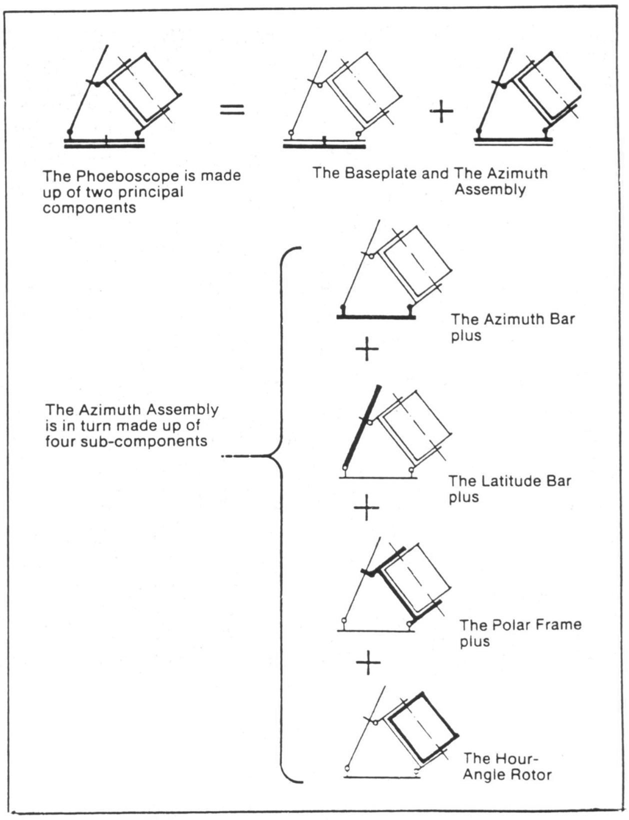


FIG. 2 THE PRINCIPAL COMPONENTS OF THE PHOEBOSCOPE

Resting on the base-plate[1] is the entire azimuth assembly, which comprises all the remaining parts of the instrument. The whole of this assembly can be rotated in azimuth (hence its name) about the hub[15].

The azimuth bar[3] carries the remaining three principal components of the azimuth assembly and also indicates the direction of the true meridian when the instrument is correctly aligned.

The latitude bar[4] allows the whole of the polar frame[5] together with the hour-angle rotor[6] to be tilted to an angle to the horizontal equal to the observer's latitude: it is engraved with a (non-linear) scale marked in degrees of latitude.

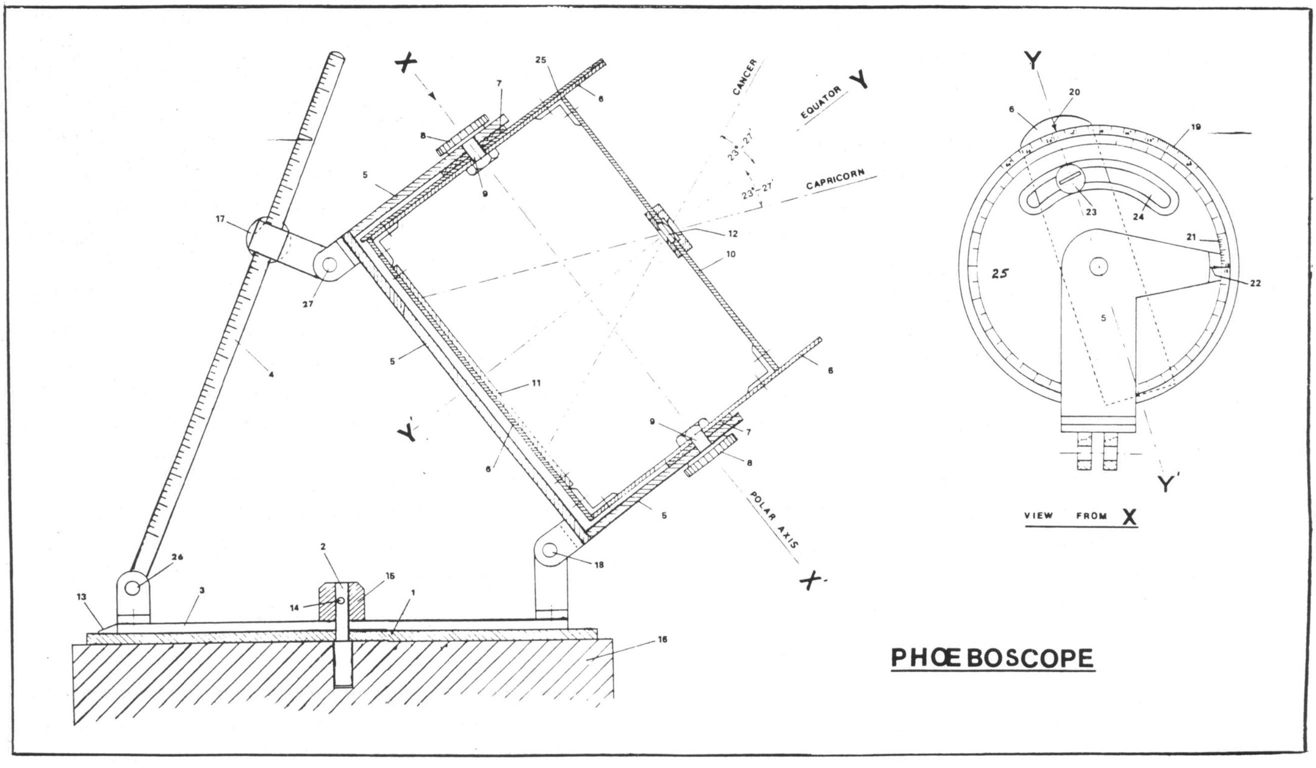


FIGURE 3: General Arrangements Drawing of the Phoeboscope

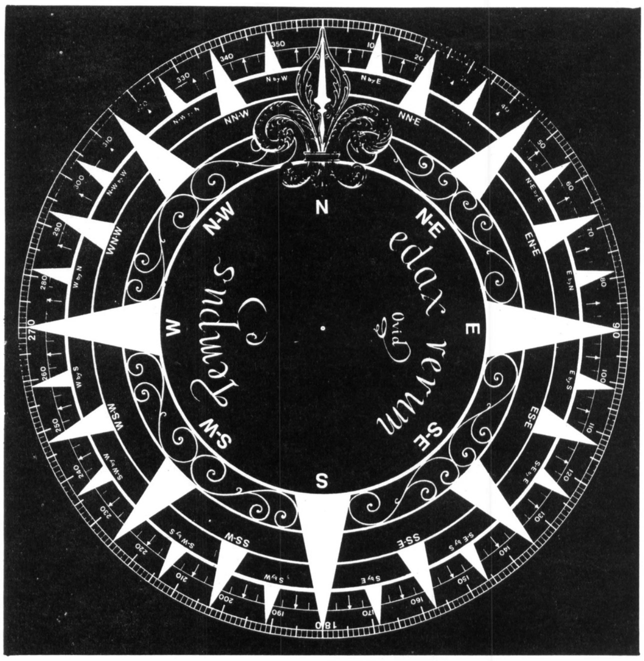


FIGURE 4: The Base-plate

The polar frame[5] serves to carry the hour-angle rotor[6] and is hinged to the azimuth-bar[3] by means of a horizontal pivot[18]. It can be clamped to the latitude-bar[4] at the required angle of tilt by means of a knurled locking screw[17].

The hour-angle rotor[6] is free to rotate on trunnions[9] against the resistance of friction washers[7]: the resistance may be adjusted by means of knurled grip-screws[8].

Integral with the hour-angle rotor[6] are the two parts that provide the means of observation - the gnomon[10] and the shadow-plate[11]. The gnomon[10] is simply a flat metal strip, in the centre of which is fixed a small convex lens[12] that can focus the sun's rays to form a bright image on the shadow-plate[11] when the hour-angle rotor is suitably orientated towards the sun. It is the shadow-plate[11] that carries the analemma (Fig.1).

Clamped to the hour-angle rotor[6] and concentric with the trunnions[9] is the hour-angle disc[25] on which are engraved two scales - the LST scale[19] and the LMT scale[21]. These initials stand for 'Longitude and Summer Time' and 'Local Mean Time' respectively.

The clamping of the hour-angle disc[25] to the hour-angle rotor[6] is effected by means of a gripping-screw[23] having a coin-groove for tightening it against the shoulders of an arc-shaped slot[24] in the disc. When the LMT scale[21] is set to 12.00 noon against the time cursor[22] and when at the same time the LST cursor[20] is set to zero on the LST scale[19], then the two axes 'XX' and 'YY' will both lie in the same vertical plane and the optical centre of the lens[12] will also lie in that plane. By setting the LST scale cursor[20] to some reading other than zero, to the right or to the left, a bias may be imparted to the gnomon either to the East or to the West so as to compensate exactly for the observer's longitude and for Summer Time where applicable. The LMT scale[21] is graduated in hours, with 5-minute sub-divisions: the reading of that scale against the time-cursor[22] is a measure of the Local Mean Time when the instrument is correctly set up for a time observation.

TO USE THE PHOEBOSCOPE AS A COMPASS

There are two ways of using the phoeboscope as a compass, for although the use of a watch is not essential it is nevertheless rather quicker and simpler to use one if available. This simpler way will first be described.

It is here assumed that the phoeboscope is to be set up in a semi-permanent position so that it can normally be used as a sundial after the direction of the meridian has once and for all been determined. It can still be used thereafter for demonstrating the instrument's capabilities as a compass, but after it has first been set up it is advisable to fix the base-plate firmly in its correctly orientated position. Theoretically the instrument need thereafter never again be used as a compass until it is moved to another site.

The first essential is to ensure that a firm foundation[16] is provided, preferably of hardwood, having a dead flat surface, horizontal in both directions and drilled with a hole to receive the lower extension of the hub-pin[2].

Place the base-plate[1] on the foundation[16] with the hub-pin extension in the hole and the entire azimuth assembly on top of it.

Tilt the polar frame[5] to the observer's latitude and clamp it firmly to the latitude bar[4] by means of the locking-screw[17]. This adjustment need never again be repeated unless the instrument is removed to another site.

Calculate the longitude adjustment (as explained below) and add it algebraically to the Summer Time correction, if any, and set the LST cursor[20] to this reading on the LST scale[19]. Clamp the hour-angle disc[25] to the hour-angle rotor[6] by means of the gripping-screw[23]. Except for the twice-yearly change in countries observing Summer Time, no further adjustment to the LST scale need be made unless the instrument is moved to another site. Set the LMT scale[21] against the cursor[22] to about a minute ahead of Local Mean Time as shown by a good watch, checked recently with a time signal. Swing the whole azimuth assembly about the hub-pin[2] until the sun's bright spot coincides exactly with the point on the analemma corresponding with the date of the observation (See plate 2). Keep moving the azimuth assembly very slightly, keeping the sun spot exactly on the analemma, until the watch time has caught up with the advance set time. The azimuth bar will then be correctly orientated North and South.

Mark on the foundation, by means of a small piece of adhesive label, the position of the azimuth bar cursor[13]. Remove the whole azimuth assembly and swing the base plate round until its North mark coincides with the mark on the label if the observer is in the Northern hemisphere, or until the South mark coincides with the label mark if the observer is in the Southern hemisphere. Repeat the whole operation to make doubly sure of the setting. Fix the base-plate[1] onto the foundation[16] by means of countersunk screws, and remove the adhesive label. The operation is complete.

When the base-plate has been correctly set up, the phoeboscope is ready to serve as a sundial.

For finding the direction of the meridian without the help of a time-keeper it is well to avoid the middle of the day when the sun is high in the sky, because the lower the sun the greater the accuracy of the operation. (In the limit, if the sun were at the zenith, as is possible in the tropics, it would be of no help whatsoever in determining the direction of the meridian. This is true of all sun-compasses).

The observer will of course have some rough idea of the direction of the North and South from the position of the sun in the morning or evening when he makes his observation. Setting the azimuth-bar[3] vaguely in that direction, rotate the hour-angle rotor[6] until the sun spot falls upon the analemma. Unless, by a sheer fluke, the azimuth bar is already correctly aligned, it will be found that the sun spot position is at some incorrect date. By moving both the azimuth assembly and the hour-angle rotor[6] simultaneously it will be found that the sun spot's position on the analemma can be brought closer to the correct date. When it is exactly at the correct date, not only will the azimuth bar be correctly aligned along the meridian but the LMT cursor[21] will indicate the correct local mean time. The observation is complete.

It is not of course the date as such that determines the direction of the meridian: it is the solar declination which is a function of the date.

CONFESSION. It must here be confessed that when I first used the prototype phoeboscope I adopted the simpler method of finding the meridian with the aid of a watch, as the capability of the solar declination to serve the same purpose had escaped by notice. For drawing my attention to this lamentable lapse I am greatly indebted to Signor Carlo G. Croce of Chiavari, Italy.

TO USE THE PHOEBOSCOPE AS A CLOCK

Having set up the base-plate in correct orientation the instrument is ready to be used as a clock.

With the entire azimuth assembly in position over the base-plate, swing it round so that the azimuth bar cursor[13] coincides with the North mark on the base-plate if the observer is in the Northern hemisphere, and with the South mark if the observer is in the Southern hemisphere. Lock the azimuth assembly in this position by means of the locking-screw[14].

Whenever it is wished to know the time, rotate the hour-angle rotor[6] until the bright solar image falls exactly on the analemma at the point corresponding to the date of observation. The local mean time can then be read directly from the LMT scale as shown by the cursor[22].

USE OF THE PHOEBOSCOPE IN THE SOUTHERN HEMISPHERE

The analemma must first be reversed so that the smaller lobe is nearer the latitude bar[4]. It will then be at the Southern end of the instrument when the polar frame is tilted towards the sun.

The left and right-hand arcs of the LST scale about the central zero are coloured black and red respectively. The LMT scale has two figures marked against each hour -one in black and one in red. These colourings relate to the tables shown in Fig.5 and which are engraved on the azimuth-bar. If the instructions on these tables are followed, the use of the instrument in the Southern hemisphere is exactly the same as in the Northern hemisphere.

LST SCALE SETTINGS

For calculating the longitude adjustments for this scale, the following examples should be helpful:

1. Northern hemisphere. Observer's position ... Dundee, Scotland, longitude 3° West ... Zone Time meridian ... 0° (Greenwich). Observer is to the West of the zone time meridian ... black scale. Summer Time in operation.

Then the LST scale setting will be ...

for longitude .... 3° black
for Summer Time .... 15° black
Combined setting .... 18° black

2. Northern hemisphere. Observer's position ... Boston, Mass., USA. Longitude 71° West. Zone Time meridian (GMT minus 5 hours) = 5 x 15 = 75 ° West. Observer is to the East of the Zone Time meridian ... red scale. No Summer Time.

Then the LST scale setting will be ...

for longitude only ... 75 - 71 = 4° red

3. Southern hemisphere. Observer's position ... Sydney, Australia. Longitude 151° East. Zone Time meridian (GMT plus 10 hours) = 10 x 15 = 150° East. Observer is to the East of the Zone Time meridian ... black scale. No Summer Time.

Then the LST scale setting will be:

for longitude only ... 151 -150 = 1° black

LST SCALE	HEMISPHERE	
	NORTHERN	SOUTHERN
FOR LONGITUDES TO WEST OF ZONE TIME MERIDIAN	BLACK	RED
FOR LONGITUDES TO EAST OF ZONE TIME MERIDIAN	RED	BLACK
FOR SUMMER TIME — (15° PER HOUR)	BLACK	RED

HEMISPHERE	TIME SCALE
NORTHERN	BLACK
SOUTHERN	RED

FIGURE 5: The Colour Scheme for the LST and LMT Scales

4. Southern hemisphere. Observer's position ... Lima, Peru. Longitude ... 75½° West. Zone Time meridian (GMT minus 5 hours) = 5 x 15 = 75° West. Observer is to the West of the Zone Time meridian ... red scale. No Summer Time.

Then the LST scale setting will be:

for longitude only ... 76½ - 75 = 1½° red.

N.B. In the United Kingdom during the 1940s Double Summer Time was in operation. It is not inconceivable that this might one day be re-introduced. It would require an LST scale adjustment of 30° (black scale). In very large countries there can be wide ranges of longitude between the observer and the Zone Time meridian. In India, for example, there are longitude differences of between 14° and 15° from the Zone Time meridian of 82½° East. Although it is higly improbable that such wide differences of longitude would ever coincide in any country with Double Summer Time, the LST scale of the phoeboscope has been made wide enough to cater for any such extreme combination of extreme conditions.

INSTRUMENT ACCURACY

A phoeboscope could be made in any size. The smaller, the cheaper, but less accurate; and vice versa. The prototype has been made with a 5-inch focal length lens and an 11-inch dia. base-plate, as a reasonable compromise between cost and accuracy. With the prototype, accuracies of about half a degree in azimuth and 1 minute of time are obtainable for most of the year. Near the Solstices the accuracy is rather less owing to the slight spherical aberration; but a compound lens should cure this. The latitude setting can be fixed to within 0.1°, and the longitude setting to within 0.2°, each being equivalent to about 7 miles in England.

CONCLUSION

The phoeboscope, named after the Greek Sun God, Phoebus Apollo, is not the only instrument that makes use of the analemma. The Ferguson chronometer makes use of half-analemmas spaced 2½° apart (equivalent to 10-minute intervals) on a card mounted in a concave semi-cylindrical shadow-plate. The card has to be changed twice yearly. The very beautiful Daniel Dolphin dial, mounted in the grounds of the National Maritime Museum, Greenwich, also used half-analemmas on a semi-cylindrical shadow-plate which have to be changed twice yearly.

In the phoeboscope a single whole analemma, which moves with a rotatable gnomon serves for the whole year and need not be moved except when changing from the Northern hemisphere to the Southern, or vice versa. Until a year or two ago I truly believed that the phoeboscope was the only clock/compass that made use of a whole analemma that moved with the gnomon; but I was wrong. Some eight months after the phoeboscope was described in the journal of 'The Model Engineer' my attention was drawn to the Heliochronometer, or Sun Clock, designed and made by Captain John P. Gunning, R.N.(Ret'd). His is a very elegant instrument designed on exactly the same principles as the phoeboscope, applied in a slightly different way.

A century or so ago the phoeboscope, or Captain Gunning's heliochronometer, if mounted on gymbals, could have served as valuable instruments at sea: but not in these days of sophisticated navigational aids. Nor can it truly be claimed that such instruments are of much practical use to the landsman now that quartz watches and radio signals are available. But utilitarianism is not everything. Such instruments are both decorative and highly instructive. They can teach the owner the fundamentals of observational astronomy and could serve as valuable aids for the instruction of embryo navigators and surveyors. Like other dial instruments they have an aesthetic appeal, and their accuracy is vastly greater than that of run-of-the-mill sundials with fixed gnomons (which can be as much as an hour-and-a-half wrong in the United Kingdom!). A critic might describe such instruments as 'pretty toys'. But then, don't most of us secretly rather like pretty toys?

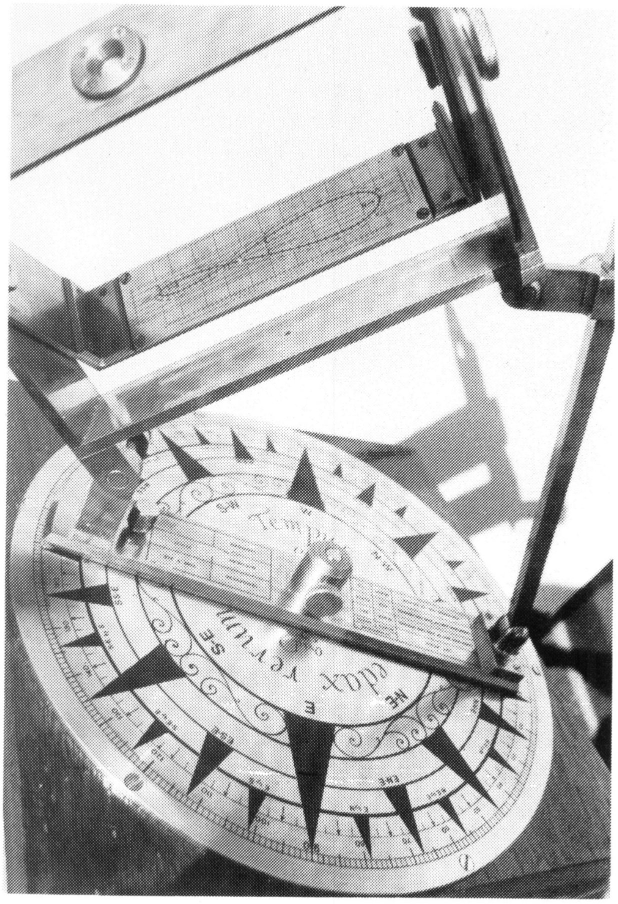


PLATE 2: The Analemma at the moment of an observation on 7th September. Note the bright sun spot.

ACKNOWLEDGEMENT

The prototype model phoeboscope was exhibited at the 58th annual Exhibition of the Model Engineers at Alexandra Palace in December/January, 1988/89, and a descriptive article on it was subsequently published in 'The Model Engineer'. I am indebted to the Editor of that journal for his kind permission to quote freely from that article, and have here done so.

HIS MAJESTY'S DIALS IN WHITEHALL GARDEN

There is a history of sundials situated in the King's Privy Garden at Whitehall, which has not been researched in any great detail, in spite of the lack of clarity in the events. The account here is of the large cubic block of stone placed in the Privy Garden in Whitehall in 1622 to replace the earlier sundial of similar size and design. At this time James I was on the throne and Prince Charles (later King Charles I) was the next in succession. The work on which the transcription here is based is entitled *THE DESCRIPTION AND USE OF HIS MAJESTIES DIALS IN WHITE-HALL GARDEN,* published by Edmund Gunter in 1624. King James I died in 1625, Charles I ascending the throne that year. The book therefore is dedicated to King James I, although its writing was initiated by Prince Charles, as will be made clear when the foreword to the book is read.

Edmund Gunter was born in Hertfordshire in 1581 and was a Queen's scholar at Westminster School, and later Christ Church in Oxford. He was early in life interested in dials and secured the patronage of the Earl of Bridgewater. For some years he taught mathematics before becoming the third Professor of Astronomy at Gresham College 1619-1626, which includes the period in which the dial was designed and the book written. See the title page illustration.

At this time it was common practice to orientate dials by the use of a magnetic compass needle since the variation in the direction of the magnetic North Pole was not then known. The checking of the setting of Gunter's dial in the Privy Garden by John Marr led to the discovery of the magnetic variation, later investigations at Limehouse and Deptford by Gellibrand and Marr established the magnitude of this variation. The various events surrounding this dial have led to some speculation that there was more than one dial erected by Gunter in the Privy Garden, but as will be learned from Gunter's treatise, the size and complication of the dial would render a second one unnecessary, and too expensive.

The dial it replaced was of similar size but made of a number of blocks of Caen stone, which is a soft yellowish oolitic building stone from Caen, France, and not suitable for public sundials exposed to public abusage, although easy to carve and incise. The Privy Garden was often full of revellers, where no dial lasted for many decades before becoming mutilated and useless. The stone for Gunter's dial was in one piece and came from Purbeck Quarry.

The foreword in Edmund Gunter's book is as follows:

TO HIS SACRED MAIESTIE

Sir, *It was the motion of many honorable Perfonages, and the speciall direction of the Prince his Highnesse, that I should write the Desfription and Vse of such Lines, as I had drawen on Your* MAIESTIES *Dials in* White-Hall *Garden.*

I have endeavoured to giue fatisfaction unto all: To Your Maiestie, and his Highneffe, by the manuscript which I deliured; And that, being here printed by order from Your Maiestie, may be fatisfaction for them also, which haue acceffe into the Garden. For others (ftudius of Mathematical Practife) I haue Printed the Generall Description of *these and fuch like Lines, on all forts of Plaines, together with fome Vfes of* Aftronomie *in Nauigation.*

I humbly entreat Your Maieftie to accept these poore fruits of my younger Studies, when I was Your Maiefties Scholler in Weftminster *and* Chriftchurch: and I fhall be ready to doe all fervice in this kinde, or better in the Church, as *Your Maiesty shall be pleased to thinke me worthy, in the name of*

Your MAIESTIES moft thankefull Scholler,
and obedient Subiect

Edm. Gunter

This short foreword is given as near to the original format as can be simulated on a modern word processor, the reason it is so presented is to demonstrate the obfuscation arising with such archaic writing although it was perfectly acceptable in the period in which it was written. In presenting Gunter's treatise to the modern reader, the present writer first took out the long-tailed 'esses' and modernised the spelling, retaining the punctuation, italics and other idiosyncracies of the text. But this proved a most laborious task, so finally the text was put into modern idiom for ease of understanding. This latter is the most important part, the reader should be able to take in a flow of ideas without spending a great deal of time pondering on the archaic wording and presentation of the original. Most of the single sentences were presented as chapters, and as this caused continual gaps in the text, they have, in the main, been drawn together in a closer embrace to reduce the number of pages. Some anachronisms [for today] remain to lend flavour to the work of almost four centuries ago.

The two tables present in the original text have been (it is hoped) made much clearer. This was a most laborious task to set each down within the confines of a single page. It makes one admire the single-mindedness of the orginal author and the tenacity of the printer. In the book the tables occupy two pages each, the presentation for accuracy of reading, however, is very poor. A sample page of each table is illustrated later:

The purists, who do not care for the modernisation of texts designed to make the work of reading easier for those unfamiliar with archaic presentations, must refer to the original work for the exact wording. The book is rare but was reprinted in 1972 by Theatrvm Orbis Terrarvm Ltd, and Da Capo Press Inc, ISBN 90 221 0465 6, Number 465 in 'The English Experience - Its Record in Early Printed Books Published in Facsimile'. It is probably still available.

As is often the case with these old works, there is no included diagram of the dial which would ease the understanding of the text by the average reader. It is not a case of a lost plate since there is no reference within the work to any illustration whatsoever. This is an account where one picture would have been worth a thousand words, and to date the writer has found no contemporary illustration of Gunter's dial.

Another curious omission is that of the craftsman/craftsmen who carved the stone and delineated the many dials to Gunter's designs and calculations. The sculptor was, appropriately enough, named Nicholas Stone, who was born 1586 at Woodbury, near Exeter. He worked as a mason and sculptor in Amsterdam, married his master's daughter and then returned to England. He worked for James I and was made his master-mason in 1619. In 1626 Charles I granted him a patent as master-mason and architect for the work at Windsor Castle. He sculpted many monuments and worked on many famous buildings. He died 24th August 1647 aged 61 and was buried in St Martins-in-the-Fields, London on 28th August 1647. His wife and youngest son died shortly after. Nicholas Stone had a part share in a stone quarry at Portland Isle, so probably the stone for the dial was supplied by him. With his many committments, it is unlikely that he personally worked on the Whitehall dial, he probably confined himself to the overseeing of the work, directing his workmen in conjunction with Edmund Gunter.

From the account which follows, it is clear that the old sundials were greatly enhanced by the use of painted lines to clarify the many indications, often the stone dial we examine today is the bare bones of the original, much eroded and bleached by the vagaries of the weather.

As with the most famous sundial erected in Whitehall Garden, the Pyramidical Dial of 1669, which perished in the following decade; Gunter's dial failed to enter the eighteenth century in its monumental form, being demolished in 1697 as a result of damage and decay. Evidently vandalism is not a novel modern manifestation, nor was it confined to the lower classes.

THE DESCRIPTION AND USE OF HIS MAJESTY'S DIALS IN WHITEHALL GARDEN

The stone whereon the Dials are described, is of the same length, breadth and depth, with that which stood in the same place before. That was of Caen stone, and of many pieces; this is of one entire stone from Purbeck Quarry. The base of it is a square of somewhat more than four feet and a half; the height three foot and 1/4: and so unwrought contained about 80 feet [cubic feet], or five tons of stone.

It is also wrought with the like Planes and Concaves as the former, and so necessarily, the like lines to show the hour of the day. But the rest of the lines are much different, and most of them such as were not in the former dials, and therefore I intend here to give an account of them.

These dials may be distinguished according as they are described: either on the upper part of the Stone; or on the sides, toward the East, West, North, South.

There are five Dials described on the upper part; four on the four corners; and one in the middle, which is the chiefest of all, the great Horizontal Concave.

THE USE OF THE CIRCLES ON THE MARGIN OF THE GREAT HORIZONTAL CONCAVE

The Margin of this Horizontal Concave contains four Circles: whereof, the upper-most is the Circle of the twelve Months, containing the several days, the Dominical letters and the Standing Festivals: The Holy days, in red; The Garter days in blue, and the common Saints' days in black. The use of them may be;

1. To find the day of the Month belonging to the Festival.

The Festival days are here set at the day of the month, wherein they fall: As, at the Feast of St. George, on the 23 of April; the Feast of St. James on the 25 of July; and so the rest of the standing Festivals. Easter, Whitsuntide, and such like, could not be set down, because they are movable.

2. To find the day of the week belonging to the Festival.

First, consider some one day, which you know to fall on such a day of the week: that one may help to find all the rest. As, knowing, that this year MDCXXIV St. George's day fell on the Friday 14; if you look into this Circle, you shall find it over against the letter A: then is A the letter for Friday; B is for Saturday, and C the Dominical letter for this year: and so, the rest in their order. If now you would know, what day of the week Christmas Day falls; look into the month of December, and there you shall find it over against the letter B: which shows, that Christmas Day, this year, falls on Saturday.

The second circle is of the twelve signs: ♈ Aries: ♉ Taurus: ♊ Gemini: ♋ Cancer: ♌ Leo: ♍ Virgo: ♎ Libra: ♏ Scorpio: ♐ Sagitarius: ♑ Capricornus: ♒ Aquarius: ♓ Pisces: Each sign being distinguished with his name and character and divided into 30 degrees. The use of it may be,

THE DAY OF THE MONTH BEING KNOWN, TO FIND THE PLACE OF THE SUN.

The day of the month, and the place of the sun, are here seen, one against the other: so you may find, that on the 23 of April, being St George's day, the sun is in 13 Degrees of Taurus. On the 25th July, being St. James' day, the sun is in 11 Degrees, 50 Minutes of Leo.

There may be some small difference in time to come, in regard of the Leap Year, as of a quarter of a degree, more or less; but, that could not be avoided. And this may serve for six score years without one degree difference.

The third circle, is a standing compass divided into thirty-two points, with the name of each point in his due place: whereby you may see, upon what point the sun bears, and how the wind blows.

The fourth and innermost circle contains another description of the days of each month, fitted to the Concave.

THE DESCRIPTION OF THE CONCAVE

The Concave is twenty inches deep, and forty inches over: and being half round resembles that half of the heavens which may be seen.

The one part, which is drawn upon the white ground, resembles so much of the heavens, as is contained between the Tropics. As there the Sun has all the variety of motion; so here the point of the style, is all variety of shadow. The other part, which is on the blue ground, is that part of the heaven where the sun never appears.

The style belonging to the Concave, is 20 inches long, and about 13 inches broad at the foot. The one edge which is upright, is the axis of the horizon, and with his shadow shows the Azimuth.

The other edge, inclining to the North, represents the axis of the world, and with his shadow shows the time of the day. The point of the style, with his shadow, will show the rest of the conclusions.

The edge of the Concave represents the circle of the horizon. The other circles described in the Concave may be known and distinguished by their colours.

The Equator, the Tropics, the Ecliptic, and the Parallels of Declination, are all drawn in red lines.

The Parallels of the Horizon, to show the sun's altitude, in yellow. The Vertical circles are drawn in blue. The olde unequal (which some call Planetary hours) in green. The common hours in black.

The days fitted to the sun's rising and setting, are drawn in the Margin. And so much is intimated in these eight Latin verses, which are written on the Concave:

Aequator, Tropiciq; & Declinatio Solis, Et Via Solaris *tramite du la rubro.*
Lineolis flauis, Solis conscensus habetur; Caeruleo tractu, Verticis ubra *cadit.*
Hora Planetarum, Viridi est signata colore: Horaq; Vulgaris *nota* colore nigro.
Ortus & Occasus Solis, Spaciumq; diei, *Atque* Dies mensis, Margine *scripta patent.*

[Hardly eight verses, and merely repeating the previous chapter in Latin].

THE USE OF THE BLACK LINES

That Line which is drawn from the South to the North, whereon the style is set, is the Meridian circle. The rest drawn on either side of the Meridian, in white upon the blue; and in black upon the white ground, are the hour circles. Those which show the hours complete, are drawn with broader lines. Each hour is divided, first into fifteen parts with small lines, every part is again subdivided into four parts more, with little black strokes, at the beginning, middle, and end of the former lines: And so, the whole hour is actually divided into sixty minutes. Of which, that line which signifies twenty minutes and that which signifieth forty minutes complete, are for distinction's sake, crossed with little red strokes. The use of them may be.

TO SHEW THE HOUR AND MINUTE OF THE DAY BY THE SHADOW OF THE STYLE.

The hour of the day will be found, at one time or other, in more then four-score several places of this dial: but nowhere so well, as in this Horizontal Concave. For the hour is found on the East side of the stone only in the morning; and on the West side only in the evening. On the South side, only in the middle of the day; on the North side either early in the morning or late in the evening. On the Equinoctial planes, either only in the Summer or only in the Winter. Here it is found generally, both in Summer and Winter, morning and evening, and at all hours of the day. Not only, the hour and quarter, (as in the rest of these dials) but the hour and minute; with many other conclusions answerable, which may not be expeected in any dial of another form.

When the sun shines, observe the shadow of the style among the hour lines; the shadow of the one edge will commonly cross the hour lines, and so is unfit for this purpose; but the shadow of the other edge, which leans to the Northward, will always fall, either between two hour lines, or upon one of them; and the hour line, where it falls, will give the hour and minute required.

2. TO SHOW THE HOUR AND MINUTE OF THE SUN'S RISING AND SETTING, AND THE LENGTH OF THE DAY, AT ALL TIMES OF THE YEAR, THOUGH THE SUN DOES NOT SHINE.

First, find the day of the month, in the inner part of the Margin; (which, from the eleventh of December until the eleventh of June, while the days are increasing, will be found on the West part of the Concave); and there, the hour line which is drawn up to the day, will give you the hour and minute of the sun's rising. But, from the eleventh of June until the eleventh of December, while the days are decreasing, the day will be found on the East side of the Concave: and there, the hour line which is drawn up to the day will give the hour and minute of the sun's setting; and the one being known will give the other.

As, if it were required to know what time the sun rises and sets on the fourth day of February. This month is found on the West part of the Concave; and the hour line which meets with the fourth day of this month, is that of 7 hours 8 minutes in the morning; and such is the time of the sun's rising. But so much as the sun rises before noon, so much it sets after noon, within a minute more or less, and therefore the time of the sun's setting is about 4 hours 52 minutes after noon.

3. TO SHOW THE DAY OF THE MONTH, WHEN THE SUN RISES OR SETS AT ANY HOUR OR MINUTE.

On the contrary, if you would find the day when the sun rises or sets at any hour, first find the hour-line in the Concave and that will lead you to the day of the month in the Margin.

As, if it were required, on what day the sun rises at five in the morning; first find the hour line of five in the West part of the Concave and that will lead you to the tenth day of April. Then because the sun, rising at five sets at seven, if you find out the hour line of seven after noon, it will lead you to the thirteenth day of August, which shows that the sun rises at five in the morning, and sets at seven after noon, both on the tenth day of April and the thirteenth of August.

The like reason holds for the rising and setting of the sun at all times of the year, as may appear by comparing the Concave with the following Table:

The Concave and this Table are both made for the Latitude of 51° 30′, serving for London and such places as lie East or West of the same latitude. But if you go from London either northward or southward, there will be some small difference. For here at London, upon the longest day, the sun sets at 8 hours 13 minutes, and so the longest day is 16 hours 26 minutes. About Scilly and the lizard, the southern most parts of England, in the latitude of 50°, the sun sets at 8 hours 5 minutes, so their longest day is about 16 hours 10 minutes.

About one hundred miles northward from London, the sun sets at 8 hours 22 minutes, and so their longest day is 16 hours 44 minutes.

About Edinburgh in the latitude of 56° the sun sets at 8 hours 40 minutes, and so their longest day is 17 hours 20 minutes.

A TABLE FOR THE HOUR AND MINUTE OF SUNSET FOR EVERY DAY OF THE YEAR

DAY	JAN	FEB	MAR	APRL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	3.59	4.47	5.42	6.44	7.37	8.10	8.04	7.22	6.23	5.24	4.26	3.50
2	4.01	4.49	5.44	6.45	7.38	8.11	8.03	7.20	6.21	5.22	4.25	3.50
3	4.24	4.50	5.46	6.47	7.40	8.11	8.02	7.18	6.19	5.20	4.23	3.49
4	4.03	4.52	5.48	6.49	7.41	8.11	8.01	7.16	6.18	5.18	4.21	3.49
5	4.04	4.54	5.50	6.50	7.43	8.12	8.00	7.14	6.16	5.16	4.20	3.48
6	4.50	4.56	5.52	6.51	7.44	8.12	7.59	7.13	6.14	5.14	4.18	3.48
7	4.06	4.58	5.54	6.53	7.46	8.12	7.57	7.11	6.12	5.12	4.16	3.48
8	4.07	5.00	5.56	6.55	7.47	8.12	7.56	7.09	6.10	5.10	4.15	3.47
9	4.08	5.02	5.58	6.57	7.48	8.13	7.55	7.07	6.08	5.08	4.13	3.47
10	4.10	5.04	6.00	6.59	7.49	8.13	7.54	7.06	6.06	5.06	4.12	3.47
11	4.11	5.06	6.02	7.01	7.51	8.13	7.53	7.04	6.04	5.05	4.11	3.47
12	4.13	5.08	6.04	7.03	7.52	8.13	7.52	7.02	6.02	5.03	4.10	3.47
13	4.14	5.10	6.06	7.05	7.53	8.13	7.50	7.00	6.00	5.01	4.08	3.47
14	4.16	5.12	6.08	7.07	7.55	8.13	7.49	6.58	5.58	4.59	4.07	3.47
15	4.17	5.14	6.10	7.09	7.56	8.13	7.48	6.56	5.56	4.57	4.05	3.47
16	4.19	5.16	6.12	7.11	7.57	8.12	7.46	6.54	5.54	4.55	4.04	3.47
17	4.20	5.18	6.14	7.13	7.58	8.12	7.45	6.52	5.52	4.53	4.03	3.48
18	4.22	5.20	6.16	7.15	7.59	8.12	7.44	6.50	5.50	4.51	4.02	3.48
19	4.24	5.22	6.18	7.16	8.00	8.11	7.42	6.48	5.48	4.49	4.00	3.48
20	4.25	5.24	6.20	7.18	8.01	8.11	7.41	6.46	5.46	4.47	3.59	3.48
21	4.27	5.26	6.22	7.20	8.02	8.10	7.39	6.45	5.44	4.46	3.58	3.49
22	4.29	5.28	6.24	7.22	8.03	8.10	7.38	6.43	5.42	4.44	3.57	3.50
23	4.30	5.30	6.26	7.24	8.04	8.10	7.36	6.41	5.40	4.42	3.56	3.50
24	4.32	5.32	6.28	7.25	8.05	8.09	7.35	6.39	5.38	4.41	3.55	3.51
25	4.34	5.34	6.30	7.27	8.06	8.09	7.33	6.37	5.36	4.39	3.54	3.52
26	4.36	5.36	6.32	7.28	8.06	8.08	7.31	6.35	5.34	4.37	3.54	3.53
27	4.38	5.38	6.34	7.30	8.07	8.07	7.30	6.33	5.32	4.35	3.53	3.54
28	4.40	5.40	6.36	7.32	8.08	8.06	7.28	6.31	5.30	4.33	3.52	3.55
29	4.41	----	6.38	7.34	8.09	8.05	7.26	6.29	5.28	4.31	3.51	3.56
30	4.43	----	6.40	7.35	8.09	8.05	7.25	6.27	5.26	4.30	3.51	3.57
31	4.45	----	6.42	----	8.10	----	7.23	6.25	----	4.28	----	3.58

About the Orkneys, in the latitude of 60°, the sun sets at 9 hours 15 minutes, and so their longest day is 18 hours 30 minutes.

THE USE OF THE RED LINES

The red lines drawn across the hour lines, are of several sorts, all intending to show the motion of the sun. That which is drawn in the centre of the white ground, directly from East to West, is the Equator. The other two, which are drawn from West to East, divided into degrees and noted with ♈ ♉ ♊, etc make up the ecliptic. The two uppermost are the two Tropics: that which is furthest from the style, touching the ecliptic in the beginning of ♑, is therefore called the Tropic of Capricon. That which is nearer the style touching the ecliptic in the beginning of ♋ is the Tropic of Cancer. The other intermediate red lines drawn between the Equator and the Tropics are Parallels of Declination, numbered at the Meridian with 5, 10, 15, 20, according to their distance from the Equator. The use of them may be:

1. TO SHOW THE DECLINATION OF THE SUN BY THE SHADOW OF THE STYLE.

When the sun shines, observe the shadow of the point of the style among the red lines. As it falls on the Equator, the sun is at one of the Equinoctial points, either at the beginning of ♈ or of ♎, and so has no declination. If it falls on the Tropic of Cancer, the sun is at its highest and the days at the longest. If on the Tropic of Capricorn, the sun is at its lowest and the days at the shortest. If it falls on any of the parallel lines between the Equator and the Tropics, the distance of that line from the Equator will be the declination of the sun.

As, if the shadow of the top of the style falls on any part of the tenth parallel above the Equator it shows the sun to be at 10 degrees of South declination. If on the twentieth parallel below the Equator, then the declination of the sun is 20 degrees from the Equator.

2. TO SHEW THE DAY OF THE MONTH BY THE SHADOW OF THE STYLE.

The shadow of the point of the style will show the declination; and the line of declination will lead you to the Day of the Month at the Margin of the Concave.

As, if the shadow of the top of the style falls on any part of the thirteenth parallel above the Equator, it shows the sun to be at 13 degrees of South declination; and that parallel of declination will lead you to the fourth of February on the West side, and to the seventeenth of October on the East side of the Concave. But which of these two is the true day of the month must be known, either by the time of the year, or the second day's observation.

3. TO SHOW THE PLACE OF THE SUN BY THE SHADOW OF THE STYLE.

The shadow of the top of the style will show the declination; and the intersection of the parallel of declination with the ecliptic will be the place of the Sun. As if the shadow of the top of the style falls on 13 degrees of South declination, this parallel will cross the ecliptic near 26 degrees of ♒ on the one side, and about the fourth of ♏ on the other side of the Concave. But which of these two is the true place of the sun will be known by the day of the month nearest to the sign of the sun.

4. TO SHOW THE HOUR AND MINUTE OF THE SUN'S RISING AND SETTING, BY THE SHADOW OF THE STYLE.

The shadow of the top of the style will show the declination, and the hour line which meets that parallel of declination at the horizon (here represented by the edge of the Margin) shall give the hour and minute of the sun's rising and setting.

As, if the shadow of the top of the style fall on 13 degrees of South declination, that parallel of declination being followed to the horizon at the West side of the Concave, will there meet at the hour-line of seven and eight minutes, and such is the time of the sun's rising. Then follow this parallel to the horizon unto the East side of the Concave, and it will there meet with the hour-line of III and 52 minutes, which is the time of the sun's setting. And the line between 7 hours 8 minutes in the morning and 4 hours 52 minutes after noon is the length of the day.

5. TO FIND THE DECLINATION OF THE SUN BY KNOWING THE DAY OF THE MONTH.

First find the day of the month in the inner circle of the Margin; the look among the red lines for the parallel of declination which is drawn up to that day: the distance of the parallel from the Equator will show you the declination of the sun.

As, if it is required to find the declination of the sun for the fourth day of February: the parallel drawn up to this day will be found about 13 degrees above the Equator, and such is the declination of the sun to the southward.

6. TO FIND THE PLACE OF THE SUN BY KNOWING THE DAY OF THE MONTH.

The day of the month will give the declination of the sun; and the parallel of declination will cross the ecliptic in the place of the sun.

As, if the day given be the fourth of February, the parallel of declination will be found to be 13 degrees southward; and this parallel crosses the ecliptic in 26 degrees of ♒, which is the place of the sun required.

THE USE OF THE BLUE LINES.

The use of the blue lines from the bottom to the edge of the Concave is to represent the vertical circles, commonly known by the Arabian name, Aximuths. These are all great circles drawn through the Zenith and the Nadir, and divide the horizon in equal parts. The Meridian is one of them: But the prime vertical circle is that which is drawn from East to West. These two divide the horizon into four equal parts, each of these parts is divided by seamen into eight; and so the whole into thirty-two points of the Compass. But Astronomers divide each forth part into 90 degrees. I have here set the points of the compass in the bottom of the Concave, and at the Margin; and the astronomical divisions between the Tropics. The use of them may be,

1. TO SHOW THE AZIMUTH OR POINT OF THE COMPASS, WHEREON THE SUN BEARS FROM US, HOW FAR IT IS FROM THE SOUTH; HOW NEAR TO THE EAST OR WEST; AND THAT BY THE SHADOW OF THE STYLE.

When the sun shines, observe where the shadow of the upright edge of the style falls among the Azimuth lines, the distance of that line from the Meridian will show the Azimuth, whereon the sun bears.

As, if on the fourth of February about 10 hours 5 minutes in the morning, the shadow of the upright edge of the style falls on the third of the blue lines from the meridian, then is the sun 30 degrees from the South. If you follow this blue line unto the margin, it will there point between N W by N and N N W, wherefore it bears from you by the contrary point between S E by E, and S S E.

2. TO FIND ON WHAT AZIMUTH OR POINT OF COMPASS THE SUN RISETH OR SETTETH.

First find the day of the month in the inner circle of the Margin: then look among the blue lines for the Azimuth which is drawn up to the day: the distance of that line from the line of East and West will give the Amplitude of the sun's rising and setting. If the day falls on the West side of the Concave, the point opposite to the day is the true point of the sun's rising: If the day falls on the East part of the Concave, the point opposite to the day, is the true point of the sun's setting.

As, if the day proposed was the fourth of February: This month is found on the West part of the Concave and the day falls near the point of W N W, whose opposite point is E S E, the point of the compass, whereon the sun rises. Or, if you look among the blue lines in the Concave, you will find the Azimuth which is drawn up to the day to be about 21 degrees from the line of East and West; which shows that the amplitude of the sun's rising is about 21 degrees from the East. The like reason holds for all other times of the year, as may appear by comparing the Concave with the following Table:

A TABLE OF AMPLITUDES FOR THE RISING AND SETTING OF THE SUN EVERY DAY OF THE YEAR

DAY	JAN'Y	FEB'Y	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT'R	NOV'R	DEC'R
1	36°39′	22°45′	5°37′	13°46′	29°48′	39°12′	37°18′	25°04′	7°15′	11°32′	29°03′	39 06′
2	36°20′	22°11′	4°59′	14°22′	30°15′	39°20′	37°03′	24°33′	6°38′	12°09′	29°32′	39°15′
3	36 00′	21°37′	4°21′	14°57′	30°41′	39°27′	36°47′	24°02′	6°01′	12°46′	30°00′	39°23′
4	35°41′	21°03′	3°43′	15°32′	31°07′	39°33′	36°30′	23°31′	5°24′	13°23′	30°28′	39°30′
5	35°21′	20°28′	3°05′	16°08′	31°32′	39°38′	36°13′	22°59′	4°47′	13°59′	30°56′	39°36′
6	35°00′	19°53′	2°27′	16°43′	31°57′	39°42′	35°55′	22°27′	4°09′	14°46′	31°23′	39°41′
7	34°39′	19°18′	1°49′	17°18′	32°21′	39°46′	35°36′	21°55′	3°31′	15°12′	31°49′	39°45′
8	34°17′	18°43′	1°11′	17°53′	32°45′	39°49′	35°17′	21°22′	2°54′	15°48′	32°15′	39°48′
9	33°54′	18°08′	0°32′	18°27′	33°08′	39°51′	34°57′	20°49′	2°16′	16°24′	32°40′	39°50′
10	33°30′	17°32′	0°06′	19°01′	33°31′	39°52′	34°37′	20°16′	1°39′	17°00′	33°05′	39°51′
11	33°06′	16°56′	0°44′	19°35′	33°53′	39°52′	34°16′	19°43′	1°01′	17°36′	33°29′	39°52′
12	32°41′	16°20′	1°22′	20°10′	34°15′	39°51′	33°55′	19°09′	0°23′	18°11′	33°52′	39°52′
13	32°16′	15°44′	2°00′	20°39′	34°36′	39°50′	33°33′	18°35′	0°15′	18°46′	34°15	39°50′
14	31°50′	15°07′	2°38′	21°15′	34°56′	39°49′	33°10′	18°01′	0°53′	19°21′	34°37′	39°48′
15	31°23′	14°30′	3°16′	21°48′	35°16′	39°46′	32°47′	17°27′	1°30′	19°56′	34°59′	39°45′
16	30°57′	13°54′	3°54′	22°20′	35°35′	39°42′	32°23′	16°52′	2°08′	20°31′	35°20′	39°41′
17	30°29′	13°17′	4°31′	22°53′	35°54′	39°37′	31°59′	16°17′	2°46′	21°05′	35°40′	39°36′
18	30°01′	12°40′	5°09′	23°25′	36°12′	39°32′	31°35′	15°42′	3°24′	21°39′	36°00′	39°30′
19	29°33′	12°03′	5°47′	23°56′	36°29′	39°26′	31°10′	15°07′	4°01′	22°13′	36°19′	39°23′
20	29°04′	11°25′	6°25′	24°28′	36°46′	39°20′	30°44′	14°32′	4°39′	22°47′	36°37′	39°15′
21	28°34′	10°48′	7°02′	24°59′	37°02′	39°13′	30°18′	13°56′	5°17′	23°20′	36°55′	39°07′
22	28°04′	10°11′	7°39′	25°30′	37°18′	39°05′	29°52′	13°20′	5°54′	23°53′	37°12′	38°58′
23	27°34′	9°33′	8°16′	26°00′	37°32′	38°56′	29°25′	12°44′	6°32′	24°26′	37°28′	38°48′
24	27°04′	8°55′	8°53′	26°30′	37°46′	38°46′	28°57′	12°08′	7°10′	24°58′	37°43′	38°37′
25	26°33′	8°17′	9°30′	27°00′	37°59′	38°36′	28°29′	11°32′	7°48′	25°20′	37°57′	38°25′
26	26°01′	7°39′	10°07′	27°29′	38°12′	38°25′	28°01′	10°56′	8°26′	26°02′	38°11′	38°12′
27	25°29′	7°02′	10°44′	27°58′	38°24′	38°13′	27°32′	10°20′	9°03′	26°33′	38°23′	37°58′
28	24°57′	6°15′	11°21′	28°26′	38°35′	38°00′	27°03′	9°43′	9°41′	27°04′	38°35′	37°44′
29	24°25′	----	11°58′	28°54′	38°45′	37°47′	26°34′	9°07′	10°18′	27°34′	38°47′	37°29′
30	23°52′	----	12°34′	29°21′	38°55′	37°33′	26°04′	8°30′	10°55′	28°04′	38°57′	37°13′
31	23°18′	----	13°10′	------	39°04′	-----	25°34′	7°53′	----	28°34′	-----	36°56′

The Concave and this Table are both made for the Latitude of 51 degrees 30 minutes serving for London and such places as lie East and West from London in the same latitude. But if you go from London either northward or southward, there will be some small difference.

For here at London the greatest amplitude is 39 degrees 50 minutes, that is, when the days are longest, the sun rises 39 degrees 50 minutes from the East northward, and sets 39 degrees 50 minutes from the West northward: when the days are at the shortest, it rises 39 degrees 50 minutes from the East southward, and sets as much from the West southward. About Scilly and the Lizard, the southernmost parts of England, in the latitude of 50 degrees, the greatest amplitude will be 38 degrees 20 minutes.

About the North of England in the latitude of 55 degrees 40 minutes the greatest amplitude will be 45 degrees. And so, when the days are longest, the sun will rise due North-East, and set in the North-West. When the days are at the shortest, it will rise in the South-East and set in the South-West.

About the North of Scotland in the latitude of 60 degrees, the greatest amplitude will be about 52 degrees 50 minutes. And after you come to 66 degrees of latitude, you may see the sun to the North.

TO FIND THE AZIMUTH OR POINT OF THE COMPASS WHEREON THE SUN BEARS, FOR ALL HOURS OF THE DAY, AT ANY TIME OF THE YEAR.

(To be continued)

LONG NEWNTON CHURCH DIAL
NEAR TETBURY, GLOUCESTERSIRE
BY COLIN McVEAN

Sometime in 1990 David Young rang me up and asked if I could go and see a Brigadier Neilson in Tetbury as he wished to get advice on restoring a church dial. Accordingly, armed with a nail board and plumb line as advocated by A.E. Waugh, made from one of my step daughter's old kitchen shelves, I went to meet the Brigadier and his wife. After coffee and a chat he took me to see the church. All that remained then of the original dial was the style and I could see that the dial had been a West vertical decliner. Needless to say the day was cold and overcast with hints of rain. However, whether by divine intervention or not, there were two brief glimpses of sunshine and I was able to mark the tip of the nail's shadow and we returned to Tetbury for an excellent lunch. Brigadier Neilson is very active in improving the amenities in Tetbury and among other activities he has been instrumental in getting a visual display of the town's history erected in the town's church.

After getting home I began to draw out the dial following A.E. Waugh's instructions to his "Sundials, their Theory and Construction". I used Burdwood's Tables to get the bearing of the sun at the times of the readings. Knowing myself to be very prone to making errors in my calculations, I went over my drawings several times and of course I found that I used G.M.T. instead of Local Apparent Time to work out the bearing of the church tower from the South.

Breathing a sigh of relief, I made a portable card model of the proposed dial and later arranged to meet the Brigadier who took me to see a Captain and Mrs. Dent who live near Long Newnton Church and who refreshed us with coffee. We than went to the Church hoping to get a reading on the dial I had made. Again we were lucky to get a glimpse or two of sun and I tested the dial only to find it was fast. I found that the style had become slightly distorted from the vertical and when this was corrected, the time shown agreed with the local apparent time on that day. Then I handed over the dial with instructions on how to use it and heard no more until last year when the Brigadier asked me to meet Mr. E.J. Clark, a highly qualified chartered engineer specialising in quality assurances. The Brigadier had persuaded him to make the dial and I was shown the beginning of the finished article, a large rectangle of wood with a slit through which the initial style was to protrude. Mr. Clark has a very professional workshop in his garage, very unlike my own untidy retreat full of junk which might come in useful one day. The Brigadier meanwhile had organised free local help with the scaffolding etc. and things now progressed to the day when the dial was erected. Of course the day was cold with a freezing wind but quite a number of people turned up warmly clad against the elements. The scaffolding was up, the power lines had been insulated and ropes to haul the dial up were in place. It will be seen from the photograph what an excellent job Mr. Clark had made of the dial in painted oak with gilded metal Roman numerals. The gilding was done by Mr. John Neilson, the Brigadier's son, who is an expert in that field.

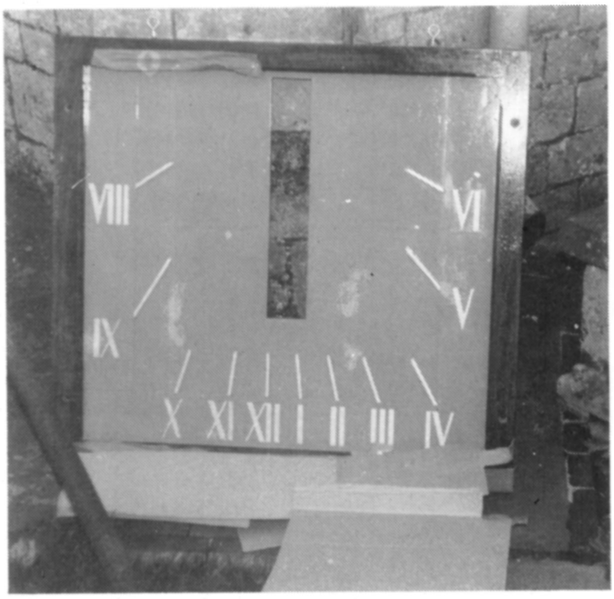


FIGURE 1: Long Newnton church dial made by Mr. E.J. Clock C.Eng., M.I.Mech.E. The slit for the style can be seen. Some of the protective covering still in place.

Next Brigadier Neilson gave a short talk on church dials and scratch dials. I described the technical aspects of the present dial and the parson, who has to look after several churches, said a very appropriate prayer. Now the Brigadier and his son got on top of the tower with ropes Mr. Clark climbed up the scaffolding with his power tools, the dial was hauled up to its new home and was firmly bolted into place. The assembled company were next entertained by Captain and Mrs. Dent to very welcome hot cups of coffee.

There was no sun that day to show whether the dial was correct so I began to suffer some anxiety until I received a very handsome letter of thanks from the Secretary of Long Newnton Parish church to say that when she went to church at 11 a.m. the dial was showing exactly 11 a.m. On the day in question, the equation of time cancelled out the difference in longitude. My lucky day!

Long Newnton may be found by taking the B40 road from Tetbury by Malmesbury. About a mile and a quarter from Tetbury, a very minor road to the left will take you to the church and following it beyond the church will take you to the A433 from Cirencester to Tetbury. The minor road is signposted Long Newnton.

According to my readings, Long Newnton church is at latitude 51° 33′ north and longitude 2° 08′ west. The dial declines west 12°.

As every time I go to look at dials they are almost always in shadow, I am now making sand, fire and water clocks.

"MAKE A SUNDIAL"

JANE WALKER

The inauguration of the British Sundial Society 5th May 1989 coincided with the introduction in schools of the National Curriculum, and this resulted in a spate of letters to our first Chairman, Dr. Andrew Somerville, requesting help and information. For the first time in this century it was considered essential for children in primary schools to be able to understand both how a sundial works and to construct one.

Many teachers wrote requesting an Educational Pack, confidently expecting material by return, something for which the embrionic society was singularly ill prepared to provide since it had no finances with which to publish such packs. To meet these demands, which he thought would ultimately benefit the BSS, Andrew initiated and assembled an educational group within the BSS, with the brief to produce a few sheets of instructions which could be duplicated as required.

This group first met as a working party in May 1990, when it soon became clear that among the eight members who had survived to this point in time, there was considerable expertise. The group consisted of several teachers, two in mathematics, one in physics, one in art, and one primary teacher, plus a civil servant and an airline chief pilot. The latter was already spending time in his local school showing children how to make a sundial from odds and ends. The enthusiasm of the group was infectious, so by the time of the second meeting, it became clear that the original brief was going to be too limited and talk commenced about "the book".

Models were made and demonstrated, concepts discussed and discarded, members worked on different aspects to such effect that by November there was sufficient material to go ahead with the project. The next task was to impose a uniformity of style and presentation on material covering a wide variety of styles and educational levels.

By this time we were running out of steam for everyone had their normal work to do as well as assisting with the book. Letters were still being received from teachers, so in January a deadline was set - a draft copy to be ready for the Edinburgh Conference held in April 1991. Then the group discovered desk top publishing. Using an Apple Mac computer and Pagemaker, we stumbled about into 'templates', 'scanners' and laser printers, improving and exchanging techniques until a satisfactory presentation was achieved which could be reproduced by at least three members of the group. British Telecom benefited considerably during this phase.

A period of feverish activity followed and instead of being writers dashing off a few well-chosen words on a favorite topic, we had become book producers with all sorts of technical problems to overcome - and a deadline to meet. The use of Desk Top Publishing was only possible because of access to the computing and duplicating facilities of two schools, one in Camberley, Surrey; and the other in Bath. A glance at a map will indicate why the method employed became known as the M4 system of book production, we arrived at school with the cleaners, remained until requested to leave by the caretaker in the evening, and then carted computers and printers to our homes. Weekends saw these loaded into cars to be driven between schools for one 'final' meeting after another, with constant revision of text and drawings up to the end of March. With only a week to spare, half the text was printed in Camberley, transported to Bath to print the covers and use the binding machine. But, still sizzling from the press, a victorious arrival was made at the Conference at Edinburgh and the comforting acclaim and a shower of £5.00 notes from BSS members.

Alas, at this point a seeming calamity struck, the National Curriculum was under revision and it seemed that the world had overturned and sundial construction was no longer held to be a suitable subject for primary school children. How could they do that to us? However a letter to the Secretary of State for Education was favourably received and the subject reinstated in a later version of the curriculum, so teachers soon commenced to write again with requests.

Once again the M4 method was used, modified by meeting halfway at the adult education hall in Marlborough. Further revisions were made, sections added, the art work given a face lift, the new edition being given a field test in several schools. Again a last minute burst of energy managed to produce thirty copies to take to the September 1991 BSS Conference at Cambridge. The "Cambridge" edition sold out within a month and of course indicated the need for still more corrections to the text.

Finally the book now published is selling well to schools, the M4 method has been abandoned in favour of the use of a local printer, so the up-to-date edition is now available from the address below. If you require a copy - hurry whilst present stocks last.

MAKE A SUNDIAL
A BRITISH SUNDIAL SOCIETY PUBLICATION

Includes projects for constructing sundials from readily available materials, with details of background activities on the use of shadows for marking the passage of time, and the relationship between indications and the mean solar time of everyday use.

More advanced constructions are given which are suitable for GCSE projects and include a design for a play area dial. Permission has been given for the activity sheets to be copied freely for classroom use, to reduce the cost to schools.

Teachers' notes are printed on pages of a different colour for their easy reference. The book includes four pages of photographs and is spiral bound for easy opening to lie flat for convenience of use.

The price of £5.70 includes the cost of packing and postage. Please make cheques payable to the British Sundial Society.

Available only from: Mrs. Jane Walker, 31 Longdown Road, Sandhurst, Camberley, Surrey, GU17 8QG.

A TIDAL DIAL

BY DENIS SCHNEIDER (FRANCE)

When the tidal time of an harbour changes each half day, and tidal tables are valid only for a given year, it does not seem likely that a dial can foretell the state of the tide in the furthest harbour as well as the nearest.

It will appear to you, however, as it did to John Marr (BSS *Bulletin* 91.1, page 5, line 26; and 91.2, page 4, line 42 with correction page 27): or as with John Bonar 91.3, page 13, if you read Gordon Taylor's account, and if you don't expect a precision better than one hour in the less favourable cases. Otherwise you had better continue to scan the tidal tables printed in your daily newspaper.

To solve this apparently complex problem, first consider the course of the sun's shadow which delays 2 minutes an hour on the moon clock, which for our present purposes, is to be preferred. It is true that the sun, rising above the horizon, has a more immediate impact on the human race, but it does need another force to raise the surface of the sea. This comes from the moon, so much smaller than the sun, but so much more powerful in its effects through being so near. From the sun, the male star, light and warmth; and from the moon, the female satellite, coolness, with more secretive forces . . .

Remember that when the sun and moon clocks are showing the same hour (at New Moon, or as at Full Moon with 12 hours difference, that is to say every 14.25 days [nearly], the time of high tide on this day is termed the "establishment" at a particular port (Port Establishment) and also its "Lunar Situation", (in all exactitude when sizygies arrive precisely locally overhead. The attraction of the oceanic waters is then exercised with maximum effect with the moon on the local meridian or anti-meridian (separated by solar time of 12h 24m) but the full effects are delayed which depends upon the inertia of the body of water affected and the coast configuration.

If the hour hand of your watch turned once in 12h 24m (12h + 12 x 2m), and if the moon's motion was uniform, the watch would indicate at every moment, a near enough indication of tidal hours, but only if you knew the "Port Establishment" of the harbour concerned. The hand would turn a complete revolution in 12 h equal to 12h 24m of the familiar mean solar time. It would be necessary to set the watch to the local time of the harbour, or even better to regulate the watch to Universal Time after having converted the "Port Establishment" of all the harbours in the world of UT, and this would allow an instantaneous knowledge of the state of the tides at any point on the globe (after having eliminated harbours subjected to tidal regimes other than the semi-diurnal lunar one, as for example the Gulf of Mexico or the Indian Ocean). For every horary angle of the moon respectively to the Greenwich Meridian would correspond to high tide in harbours with which the UT values of the Establishment coincided.

Every twelve lunar hours on average, the world system of high tides develops itself in the same sequence, with changes of intensity essentially depending upon, in this sidereal orchestra, the distance of the principal actor (the moon), its declination of Jupiter's and Venus's influence; and above all of the difference of right ascension between moon and sun (depending of course upon the age of the moon). This difference of right ascension reveals the solar component of the tides by changing chiefly the tidal coefficient, but also the tidal hour by advancing it or retarding it a little, these differences add algebraically to zero at New or Full Moon. Therefore it is possible to give mean corrections in accordance with the moon's age when considering "Port Establishments".

Every dial surface with an oriented style is suitable, but only if the shadow is clear enough, and in the case of night observations, only in the second and third quarters of the moon. The occasions where the knowledge of tidal hours was required by dials would be too few if it there were not methods to estimate them almost permanently. Thus to know the moon horary angle each time it is visible, by day and night, it is much better to utilize an optical sight, such as an alidade with holes, turning around an axis parallel to the polar axis and set on an equatorial dial, the noon of which is set to the Greenwich Meridian.

By such means it is possible to know the moon horary angle with sufficient accuracy, even when it is invisible: by day from the sun shadow by subtracting the difference of right ascension between the sun and moon from the sun horary angle, thanks to knowledge of the age of the moon, or from circumpolar stars horary angle (for example the alpha and beta stars of the Great Bear) thanks to the principle of the nocturlabe which converts star time to solar time before estimating the lunar hour by means of the previously described manner. Except with a cloudy sky, essentially, you can therefore estimate where the moon stands on the horary dial.

Soon the moon is not visible, how is it possible to know the age of the moon? In the absence of a calendar, ephemeris, or moon perpetual calendar (ecclesiastic moon, accurate to one or two days), it is still possible to know it to a similar approximation in adding the Epact (bound to Meton's cycle), the day of the month and the correct month lunar key which takes into account the number of days in the months of the year and the alternance of moons having 29 and 30 days difference (average $29^1/_2$, and substracting 30 if the calculated age exceeds this value:

Month Lunar Key

Jan 0 Feb 1 March 0 April 1 May 2 June 3

July 4 Aug 5 Sept 7 Oct 7 Nov 9 Dec 9

Following this arithmetical exercise, consult Fig. 1a, which will give the mean delay of the moon from the sun for every age of the moon (in setting the New Moon on 12 h). Figure 1a shows the horary angle and age of the moon graduated in the same sense. It is sufficient to subtract the mean delay of the moon from the sun to obtain the lunar hour. This system also allows the knowledge of high tide solar hour or any harbour for each age of the moon by setting the New Moon on the "Port Establishment" E, see Fig. 1b. By setting the age of the moon on the solar hour, the lunar hour, the lunar hour lead on the NM may be read, see Fig. 1c.

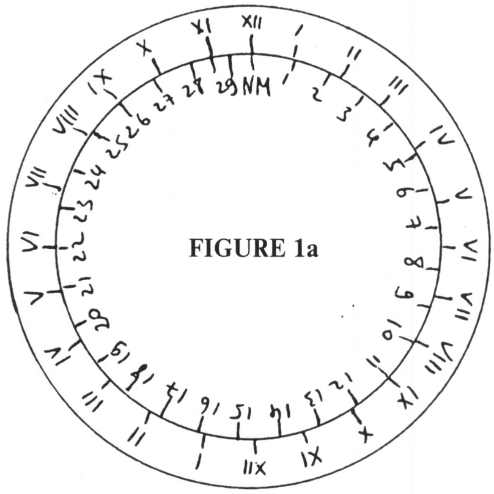
It is more convenient to find in which part of the horary dial the moon stands by the use of inverse sense graduated discs - Fig. 2. By setting NM on the solar shadow, the lunar hour is read in respect of the age of the moon.

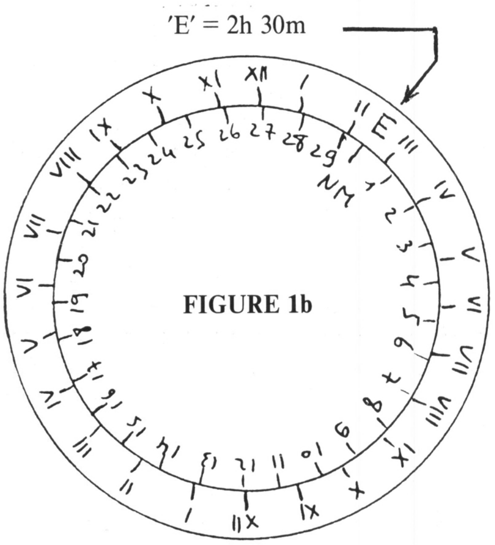
By taking the previous horary discrepancies into account in respect of the "Port Establishment" according to the age of the moon, and having converted all the "Port Establishment" into UT values or the local time of your meridian, a perpetual book of tide-hours may be compiled.

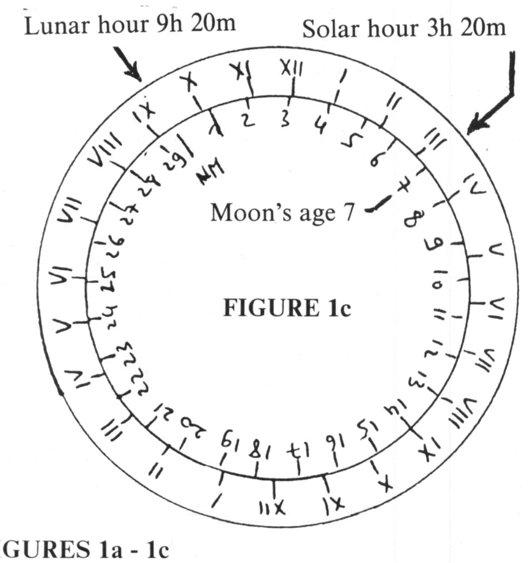
Do not seek to know the tidal coefficient, nevertheless remember that great tides arrive 36 hours after NM and FM, also that these are greater when the moon and sun are in perigee (the mean motion of the moon's perigee is 45° per year, that is to say 5° every 45 days). On the platform of my dial, 75 holes are perforated to allow an advance of 5° every forty-five days, see Fig. 3.

Figure 5 gives an overall view of the complete instrument with integral plumbob and levelling screws in the brass to allow accurate setting of the instrument.

Remember that a number of distant harbours do not obey the lunar semi-diurnal regime and it will be better to







FIGURES 1a - 1c

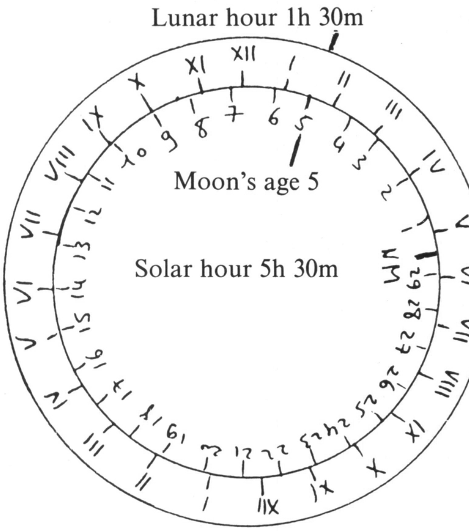


FIGURE 2

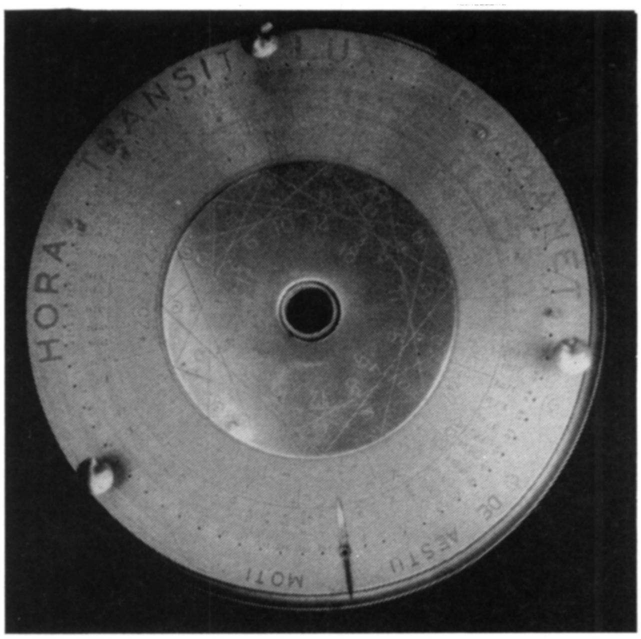


FIGURE 3: The axis of the cylinder is positioned parallel to the axis of the world; on each of its 24 hours graduations are engraved the names of the harbours according to the order of the "E" values converted to U.T. Beneath is the index of the nocturlabe to turn the alidade and the slide to use as the style.

find these out if you intend to maintain a coastal trade in all oceans!

I have never ventured upon this myself, but when I informed the National Hydrographic Service of seeming anomalies revealed by my dial (containing 761 harbours engraved upon it), of harbours in New Zealand, I was surprised to learn by return post that the date of the International Hydrographic Board would be corrected for six harbours of this country. In thanking me, the Principal Engineer confided in me that it was due to typographical errors!

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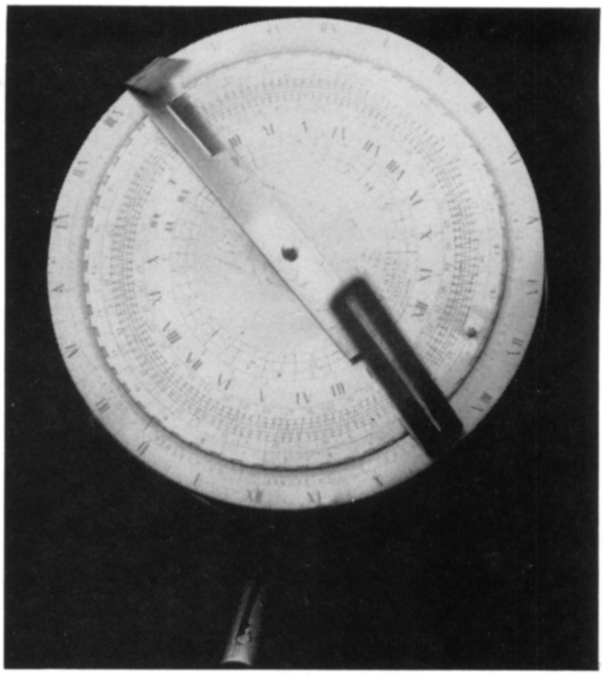

FIGURE 4: Upper face of the cylinder to find moon or sun hour. The inner movable disc (graduated in hours at 15° intervals, and also the age of the moon graduated in the same sense) is used to convert the sun hour into the moon hour. The branches of the alidade are inclined at 61° 30′ = 90° - [23° 27′ + 5° 03′], one may be shortened to permit sighting the moon whatever its declination + or -, one is slotted, the other is pierced by two holes.

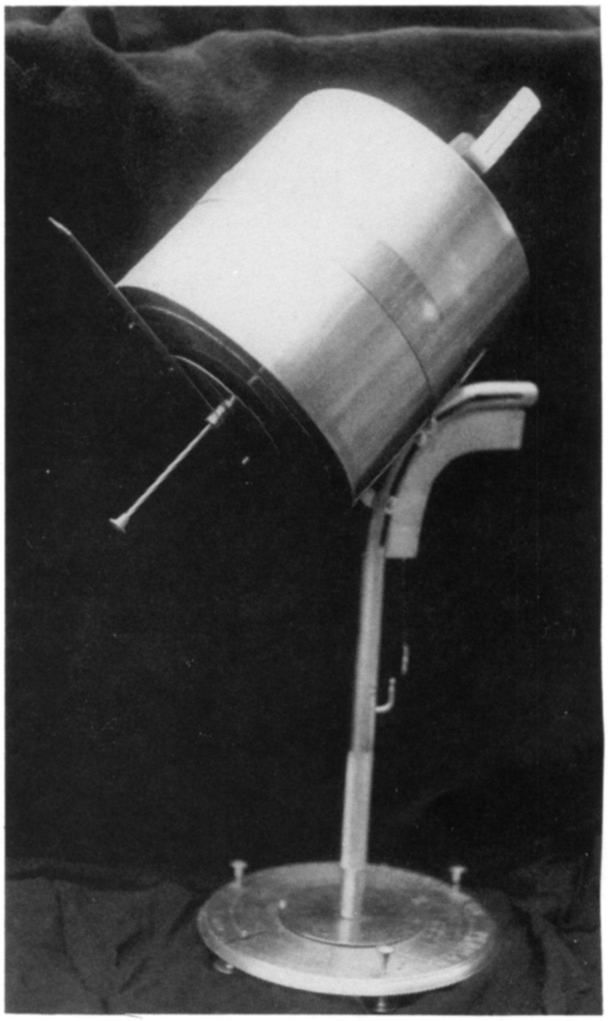

FIGURE 5: The base of the stand has a central movable disc with the 19 Golden Number arranged in 15 points to allow the age of the moon until the year 2199 in conjunction with the mean corrections of the solar components on the fixed disc. Around the periphery are the 72 holes with the dates of the year in steps of 5 days, to allow the advance every period of 45 days of the pointer showing the position of the moon's perigee.

BOOK REVIEW

SCRATCH DIALS of old Axbridge and Long Ashton Districts of North West Somerset by Lawrence N. Price, 92 pages, 32 photographs, 2 line diagrams, hard bound with marbled end papers. Published 1991 at Weston-Super-Mare by Sun & Harvest Publications. 22 cm x 16 cm, ISBN 0 95118347 0 3. Price £33.50 plus £1.50 p. & p., from Sterling Books, 43a Locking Road, Weston-Super-Mare, Somerset BS23 3DG.

This is the second edition of what was first published as a limited edition of six copies in August 1991, and is the first book devoted to Scratch Dials for many decades. When the British Sundial Society was founded and questionnaires were sent out to find exactly what the members wished to read about, the very excellent analysis made by Mrs. Anne Somerville revealed that apparently few people were interested in the subject of scratch dials. Yet at the Cambridge Conference of September 1991, about twenty members were interested enough to attend a debate on the subject and to approve the setting-up of a group to study these enigmatic relics of the past.

Few possess the total literature on scratch dials, the reviewer has acquired whatever was available - even when paying £10 or more for leaflets which originally sold for 1½d (old money). He has also some of the correspondence of Dr. Arthur Robert Green and has studied the literature of Professor G. Baldwin Brown and the Reverend Daniel Henry Haigh, these two apparently laying the foundation upon which much of the later discussions on scratch dials were based. The present work is based upon that of Dom Ethelbert Horne and that of Dr. Green. Green spent much time and effort into trying to fit the scratch dial into some comformable time system on the assumption that hours of equal length came into use in the fourth century of our era. His attempts, although heroic, were doomed to failure since scratch dials, which were imported by the Normans, were brought from a country which used an unequal hour system, into a country in which rude subdivisions of the day were customary but still with the daylight period divided into equal parts and thus varying with the season. The real problem was that the imported system was derived in the Mediterranean regions where the altitude of the sun is predominant, whereas in these Northern climes it is the Sun's direction which is predominant. The great change between the summer and winter hours for unequal hours is far too great for use in northern climes although more acceptable much further south.

The early Greek sundials, whilst not having polar gnomons, because of their construction used the tip of the horizontal rod gnomon to form the indicating shadow, and this tip might be considered as the point on an imaginary polar gnomon. Hence the accuracy of these dials was quite sufficient to regulate the day-to-day activities of even a complex city like Athens. The early Anglo-Saxon sundials, although immeasurably superior in design and craftsmanship to the humble scratch dial, were only reasonably correct in summertime. No one yet has discovered the true elements of the Anglo-Saxon time system. It was apparently worked out by Haigh and has not been contested since he propounded his theories. When one looks into these matters it is found to be unwise to place too much faith in Baldwin Brown and Haigh who often replaced the lack of facts by conjecture which crystallized into reality by repetition.

This lengthy preamble has been written to set the scene for the present book, in which the author relies upon Horne and Green. Horne's greatest contribution was to find and record all the scratch dials he could, yet he made no real impact as to the why and wherefore of these rude dials. Green only confused the issue and so the present work really adds nothing to the subject except as an excellent illustrated guide to the examples still extant in the stated districts. So the remark on page 12 by the author sums it up: "So far from being a crude marker of time, the dial (scratch) was a good timepiece, not only telling the time of Mass". In the reviewer's humble opinion, the scratch dial is merely an event marker, for which the precise time is not of any importance but which enables a group of people to synchronize communal activities such as attending a church service. Since God is on a twenty-four hour duty cycle each day, a local service at 9, 9.30 or 10 a.m. will be equally acceptable, since local time in a global or universal sense is quite irrelevant.

There are hundreds of scratch dials in France, and since there were none in England until the Normans invaded, it is reasonable to assume that scratch dials came with them and they are not an English adaptation as Horne seemed to think. It is surprising, in view of their widespread use, that there is nothing to be found about them in any known source. The nine pages of text in the present book do not add anything to the subject. It would seem that the author had been extremely diligent and enthusiastic but has been a lone worker and apparently without the knowledge that there were others in the field.

The photographs are in a sepia tone and generally excellent. One has to look hard at example 22 - Wrington Church to spot the dial, evidently the shadow of a tree fell upon it at a critical moment. Each photograph is faced by a page containing only a title, this could generally have included more facts such as the overall size of the dial, present height above ground, age of the church, possible renovations over the years, and so on; just to give some idea of the what extra information could have been incorporated. It is very unwise to study any object in isolation, and the scratch dial was only a means to an end, it was never a device which stood aloof in its own right; in fact it is this which has caused it to be ignored until quite recently. The examples which are preceded be a view of the church seem to be the best approach. There are only twenty-five examples covered in the book.

For some time now the wear and tear of these dials has caused the reviewer to speculate on how some of these dials are now approaching one thousand years of age, since in his own lifetime he has seen dials visibly deteriorate merely by weathering. Much depends upon the material, nevertheless it seems that modern pollution has wrought havoc upon these ancient emblems. Not one has received any protection unless fixed inside the church for some now unknown reason.

The book itself is an oddity since each leaf consists of two sheets of paper attached at the outer edge. This was necessary to thicken the book up to a decent proportion, the photographs are affixed to the right hand pages and the extra thickness in the centre of the pages bows the book covers. An 1892 map of the districts covered is included at the end, it would have been nice to have had

Ordnance Survey map references to locate the churches easily, and a more modern map. No listing of the examples is included in the book, again an oversight on the part of the author and regrettable in view of the space available.

In spite of the strictures here, the reviewer, conscious of the difficulties in locating these elusive artefacts and of obtaining good photographs under the restrictions of access in churchyards, congratulates the author on his attempts to make a sound record of his chosen area. In years to come these photographs will be the only evidence of what was taken for granted and studiously ignored. The book is expensive but as the scratch dial enthusiast does not often get the opportunity to purchase literature on the subject, it will be an essential purchase. With a more methodical approach and systematical analysis based on more accurate sources, the book could be improved to become something much better if it should enter into a third edition. For example the inclusion of a bibliography of scratch dial literature seems almost an essential feature.

The reviewer would like to add that it is easy to criticise, less easy to do better, and impossible to be authorative with so little to go on; yet the task of the reviewer, is to attempt to arrive at the true worth of the book with an impartial mind. It is an achievement merely to produce such a book for such a limited readership and Mr. Price must be commended if only for this.

LETTERS TO THE EDITOR

MANUSCRIPT 225 RIPOLI

I should like to raise the point with respect to Eduard Farré i Olivé's article in BSS *Bulletin* 91.2, July 1991.

The manuscript is quite interesting historically but does not seem to me to be correct and merits criticism about the drawing of temporary hours, if I am not in error.

I think that drawings for temporary hour lines can be correct only if the plane is equatorial and if the style is perpendicular to the plane. It is seldom the case where the shadow of a style progresses according to equal angles in equal time spans. On a horizontal sundial, the shadow of a perpendicular gnomon actually shows azimuths but the azimuth is not a linear function of time (the variation of speed of the azimuth is always greater towards noon than at any other time).

In my opinion, in the case of a horizontal dial, we need the "analemmatic dial", the projection of the equator then brings an ellipse. The days of the equinoxes are the simplest case, not only is it useful to translate the hour ellipse in relation to the foot of the gnomon, but because equinoctial hours correspond then to temporary hours of 60 minutes duration also.

However, even in that case, the half circle circumscribing the ellipse being divided into 12 equal parts, the 12 hour points of the ellipse are found from the intersection of the ellipse with the orthogonal projection, in respect of the abscissae axes, of equi-spaced hourpoints of the circle.

For other days of the year, the correct method would seem to be:

1. Draw the ellipse for the latitude of use.
2. Calculate the length of the day at every change of zodiacal sign and divide also into equal parts on the arc of the circle, mark the hour points on the ellipse centred on the correct displacement.
3. Calculate the azimuths for each temporary hour and for every position of the gnomon.
4. Mark on each month circle, centred on the foot of the perpendicular gnomon, (now fixed), the azimuth for each temporary hour, and these can be joined by a continuous curved line.

DENIS SCHNEIDER
FRANCE

EDITOR, YOUNG TELEGRAPH - SUNDIALS

Has neither Phillips Perry not Joy Fitzsimmons ever looked at an ordinary horizontal 'Moorish' sundial? The illustration on page 14 of this week's Young *Telegraph* is utterly wrong.

The piece in the centre (the gnomon) must be situated along the north-south Meridian with the lower end south (in the northern hemisphere). Its angle to the plane of the dial must be the latitude of the place where it is used.

The layout of the hour numerals is **NOT** as on a clock face as you have it shown, but is quite complicated. The Moors did the mathematics involved long ago. 5, 6 and 7 appear twice on a sundial, for the morning and evening hours.

Surely your researcher and/or illustrator could be expected to have at least glanced at a picture of a sundial?

Attached is a current advertisement for a sundial.

Yours sincerely,
James McGregor.

A reply was received by Mr. McGregor:
Dear Mr. McGregor,

I apologise for our oversight in our sundial piece on Saturday, I am afraid I don't know where the illustrator found her reference, but obviously it was not a bona fide source. Many thanks for your corrected version which makes much more sense. I am sorry that the error was not picked up earlier at our end.

I do hope you will continue to enjoy reading Young Telegraph.

Damian Kelleher,
Acting Editor.

Thanks are expressed to Mr. McGregor for sending copies of the letters and the offending article in the Young Telegraph of 18th April, 1992. The illustrations show not only the most abysmal lack of understanding of the priciple of a sundial, but even as to the position of the sun in the sky.

The Editor of the BSS Bulletin is always pleased to receive copies of such items from newspapers and journals. Over the years a collation of these oddities will become very interesting in its own right.

BOOKS ON DEMAND

In its project to microfilm all books published in England before the year 1700, University Microfilms International has captured many dialling books in its nets. UMI will publish any of these books on demand, making xerographic copies on acid-free paper and binding (soft or hardbound) the resulting books in the original size format. The following is a (no-doubt partial) list of available titles, along with the Short-Title Catalog and Microfilm reel numbers to use in ordering, and an approximate page count to estimate the cost of the publication.

Early English Books Series $.26/page, minimum $20.00/book. Additional $6.00 if hardbound. Plus shipping (in USA) of $2.25 plus $.75 for each additional book.

University Microfilms International
300 North Zeeb Road Ann Arbor, Michigan 48106 USA
(800) 521-3042

AUTHOR	TITLE	STC #	REEL	PAGES
Blagrave, John	Art of Dyalling in 2 Parts 1609	3116	654	165
Brown, John	Desc. & Use of the Triang. Quad.	B5041	933	534
Brown, John	Horologiographia	B5042	955	349
Brown, John	The Triangular Quadrant	B5043	1545	27
Clerke, Gilbert	The Spot Dial	C4449	348	30
Collins, John	Geometrical Dyalling	C5373	958	121
Collins, John	The Sector on a Quadrant 1658	C5381	LT	
Collins, John	The Sector on a Quadrant 1659	C5382	1524	400
Fale, Thomas	Horologiographia 1593	10678	314	165
Fale, Thomas	Horologiographia 1626	10679	790	165
Fale, Thomas	Horologiographia 1627	10680	790	165
Fale, Thomas	Horologiographia 1633	10681	790	165
Fale, Thomas	Horologiographia 1652	F 310	416	160
Foster, Samuel	The Art of Dialling 1638	11201	1097	58
Foster, Samuel	De instrumentis planetariis	F1630	1123	52
Foster, Samuel	Description & Use of a Nocturnal	F1631	1123	16
Foster, Samuel	Ellipt. or Azimut. Horolog. 1654	F1632	143	220
Foster, Samuel	The Geometrical Square 1659	F1633	94	26
Foster, Samuel	Miscellanies or Math. Lucubrations	F1634	1384	347
Foster, Samuel	Posthuma Fosteri 1652	F1635	LT	89
Foster, Samuel	The Uses of a Quadrant 1652	F1636	LT	70
Gunter, Edmund	Desc. & Use, His Majesties Dials 1624	12524	1069	65
Gunter, Edmund	The Works of... (1636 2nd edn)	12523	1103	615
Gunter, Edmund	The Works of... (1653 3rd edn)	G2239	1462	615
Gunter, Edmund	The Works of... (1662 4th edn)	G2240	714	615
Gunter, Edmund	The Works of... (1673 5th edn)	G2241	599	615
Gunter, Edmund	The Works of... (1680 6th edn)	G2242	1778	169
Hanbury, Nathan	Horologia Scioterica	H 637	533	47
Holwell, John	Clavis Horologiae	H2517a	1795	370
King, Daniel	Desargue's Universal Dyalling 1559		414	108
LaHire, Philippe	Gnomoniques	L 181a	1529	215
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Leybourn, William	Dialling (2nd Edition) 1700	L1913	282	407
Leybourn, William	The Art of Dialling 1669	L1900	215	202
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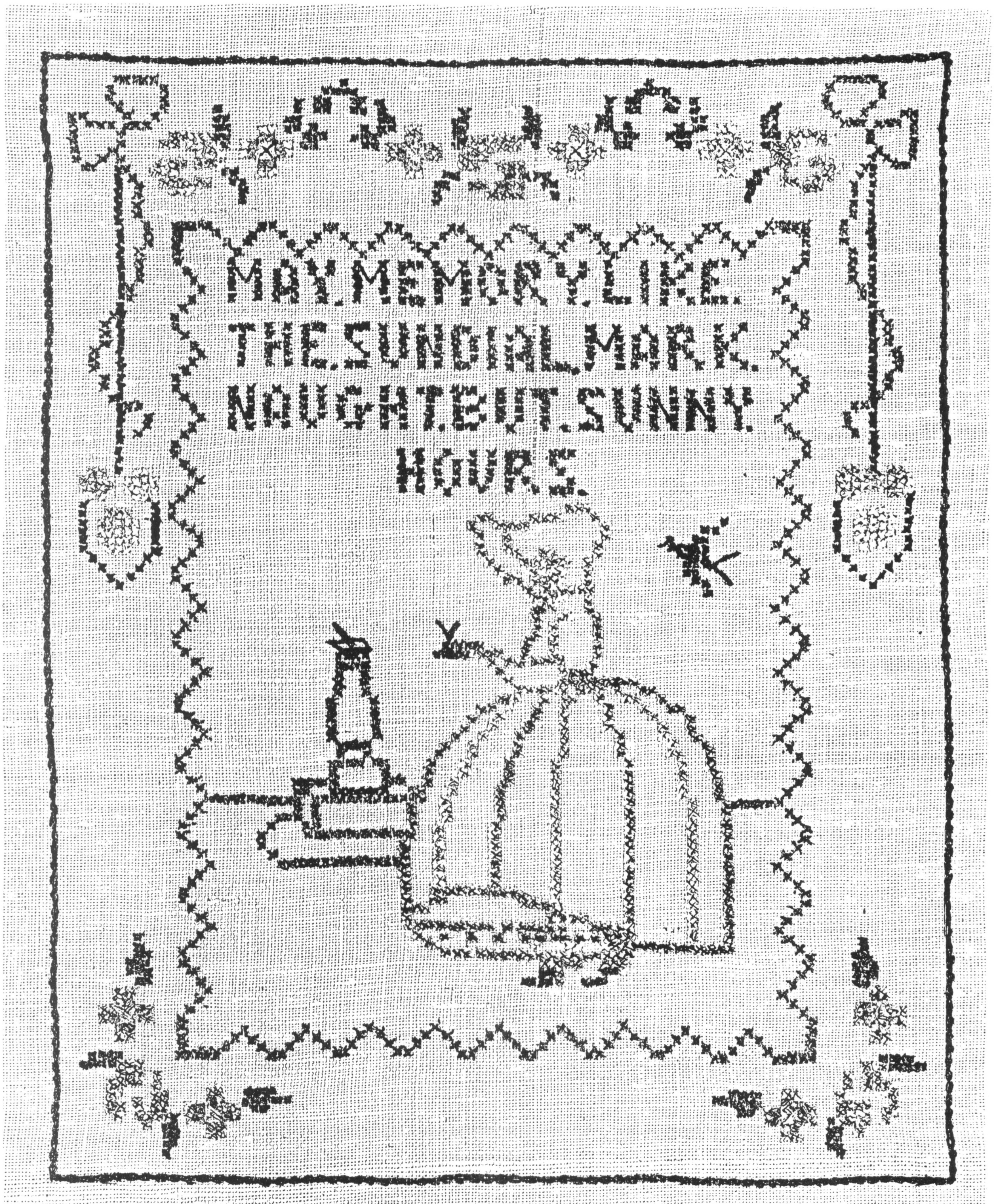
Morgan, Sylvanus	Horologiographica	M2741	LT	144
Oughtred, William	Desc. & Use, Double Horiz Dyall 1636	18900	1148	20
Oughtred, William	Horolog. scioter. in plano 1652		156	41
Palmer, John	The planetary instrument	P 249	1799	11
S(erle), G(eorge)	Dialling Universal 1657	S2622	LT	39
Smith, John	On the unequality of natural time	S4107	548	136
Stirrup, Thomas	Horometria	S5689	LT	192
Sturmy, Samuel	The Mariner's Magazine 1669		581	528
Wells, John	Sciographia, The Art of Shadowes 1635	25234	979	510
Wright, Edward	A Short Treatise of Dialling 1614	26023	946	54

LT titles are part of the Thomason tract series; reel locations of those cited in this list are as follows:

Collins	C5381	Thomason tract	E956(1)	Reel 143
Foster	F1635		E675(1)	Reel 104
Foster	F1636		E1294(3)	Reel 174
Morgan	M2741		E652(16)	Reel 100
Serle	S2622		E956(3)	Reel 143
Smith	S5689		E956(2)	Reel 143

Frederick W. Sawyer III, 8 Sachem Drive, Glastonbury Ct 06033 USA



A sampler worked by a schoolgirl in the 1930's reflects the diallist's thoughts in cross-stitched design.