

The British Sundial Society



BULLETIN

No. 93.2



JUNE 1993

ISSN 0958-4315

HONORARY OFFICIALS OF THE BRITISH SUNDIAL SOCIETY

PATRON: THE RT. HON. THE EARL OF PERTH P.C.
PRESIDENT: SIR FRANCIS GRAHAM-SMITH
VICE-PRESIDENT: M. RENÉ R.-J. ROHR (France)
VICE-PRESIDENT: DR. MARINUS J. HAGEN (Netherlands)

COUNCIL:

CHAIRMAN: MR. CHRISTOPHER ST. J.H. DANIEL
GENERAL SECRETARY: MR. DAVID YOUNG
FINANCE: MR. R.A. NICHOLLS
MEMBERSHIP: MR. ROBERT B. SYLVESTER
BULLETIN EDITOR: MR. CHARLES K. AKED
DIAL RECORDING: DR. I.D.P. WOOTTON
EDUCATION: MRS. JANE WALKER
LIBRARY AND RECORDS: MRS. ANNE SOMERVILLE

BULLETIN 93/2 - JUNE 1993 - CONTENTS

Page

1. DIALOGUE - Hungary, De Zonnewijzerkring.
 2. Il Quarantale, by Giovanni Paltrinieri (Italy).
 8. A Cold Look at Kratzer's "Polyhedral" Sundial, by P.I. Drinkwater.
 11. The Meridians of St. Sulpice Church, Paris, Part 2.
 18. The Analemma of Vitruvius, by P.I. Drinkwater.
 21. High Noon, by Charles K. Aked.
 25. A Qibla Line Construction, by F.W. Sawyer III, (USA).
 26. A Japanese Sundial, By Robert A. Mills
 28. Laying out a Vertical Declining Dial, by Colin McVean.
 30. From the Chairman's Pen, Errors and Misconceptions.
 33. The Celestial Sphere, by C. Philip Adams.
 38. Book Reviews.
 40. The Merton College Chapel Dial, by Charles K. Aked.
 42. Kircher's Sunflower Clock, by John Briggs.
 43. A Word from the Editor.
 44. A Yorkshire Sundial at Stainborough.
- Inside back cover - Useful Addresses.

Cover Illustration - "Midday", drawn by Lancret, engraved by Larmessin, now in the National Library, Paris. The shadow of the cherub's arm was omitted by the painter or engraver and has been supplied by the Editor.

DIALOGUE

HUNGARY

Mr Lajos Bartha, writing from Budapest, included a report of the activities of the Hungarian Astronomical Association and the Sundial Working Group of the Austrian Astronomical Society, first mentioning a proposed meeting in late September or early October 1993, at Szombathely, Hungary, close to the Austrian border and near to Vienna. BSS members are welcome if they wish to attend.

The Sundial Working Group of the Austrian Astronomical Association organized an annual meeting for Austrian members and foreign participants in Salzburg, the Chairman was Mr Karl Schwarzinger, and the main organizer was Mr Peter Husty, a scientist in the Carolino-Augusteum Museum in Salzburg.

This is a splendid museum and has a nice collection of portable and other sundials, unfortunately most are kept in the reserve collections and were on display for the days of the meeting only. The most interesting example was made for the Duke/Bishop of Salzburg, the oldest example is an ivory diptych sundial from Nuremberg, estimated as circa 1570. Three similar sundials exist in Hungary and another at Ulm, Germany, whose dates have been put at 1530-40, so it is possible that the Austrian example is of the same age.

On the morning of 3 October 1992, the party visited the Carolino-Augusteum Museum, and also viewed the famous sundials on the walls of the houses in the City of Salzburg. In general, the condition of these sundials is good. On the next day, 4 October, a group of the members visited the sundials in the villages near to Salzburg by coach.

Also on 3rd October was the lecture sessions which approximately 60 members attended. The proceedings were opened by Mr Schwarzinger and Mr Johan Albrecht, President of the AAS. Mr Ponori Thewrewk, Chairman of the Hungarian Astronomical Association, reported on the work of Hungarian diallists and the Hungarian sundial catalogue. Later he gave an interesting lecture of the calculating and use of horizontal stereographic sundials. Dr I Fabian lectured on the portection of old fixed sundials. Mr A Zenkert of Germany spoke of the imagery of vertical sundials, whilst Dr Eng H Philipp, the President of the sundial section of the German Chronometrical Association, spoke about new uses of the old scale on vertical dials.

One of the most interesting lectures was by Mr M Korn., Salzburg, of the holographic sundials he has designed (an article on these will appear in the BSS Bulletin); an example of his new type has been placed on the wall of a technical school in Salzburg. Slides showing the sundial village of Taubenheim in Germany were presented by Mr H Raus, there are two dozen sundials in the village. Mr R Wilhelm of France also presented a lecture with slides showing interesting examples. Short abstracts of these lectures have been printed in the *Rundschreibe*, issues No's 5 and 6.

The BSS Council notes the increasing activities of sundial groups in Europe and compliments the various groups on the interesting meetings arranged by them.

DE ZONNEWIJZERKRING

Bulletin 92.5 is another information-packed issue. An account is given of the De Zonnewijzerkring Summer excursion on 20 June, when a visit was made by coach to various dials in Zwelle and its surroundings. There appears to be a great wealth of dialling material in this area.

A special exhibition was held at Hengelo, and De Zonnewijzerkring members loaned about sixty sundials for this.

An interesting story is related about the difference in time in the Netherlands in the last century. The railways used Amsterdam time based on local solar time, whereas the city of Utrecht used the Cathedral time. After a detachment of troops missed a train because of this difference in time, the Burgomaster of Utrecht decreed that the cathedral clock should be advanced by three minutes, and after a few months it was adjusted to Amsterdam time permanently.

A mathematical article deals with the signs of the Zodiac, whilst another deals with a problem involving the gnomon. There is a discussion on the value of 15° per hour for the sun's movement; and a description in English of the Sibton Abbey Venetian Ship dial now at the National Maritime Museum. This includes a number of illustrations.

An article of unusual interest is that on Moon dials, it contains mention of the dial at Queens' College, Cambridge. There is a follow-up on some correspondence about planetary time and a reproduction of the letter heading of the Foundation of Notaries in the Netherlands which shows a sundial.

The list of Netherlands sundials is constantly being added to and in this issue nine pages are devoted to recording new ones found, together with illustrations. In addition an illustration is given of a complicated dial in Mallorca. Seven pages are devoted to book reviews and periodicals, and in conclusion there is a two-page table of the Equation of Time, and Sun's Declination, for 1993.

LA BUSCA DE PAPER

Issues No 11 and 12 were received only recently although dated 1991. Issue No 11 contains an important article under the title "Study of Solar Illumination of a Sundial" by Rafael Solier i Gayà. This allows the determination of the time of illumination of a sundial by first determining the landscape profile, reproducing this on a grid with true azimuths on the horizontal and altitudes on the vertical axis. Projecting the apparent orbits of the sun on to this profile allows determination of the time the sun begins to shine on the dial and the end. A series of tables of solar altitudes according to true azimuths up to latitude 45° is given, also a two-page diagram of such a treatment.

Issue 12 contains brief notes on planispheric astrolabes by Eduard Farré i Olivé, which give the names of the parts comprising the astrolabe, also a brief history of the instrument. A clear mathematical exposition of the variation of declination with time is given by Josep Maria Albaiges Olivart. The English translations of the Catalan text by William Bain are excellent, the texts of the articles are also given in Spanish. The articles too are excellent.

IL QUARANTALE

AN UNKNOWN INSTRUMENT BY GEMINIANO MONTANARI

BY GIOVANNI PALTRINIERI (Gnomonist, Bologna, Italy)

The old palace Pietramellara (now Sassoli de Bianchi), is situated at 14 via Farini, and was the residence of the patrician family which contained many notable persons.

Amongst these was Giacomo Vassé Pietramellara, called to Bologna in 1496 by Giovanni II Bentivoglio to take up the Chair of Astronomy, and who eventually obtained citizenship of Bologna.

In the second half of the seventeenth century, Giovanni Antonio Vassé Pietramellara (Senator and Bolognese Ambassador to Rome, Premier Extraordinary with Clement IX, and successively Ordinary with Clement X) charged the astronomer Geminiano Montanari to lay out a meridian line in honour of his illustrious grandfather. The meridian line, which is still extant, is traced on the floor of a vast rectangular hall, the longest sides of which are almost perfectly aligned in the North to South direction.

A particularly charming atmosphere is produced by the frescoes, which cover the whole of the under surface of the vault. The work was done by Bartolomeo Morelli for the figures and Domenico Santi for the ornamental design, and represents the Triumph of Urania (the Muse of Astronomy) together with other allegorical figures. The cornice under the vault contains along its perimeter the representation of the twelve signs of the Zodiac, to underline the astronomical significance of the hall. Other peculiarities of the hall are the four doors which open on to the two major walls, on each one is painted a cornice frieze, the whole of which lacks any coat of arms or inscription.

DETAILS OF THE MERIDIAN

From the books which contain descriptions of the Palace, only a few mention the presence of the meridian and indicate its origins and the year of its construction. The dimensions are listed in an interesting manuscript (unpublished) dated 1766, compiled by Don Domenicus Gatti, Parish Priest of the Quarto Superiore (in the former outskirts of Bologna), under the title of "Gnomon Information". In the following extract, the author refers to the Bolognese unit of linear measurement then in force (1 Foot = 380.09829 mm). The values indicated in the brackets are given in millimetres.

"... the Melara meridian has its aperture at a vertical height of 16ft $\frac{1}{2}$ in (6097.41). The whole has a diameter of $\frac{1}{4}$ in (7.91); its length is 39ft $\frac{1}{2}$ in (15029.72). The diameter of the Summer Solstice image is 2 $\frac{1}{4}$ in (71.268); at Gemini it is 13in wide (411.773), and a generous 4 $\frac{3}{4}$ in length (150.455)".

This instrument was made 19 years after the meridian of San Petroni by Doctor Geminiano Montanari, Modenese Public Lecturer in the school. The Melara Meridian has an inscription on a brass arrow indicating the height of the hole or vertice in its tenth parts 19 $\frac{1}{4}$ in (609.741). The ellipse of Capricorn is six times longer plus $\frac{1}{3}$ inch than in Cancer (438.05).

EXAMINATION OF THE MERIDIAN

We now turn to the examination of the meridian which we shall shortly see contains some surprises. The hole in the vault, almost in the depths of the hall, is shut. Its entrance is clearly visible and positioned in the centre of a

painted shield at the feet of one of the figures in the fresco and at the side of a child, with one hand supporting the shield, the other indicating the gnomon aperture.

The meridian line starts from the vertical below the hole and runs parallel to the axis of the hall, outlined by a series of brass plates 26mm in width laid end to end, on which are engraved longitudinally five equally spaced grooves. On the eastern side of the meridian is engraved a numerical progression which commences at zero and ends at 253.5, (see Figure 1). Its precise measurement is obtained in the following way.

Each interval corresponds to the one hundredth part of the vertical height of the gnomon aperture above the floor, the measurement of the distance 0-100 gives the fundamental dimension of the instrument - that is the gnomon height is 6097mm (identical to the value given by Don Gatti). But the gnomon height is composed of 100 modular units, hence each module = 60.97mm and is the unit of measurement applied to the whole instrument. Since the entire strip of brass has a total length of 60.97 x 253.5 = 15455.8mm (a value somewhat different to that given by Don Gatti; perhaps he was referring to the lower edge of the luminous ellipse at the winter solstice). The modular units engraved on the line are themselves divided into ten parts, each with an interval of 6.097mm. The entire strip of brass is contained within two lines of white marble which form a rectangle 61mm wide. To the western side of this is a scale of five modular units.

If one carefully observes the points projected by the solstices on the brass strip, one notes, with a little surprise, that these places are engraved with the extreme edges of the solar image. At the Summer Solstice is found two engraved lines; one at modular 37.78 (2303.4), and the other at 39.0 modular units (2377.8). At the Winter Solstice at the modular distance 243.3 (14834.0) and 250.15 (15251.6). Assuming that this was the result of the direct observations of Montanari, this is almost identical with the calculated amount, taking into account the obliquity of the Ecliptic in 1674.

The Western side of the strip contains another surprise: it is engraved with a second numerical progression but which is in inverse sense to the first. This again is subdivided in modular intervals of the same length, but indicating in groups of five only, which for greater clarity of reading are shown on the adjacent line of marble. Its start is coincident with the modular 250 on the first numerical scale, increasing progressively until it reaches the vertical line subtended by the aperture. One is in fact dealing with two engraved series of modular progressions, one opposed to the other: a peculiarity not found on any other meridian examined by the writer.

Along the side of the strip of marble are positioned squares of the same material, these originally contained the Zodiacal Signs and the respective dates of entry of the Sun into these signs. At the origin of the line is placed a tablet on which is engraved the following inscription:

**MERIDIANA SEMITA/AD SOLEM LUNAM ET
ASTRA/A VERTICE AD GR 70 IN MERID.**
(Meridian path for the sun, moon and stars, from the Zenith to 70° towards the south).

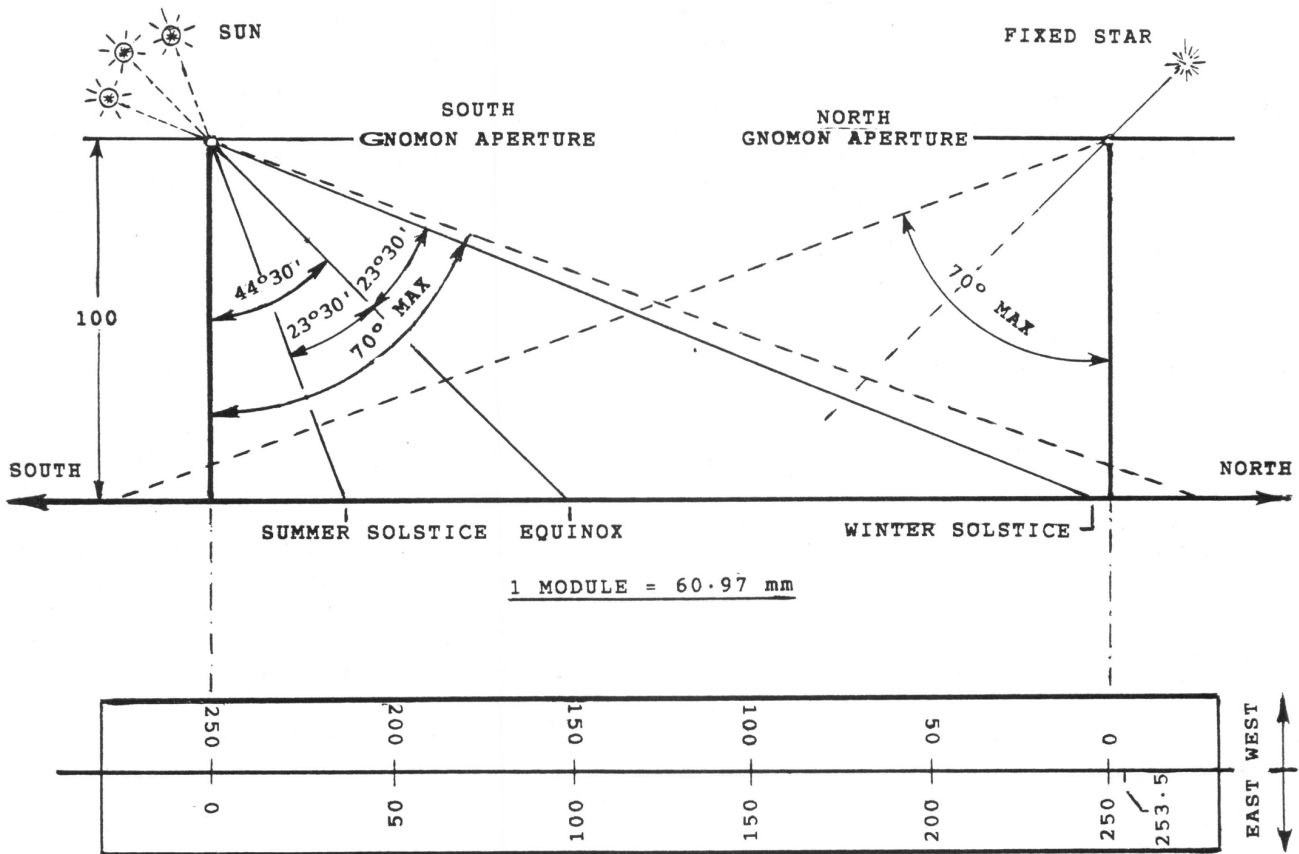


FIGURE 1

Longitudinally is engraved:
**SIGNA ZODIACI ASCENDENTIA/TANGENTES
 DISTANTIAR. A VERTICE/ SIGNA ZODIACI
 DESCENDENTIA.**

(Ascending Zodiac signs, tangential distance from the Zenith, descending Zodiac signs).

At the end of the line, that is on the opposite side of the hall are situated two more marble tablets. The first, across the brass line, had the task of receiving the image of the sun at the Winter Solstice on its light and uniform surface. On this is engraved the modular 250, with an inscription (now illegible) of two lines.

On the second of the two tablets is engraved transversely the following inscription:

**MERIDIANA SEMITA/AD FIXAS/A VERTICE AD
 GR 70 IN SEPTENTRIONEM.**

(Meridian path to the fixed stars, from the Zenith up to 70° North).

And longitudinally:

TANGENTES DISTANTIAR A VERTICE. (Tangential distance from the Zenith).

Finally, among small terracotta squares laid in the floor are inlaid eight pairs of brass squares, forming at the centre a hole of 9mm, passing between one pair and the other, although this distance is not quite uniform. Let us examine the usefulness of these squares briefly.

The brass line is sufficiently preserved so that the modular figures can still be read, and each of the decimal subdivisions. Some features of the brass line are missing. A worse fate has befallen the marble, the numerals engraved in groups of five on the two strips of marble near the brass line are now almost completely erased. The

marble at the head of the line, because of the continued trampling by feet, has suffered considerable abrasion and many of the engraved plates letters have now disappeared. The same thing has occurred to the squares which at one time were marked with the zodiacal symbols, in some a faint trace still survives.

In conclusion one can judge the present state of the instrument to be fairly good considering its great age. In fact it seems from the time of Montanari until today, the meridian has not seen any modification; for example such as the one which has happened to the meridian at San Petronio which was reconstructed in 1776.

THE WORK OF MONTANARI

We now come to examine the work of Geminiano Montanari in its various aspects, and consider the double numerical progression adjacent to the line. It has already been seen that the marble tablet under the gnomon aperture mentions the possibility of observing the sun, the moon, and the stars from the zenith up to 70° towards the south. On the facing side a second marble tablet notes the possibility of investigating the fixed stars from the zenith up to 70° towards the north. In fact, in the first case, one can obtain the projection of the sun, moon, and with appropriate details, also of the stars which traverse the meridian from the zenith up to 70° towards the south via the gnomon aperture. In the second case, if one wishes to observe the stars from 0° to 70° towards the north, it is necessary to make use of the second gnomon aperture situated at the opposite end of the line. Only by admitting the presence of a second aperture can the engraving on the marble and the double progression be justified.

This arrangement does not frequently occur but it is not unique: Cassini in 1695, on the occasion of the first restoration of the San Petronio meridian line, seeking to determine the local latitude with absolute precision, had devised an instrument which is still preserved in the Museum of the Basilica. It comprised a structure placed approximately on the line, which permitted the tracking of the Pole Star, a rod situated on the window of the central door; the value of the modular units obtained corresponded to the tangent of the local latitude.

Another example is the meridian of the church of Santa Maria degli Angeli in Rome, laid down in 1702 by Francesco Bianchini. This was furnished with two gnomon apertures, one south and the other to the north. This latter has the form of a vertical rectangle so that it was possible to observe the upper and lower culminations of the Pole Star, thus obtaining the absolute latitude of the place. In order to project the stellar image on to the meridian line, Bianchini made use of a telescope almost 21 metres in length, held firmly by a special adjustable support which he called "The Machine", the mounting being calibrated in degrees to determine the required elevation.

By returning to the Bolognese meridian we must unfortunately report on its present non-operative state. The first gnomon aperture on the south was closed to protect the vault and its frescoes from the danger of water penetration, the second gnomon aperture has vanished without trace long ago; the only record of its former presence seems to be the faint inscription on the tablet.

MANUSCRIPT DETAILS OF INSCRIPTION

The research on the meridian appeared to have reached a conclusion, however, on examining a series of documents preserved in the Department of Astronomy at the University of Bologna, a sheet of paper bearing handwriting of the second half of the seventeenth century came into my hands. The sheet, written in Latin on both sides of the paper, is sub-divided into four passages, and carries the heading: (See Fig. 2)

Inscription in the Melara Gallery

MERIDIANUM HUNC TRAMITEM AD SOLIS, LUNAE CAETERORUMQUE ERRANTIUM PARITER ET AFFIXORUM SIDERUM MERIDIANS ALTITUDINES PERSCRUTANDAS A VERTICE USQUE AD LXX GRADUUM DISTANTIAM IN UTRAMQUE PLAGAM, CAETERAQUE HUC PERTINENTIA INSTRUMENTA EXACTISSIMO STUDIO, AC DILIGENTI LABORE PARAVIT GEMINIANUS MONTANARIUS CIVIS MUTINIENSIS I.V.D AC BONONIEN. ARCHIGYMNASIJ MATHEMATICARUM PROFESSOR. ANNO DNI MDCLXXIV

(Geminiano Montanari, Citizen of Modena, and Professor of Mathematics of the University of Bologna, in the year of our Lord 1674, prepared - with a precise study and diligent execution, the meridian line, and the other instruments pertinent to it, in order to determine the altitude of sun's meridian, of the moon, and of other stars both mobile and fixed, from the zenith up to an angle of 70 degrees in one or other parts of the sky).

AD STELLARUM MERIDIANAS DISTANTIAS A VERTICE EXPLORANDAS APERTIS FENESTRULIS CENTROLRUM CRUCES SUIS LOCIS EXACTE ADAPTENTUR QUARANTALE INSTRUMENTUM OPPORTUNE SUPER MERIDIANA COLLOCETUR HABITA, VERO PER OBSERVATIONEM TANGENS QUARTA SUI PARTE AUGEATUR, NEMPE INSTRUMENTUM IPSUM QUINTA PERPENDICULI PARTE SUPRA PAVIMENTUM EXTOLLITUR

(In order to measure the angle of the stellar meridian from the zenith, open the little window and place the little cross in the exact centre, suitably arranging the instrument "Quarantale" on the meridian and so increasing the tangent obtained by the observation by a quarter. Naturally the same instrument is raised by a fifth from the floor on the vertical).

DOMUM HANC ASTRONONICO RADIO ILLUSTRAVIT PRIMUS JACOBUS DE VASSE PETRAMELLARA ASTRONOMIAE SYDUS CLARISSIMUM E GENTILI GALLIA IN NEAPOLITANUM REGNUM TRANSLATUS ET EX INDE ANNO MCCCCCLXXXVI AD ASTRONOMICAM CATHEDRAM A BONONIEN= SIBUS EVOCATUS. HANC EANDEM IOANNES ANTONIUS JACOBI ABNEPOS ET BONONIAE SENATOR AD AVITAE MEMORIAM ERUDITIONIS MERIDIANA LINEA COLLUSTRATAM VOLUIT

(Giacomo de Vassé Pietramellara, the shining star of Astronomy, moved from his country of origin Gaul to the Kingdom of Naples and was called from there in 1496 to the Chair of Astronomy, primarily to give lustre to this house with a ray of astronomical light. Giovanni Antonio, a great nephew of Giacomo, and Senator of Bologna, wished - in memory of the erudition of his grandfather - that the same house would gain more fame by means of the construction of a meridian line).

SOLIS LUNAEQUE SPECIES IN HAC MERIDIANA EXCIPIENS MEMENTO ILLIUS TANGENTES CORRIGERE MINOREM CENTUM PARTICULIS AUGENDO, TOTIDEMQUE MAIOREM MINUENDO RATIONE FORAMINIS QUOD AD DUCENTAS PARTICULAS IN DIAMETRO PRAECISE EST EFFORMATUM. DIVISIONES VERO MINIMAS IN AENA SEMITA EXCISASSCITO AEQUARI CENTUM HUIUSMODI: PARTICULIS, QUARUM IN PERPENDICULO A CENTRO FORAMINIS AD PAVIMENTUM CENTUM MILLIA EXACTE NUMERANTUR.

(In observing the appearance of the sun and the moon on this meridian remember to correct the tangents, increasing the smaller by 100 parts, and reducing the large equally to take account of the hole which has a diameter of 200 parts precisely. Each of the small subdivisions engraved on the bronze strips is equivalent to 100 of such parts, of these the vertical dropped from the centre of the hole to the floor measures exactly 100 thousand).

(These Latin passages were translated into Italian by Renato Peri, the English version is by Charled K. Aked).

Utriusque ad septem milia

Meridianus hunc transitum ad solis lunae quatuordecim: curvatum
 partem et affixum solum meridianae altitudinis persimilitudine a
 Venetis usque ad LXX graduum distantiam in utraque plagam,
 utraque huc pertinentia instrumenta ex aethiopia India, ac
 diligenti labore paravit Geminianus Montanarius Cuius Mathinensis
 J. V. D. ac Bononiensis Archigymnasij Mathematicarum Professor
 anno Dni MDCLXXIV

Ad Stellarum meridianas distantias a venetis explorandas
 quorundam generum antonom Cuius sui longi exacte adaptabitur
 Quarantale instrumentum quatuordecim super Meridianas collocatum
 habita vero per ^{Observationem} elevationem tangentis quarta sui parte
 augetur, namque instrumentum ipsum quinta perpendiculari
 parte supra pavementum ex tollitur

Donum hanc astronomico vobis illustravit primus Jacobus de
 Vafis Petramellara Bononiensis Sydy Clarissimum & gentili
 Sallia in Neapolitanum Regnum translatae translatus & ex inde
 anno MCCCCXXXVI ad Bononiam Cathedraliam a Bononiensis
 sibi evocavit. Hanc eandem Joannes Antonius Jacobi Bonifas
 et Bononiensis Senator ad auctae memoriam Eruditionis Meridiana
 linea collocatam voluit

Solis lunaeque speciem in hac meridiana ex aequidistantibus
 illius tangentibus corrigent minorum centrum partem auferendo,
 totamque maiorem minuendo ratione foraminis quod ad
 ducentos partiales in diametro praesens est efformatum. Divisi-
 ones vero minime in linea semita ex usque sito & pari centrum
 huiusmodi partiales, quarum in perpendiculari a centro foraminis
 ad pavementum centrum millia exacte numerantur.

FIGURE 2 Manuscript details of inscription in Latin

DISCUSSION OF MANUSCRIPT DETAILS

A first examination would give the impression that the unknown writer had copied the four inscriptions which at that time were to be found in the meridian hall, perhaps painted at the top of the small door along the length which today shows only a plain cornice. Analysis of the manuscript with more care, it is observed that there are some alterations to the text, almost indicating a badly copied composition, and we do not know the motives behind the disappearance of these inscriptions. Perhaps they became indistinct with time, and later were completely blotted out.

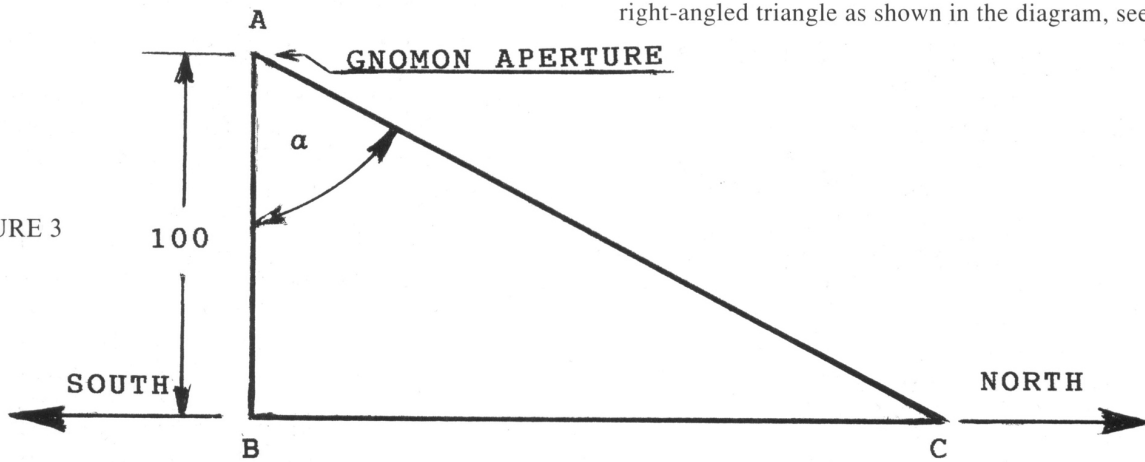
Alternatively it may be that the inscription disappeared when the northern gnomon aperture was eliminated and at the same time the restoration of the frescoes was

undertaken. Or possibly, for some reason unknown to us, the writing was never put on the wall. The text is nevertheless of extreme interest inasmuch as its discovery brought to light some data previously unknown and unpublished.

Primarily it confirmed the existence of the two gnomon apertures; moreover it indicated the existence of a previously unknown gnomonic instrument invented by Geminiano Montanari: the QUARANTALE (a name of doubtful origin). From an analysis of the extract mentioning the Quarantale, it is possible to derive some idea of its dimensions and the manner of its use by Montanari at the Pietramellara Palace. But to proceed further:

A meridian can on the whole be considered as a large right-angled triangle as shown in the diagram, see Fig. 2,

FIGURE 3



where the vertical height is represented by the side AB, A is the gnomon aperture through which the rays of the sun enter the hall and B is the point vertically below and defined on the floor. To the distance AB, no matter what its dimension may be, is assigned the value of 100 which for convenience here we call the "moduli". At midday for the locality on any date, the centre of the sun's rays are projected on to the floor and strike the meridian line at the point C; and therefore the horizontal distance BC represents the tangent of the zenith angle α , a function of the gnomon aperture height.

In consequence, on a given date, the distance BC is obtained and thus:

$$\tan \alpha = BC/AB$$

$$\tan \alpha = BC/100$$

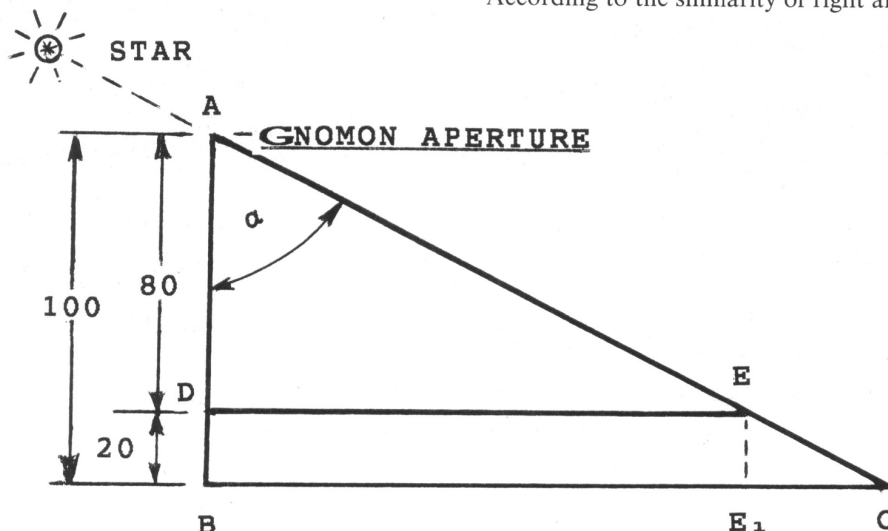
or more simply

Once the zenith angle is obtained (with any corrections for refraction), and knowing the local latitude accurately, it is simple to obtain the declination of the sun.

Apart from the sun and moon, no other celestial body is sufficiently luminous to project an image on to the meridian line. Montanari instead, in designing his Quarantale, so arranged the dimensions that the zenith angle of whatever star crossed the meridian at 70° would in one sense or another, therefore cover an arc of 140° .

The principle of this unique instrument (now unfortunately lost), is that of similar right angled triangles. Reconsider the previous diagram and add to the horizontal line DE at $\frac{1}{5}$ of the gnomon aperture height as in Fig. 3. We can now imagine the projection of the luminous image is no longer at C but falls on E. According to the similarity of right angled triangles:

FIGURE 4



Triangle ABC is similar to triangle ADE

Where $AB = 100$, $AD = 80$, and the length DE is variable as a function of the angle α , thus we have the ratios:

$$AB:AD = BC:DE \quad \text{and} \quad BC = AB \times DE/AD$$

$$\text{and therefore} \quad BC = 100 \times DE/80$$

By simplification we obtain the constant $BC = 1.25 DE$

In other words, raising the point of projection by one-fifth of the gnomon aperture height, and measuring the distance DE , the same projection on the meridian line will be increased by 0.25, therefore $BC = DE + \frac{1}{4}$. This interesting numerical relationship allows the reading on the meridian of the tangent of the angle α by the distance from the same, and represents the kernel of the idea of Montanari, it allows direct stellar observations at the meridian which would not be obtainable otherwise.

Since one is dealing with a bearing of the zenith angle quite different to that observed by the projection on the line itself, the Astronomer employs an optical sight which is precisely 20 modules (1219.4 mm) above the ground; the instrument has the facility of running along the meridian line to check the measurement: Star - AE. At the point E a plumb line is fixed so as to project this point vertically downwards on to the meridian at E_1 . From the simple equation $BC = E_1 \times 1.25$, the tangent of the corresponding zenith angle can be computed.

To take a practical example. Suppose that from the observation of a star crossing the meridian, the plumb line indicates on the meridian line the distance B to $E_1 = 138.56$. The distance BC will be:

$$BC = BE_1 \times 1.25 = 138.56 \times 1.25 = 173.2$$

Therefore a simple multiplication by 1.25, or adding a quarter to the observed value, the tangent of the zenith angle will be:

$$\tan \alpha = BC/AB = 173.2/100 = 1.732$$

And finally by reference to a table of tangents:

$$\text{The zenith angle } \alpha = 59^\circ 59' 57.3''$$



Figure 5: South gnomon aperture, Pietramellara Palace, Bologna.

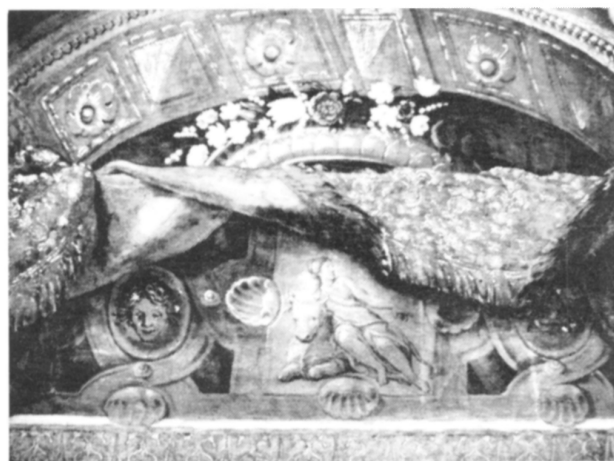


Figure 6: Fresco with Zodiacal signs, Pietramellara Palace, Bologna.

ACKNOWLEDGEMENTS:

The Editor would like to place on record his grateful thanks for the translation of the original Italian text into English by Mr. Ron Satchell.

FUNCTION OF THE QUARANTALE

This example clearly indicates the function of the Quarantale which is referred to the inscriptions and its use in the hall of the Pietramellara Palace. The existence of the brass squares adjacent to the meridian line and which in all probability accommodated the studs fixing the two distinct tracks; on these ran the instrument which ran longitudinally and could be turned to either of the gnomon apertures for observations, thus covering a total meridian arc of 140° with one instrument.

The text also gives some information of the characteristics of the two gnomon apertures, in order to track the course of a star in the celestial vault easily, the small window has to be opened and a small frame with a cross sight inserted in place.

With a little imagination it is possible to envisage an astronomical observation being conducted by Montanari in the hall, the astronomer is seated in a comfortable position by the Quarantale with his eye applied to the optical sight, instructing his assistant to move the machine slowly to obtain exact alignment with the chosen star, whilst another assistant observes the modular value indicated by the plumb line from the instrument.

The **Quarantale**, the lost invention of Montanari which has not attracted much attention previously, has now been restored (at least historically) thanks to the discovery of the four inscriptions and their non too easy interpretation. Also the idea of the alternative gnomon aperture for the North is certainly Montanari's. Following him, Cassini used the same means to determine the accurate latitude at San Petronio in Bologna.

The meridian line in the Roman church of St Mary of the Angels, also with two gnomon apertures, was constructed by Francesco Bianchini, a pupil of Montanari.

A COLD LOOK AT KRATZER'S "POLYHEDRAL" SUNDIAL

BY PETER DRINKWATER

It is a known fact that Francis I of France and Henry VIII of England strove to outdo each other in all fields. The incipient Art of Dialling was no exception, both Kings retained a resident Diallist, who was fitted into some near sinecure post in the respective country's leading University, given little tasks of minor diplomacy to do from time to time, and expected to turn out something spectacular in their own specialist discipline as the mood took them. Francis had his Oronce Finé, and Henry his Nicolaus Kratzer. The two diallists were very close in age (Kratzer being the elder), and both relied equally heavily for their knowledge and expertise on similar MS collections of medieval dialling tracts, many of them emanating from the teachings of Regiomontanus and George of Peurbach, both of whom were 15th century figures. Finé published an editing of his collection and, as one who has had the dubious honour of interpreting much of his work for English readers, I must confess I have not found much there which leads me to a high view of his genius and competence in his professed Art: rather a strong tendency to make fundamental mistakes in simple geometry, and to cloak them in bewildering geometrical irrelevancies. He also got into trouble with his royal patron over an injudicious use of astrological prediction. Kratzer, perhaps more wisely, kept his materials in Ms, and (apparently) a clean nose also. Not easy with Henry VIII!

I have no knowledge of any surviving dials by Finé, but a surprising number of Kratzer's dials have either survived, or have been recorded visually by independent witnesses. Of those which have survived materially, there is the little gilt-brass composite dial which he made for Cardinal Wolsey as Archbishop of York, which is now in the Museum of the History of Science at Oxford: it has all the usual five direct faces with a pair of Æquinoctial and a pair of Polar dials, all with the same sort of angled gnomons, a different edge, or the point of the triangle, telling the time as appropriate. Commentators fall short of calling it a rough piece of work. There is also the very rough composite stone dial recently found at Iron Acton, made by Kratzer in 1520 for a member of the Poyntz family (favourites of Henry VIII). This has a fundamental geometric error and appears to have been scrapped even before completion: perhaps a non-surviving correct version was made later. Of those merely recorded, there is the composite stone dial which he erected in the orchard of Corpus Christi College in Oxford: it is like a larger, elaborated, version of the one he made for Wolsey; having north and south direct dials, two at least Æquinoctial dials, three polar dials (there is an extra one on the base), a horizontal Scaphe (surely this would have filled with stagnant water), and (apparently) large scaphes on the east and west faces; over all stands a gnomoned spherical dial supported by metal hoops.

This was described and illustrated by a Fellow of the college in the early 17th century, about one hundred years after it was made; it nearly managed another one hundred. In 1523 he erected a fairly simple, potentially four-faced dial, on a pillar in St. Mary's churchyard in Oxford. This was described by a near contemporary and appears in a topographical view of the late seventeenth

century. Kratzer wrote a poem on this dial (preserved in his surviving notebook) in which, amongst other things, he celebrates his ability to quaff beer: perhaps something similar was flowing when the botch at Iron Acton was being perpetrated! Its east and west facets were elaborated to give Babylonian and Italian hours respectively, whilst its south facet covered the old Temporal hours and Solar declination. There was a Polar dial (or something close to it) on the south face of the surmounting pyramidal cap, and an elaborated noon mark on the column below. No opportunity was taken to provide direct east and west recliners on two of the other faces of the cap, nor was the north side provided with an actual dial, only impressive tables and diagrams. Nothing on any of these heretofore described instruments calls for anything other than is already in Kratzer's Notebook, which (as above intimated) is mainly a copy of copies of old tracts on dialling, etc. There is nothing to suggest that Kratzer either knew or practised the art of making real indirect or declining dials, unless he managed it with the clumsy old "Rectificatory with a Circle", let alone the even more difficult declining recliners, in which a later generation of diallists gloried: certainly there is nothing of the sort described in his notebook.

Kratzer triumphed, not through genius or creativity, but through having learned what others had discovered and invented, and by being the first to apply that learning in England. He was a great friend of Holbein, Henry VIII's court painter, and annotated the latter's cartoon for the famous lost painting of the family of Sir Thomas More. Holbein in turn painted Kratzer as a working diallist, surrounded by some of his creations: most of which can be traced back to prototypes described in his notebook: not all are dials, some are examples of empirical astronomical instruments of observation. Some of them appear again as part of a display laid on for the Ambassadors of Francis I of France (who else), which Holbein also painted. In all of this collection (which presumably has been lost - or perhaps now lies hidden somewhere in some royal residence), there are only two articles not emanating directly from the pages of Kratzer's notebook. One of them is the curious piece of horological fantasy of which Figure 1 is a rational 'working drawing': I am waiting for someone to tell me that this is some early form of analemmatic dial (if so, pray, how is it supposed to work?); but it is impossible for there to be any rational balanced relationship between the displaced hour circle and the off-centre gnomon. I am afraid it is like some "modern" oriental astrolabes, performing no known functions and meant to impress rather than to be used. I will make a working example for anyone who can convince me otherwise!

The only other 'new' instrument is an apparent polyhedral sundial, of which a finished example appears in The Ambassadors, whilst a different and uncompleted specimen lies in the Master's hands in his own portrait. Its basic appearance is that of two tall square pyramids fastened together base to base, with their apexes both sliced off: so that there are two faces which are perfect squares and eight which are parallelograms; two of the latter lie under the instrument and are uncalibrated, they



FIGURE 3: The portrait of Nicolas Kratzer, painted in 1528 by Hans Holbein the Younger.

5/7 the only logical 'back hours' for the two top facets, and 1/11 the 'back hours' for the four side facets. Whilst one can accept philosophically the 'full circle' hours of the two Æquinoctial dials, which would apply if the dial were taken beyond the Arctic or Antarctic circles, it needs to be stressed that the complete mark up of all the other facets as given for B G L M is the only possible one, regardless of the latitude at which the dial is used: the hour lines can only be spaced thus, and there can be one pair of back hours only.

Since one has no knowledge of any British or French settlements at this date as far south as latitude $23\frac{1}{2}^{\circ}$, and since Kratzer apparently made more than one of these dials, some concept of universality would suggest itself;

probably achieved by the use of an adjustable strut hidden within the lower facets. This would enable it to be raised up towards the North to the correct elevation of the pole. But no such strut is apparent in either of the paintings and, more disquieting still, the hour lines represented in the painting of *The Ambassadors* cannot fit the gnomons shown: not only is their spread (from 3 am to 9 pm on the 'horizontal' facet; from 10 pm (sic) to 2 pm on the visible side facets) far too wide, but they very obviously do not cluster around the gnomons as they should: they are not, however, equally spaced either; close analysis reveals that their spacing is not at all incompatible with those on an ordinary horizontal dial at latitudes in the low 50's.

continued on page 20

THE MERIDIANS OF ST. SULPICE CHURCH, PARIS

Continued from page 25 of Issue No. 93.1, February 1993

The proportions observed in the height of this obelisk entirely conform to the classical proportions given by the Ancient Authors on the Obelisks transported from Egypt to Rome, where the shaft was in strict proportion to the base. The obelisk is almost 30 feet high, and 33 feet to the top of the ball and crown.

The pyramid is in white marble. On the front face and exactly vertical on this obelisk, and on the meridian which cuts it in the centre, are engraved the transversals of 3 minutes and their sub-divisions at 5 seconds intervals which correspond to the upper and lower edges of the image of the Sun at the Winter Solstice. The meridian line is indicated by a copper strip of 2 lignes width [about 4.5mm or 0.18 inches] set in the face of the marble. The sign of Capricorn, indicating the date of the Winter

Solstice [21st December] is engraved 25 feet above ground level and, lower on each side of the line, Aquarius on the right and Sagitarius on the left, marking the dates of 21st January and 21st November respectively.

In order to engrave the divisions of minutes and half-minutes at the moment of the Winter Solstice of 1744, Le Monnier, some days before and after the Solstice, marked the marble with crayon at the upper and lower edges of the sun's image, calculated the declination of the distance of the Sun from the Solstice and then drew the position of the solstitial point.

A pedestal supports the pyramidal column, decorated at its base by two gilt lizards, symbols of Time. This pedestal is very informative, setting out the purposes of the meridian, and the scientific/ecclesiastic times, Fig 13.

Upper left, the inscription:
GNOMON ASTRONOMICUS
AD CERTAM PASCHALIS
AEQUINOCTII
EXPLORATIONEM

Astronomical Gnomon
For the determination
of the Easter Equinox

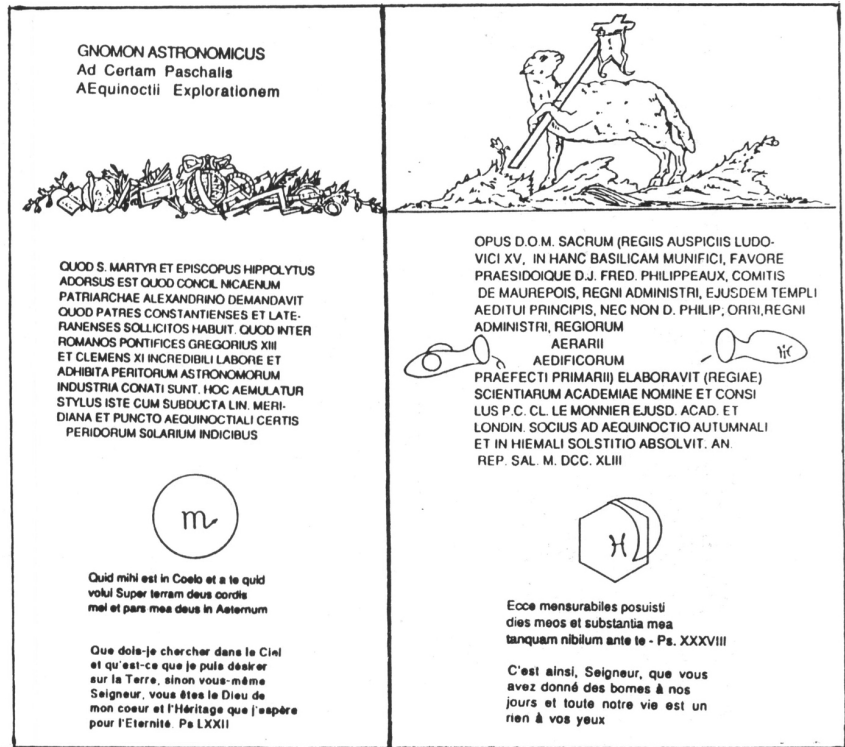


FIGURE 13:

The pedestal of the obelisk, reconstituted to the appearance before the Revolution, from the details in a document by the astronomer La Caille

Below:

Under the tangle of astronomical instruments, an inscription recalls the role of meridians for the study of the Easter Calendar.

QUOD S MARTYR ET EPISCOPUS HYPPOLYTUS
ADORSUS EST QUOD CONCIL NICAENUM
PATRIARCHAE ALEXANDRINO DENAMDAVIT
QUOD PATRES CONSTANTIENSES ET LATE-
RANENSES SOLLICITOS HABUIT. QUOD INTER
ROMANOS PONTIFICES GREGORIUS XIII ET
CLEMENS XI INCREDIBILI LABORE ET
ADHIBITA PERITORUM ASTRONOMORUM
INDUSTRIA CONATI SUNT. HOC AEMULATUR
STYLUS ISTE CUM SUBDUCTA LIN. MERI-
DIANA ET PUNCTO AEQUINOCTIAL CERTIS
PERIDORUM SOLARIUM INDICIBUS

In that Saint, Martyr and Bishop Hyppolytus as Patriarche of Alexandria was entrusted by the Council of Nicea and the Fathers of the Council of Constance and of Latran in these matters. Gregory XIII and Clement XI determined these thanks to the incredible labour and assiduous activities of the most skilful astronomers. This gnomon, associated here with a meridian line below and an equinoctial point, constitutes a precise indicator of the solar periods.

To the right, under the Pascal Lamb, the secular and scientific inscriptions. The parts mutilated in the Revolution are given in parentheses:

OPUS D.O.M. SACRUM (REGIIS AUSPICIS
LUDO VICI XV, IN HANC BASILICUM MUNI-
FICI, FAVORE PRAESIDOIQUE D.J. FRED
PHILIPPEAUX, C. DE MAUREPOIS, REGNI
ADMINISTRARI, ESJUSDEM TEMPLI AEDITUI
PRINCIPIS, NECNON D. PHILIP: ORRI,
REGNI ADMINISTRARI, REGIORUM
AERARII
AEDIFOCRUM
PRAEFECTI PRIMARII) ELABORAVIT (REGIAE)
SCIENTIARUM ACADEMIAE NOMINE ET CONSI-
LUS P.C. CL. LE MONNIER EJUSD. ACAD. ET
LONDIN, SOCIUS AD AEQUINOCTIO AUTUMNALI
ET IN HIEMALI SOLSTITIO ABSOLVIT. AN.
REP. SAL. M. DCC. XLIII.

In the middle of the inscription on the right can be seen the pitcher of water and the sign of Aquarius. The sign of

This is (under the auspices of the King Louis XV, Benefactor of this Basilica, and with the favour and protection of Jean-Frederic Philippeaux, Count of Maurepas, Minister of State, Benefactor of this Church, and of Phillibert Orry, Minister of State, Director General of Building of the King, that this work is consecrated to God Most High), has been calculated in the name of the Royal Academy of Sciences, Pierre-Charles Monnier, Member of this Academy and that of London, to compute the Autumnal Equinox, and he achieved this at the Winter Solstice, in the year 1743.

Scorpio is surrounded by a circle, that of Pisces by a hexagon, with a half-moon to its right.

THE IMAGE OF THE SUN

ON THE OBELISK AT THE WINTER SOLSTICE

It is described by Le Monnier:

Its speed is great [passage over the meridian line], three times as that of the Summer Solstice. The image of the Sun being received almost directly on the Obelisk at the distance of 170 feet from the opening in the meridional window of the church, this image moves with a singular rapidity, for it traverses two lignes per second [about 4.5m or 1/2th of an inch]. Its diameter, which corresponds closely to the diameter of the Sun, occupies 20 2/3 pouces about 0.55m on the Obelisk towards the time of the Winter Solstice.

Its form is almost round and distinct: also one can determine there the instant of Noon, in taking the middle between the passage of the two edges, to less than half a second or even a quarter-second, then when the sun is found elongated in the form of an ellipse, badly shaped, surrounded by penumbra, badly terminated giving rise to a large penumbra and imperfectly indicates the apparent height of the Sun. Its greatest height is 25 feet and a little more than 3 lignes [8.12m]; Although the height of the centre of the image at the Winter Solstice never rises much more than about 25 feet . . . it was determined nevertheless to prolong the meridian above, principally on account of the full moons of Spring and beginning of Summer.

ON THE MARBLE TABLE AT THE SUMMER SOLSTICE

Its velocity is much less rapid than that of the Winter Solstice [note this is because the radius of movement from the aperture is much less, not that the Sun's passage is so much slower]: The image of the sun does not traverse more than about 1 1/2 lignes in two seconds. In 1745 Le Monnier measured the axis of the elliptical image and found it to be 9 pouces 7 1/2 lignes, about 26 cm.

In the Memoir of the Academy of Sciences of 1762, Le Monnier had added a plate where he represented the image of the Sun by means of the objective lens of 80 feet focal length observed on 22 June 1764; it measured 14.1 by 12.6cm.

The sun meridian is a simple line of brass or yellow copper, surrounded by bands of marble of 0.10m width, from the marble tablet to the obelisk, and traverses the choir for 4.36m. Its length to the sun [aperture] is 40.295m.

LE MONNIER'S OBSERVATIONS AT THE MERIDIAN

These were made without break, up to the Revolution, some by Le Monnier himself, sometimes by various helpers, amongst whom may be mentioned: Grandjean de Fouchy in 1761, Tuiller in 1761, 1762 and 1763, Duvaucel in 1767, Wallot in 1772 and 1773.

In 1748, de la Condamine and Le Gentil replaced him during his travels in Scotland. La Lande wrote in 1780: *The beautiful meridian where I have myself observed the Summer Solstices there for 30 years, give almost the same results as my observations made at the Mazarin college.* The results obtained at the Summer Solstices from 1745-1761 are incorporated in the *Memoirs of the Academy of 1762.*

But in 1763, its gnomons indicated the same obliquity as 18 years before, whereas other astronomers of the period, Bradley and La Caille, had agreed a mean obliquity for the ecliptic of 23° 28' 19", and a diminution of 45" per century. La Lande tried to explain the bad results at Saint Sulpice by a settlement of the wall of the church, as that already produced at Bologna for example. It sufficed that the wall of Saint-Sulpice church and the objective had been subsiding a ligne in 18 years [1/12 inch; about 0.2mm a year!] in order to make the obliquity of the ecliptic appear constant.

Le Monnier, 9 February 1765, refuted the hypothesis of settlement. The meridional portal, which has been built on rock has not moved and explained the results obtained at Saint-Sulpice by the relative variations of the apparent distance of the Tropics [inequalities of the refractions at the Solstices of Winter and Summer]. In 1767 and 1773, he found 0.3" per annum. On 23 December he communicated his observations of 22 June and 21 December to the Academy of Sciences and this time, stated a diminution of 11" in 30 years, or about 33"

per century. This result differed from Lagrange, who published his results in the same year and who had found 56" per annum.

Finally, in 1780, a new set of observations at Saint Sulpice gave 34" per century. Lalande recognised that the meridian gave closer results to those of other observations which to him appeared more certain. In 1788, Le Monnier communicated his observations to the Academy for the last time, those of the Summer Solstice of 1782. Bigourdan's summary states: The last observations which he [Le Monnier] had written in the registers are for October 1791. a month later, 10 November 1791, Le Monnier was struck by an attack of paralysis. He had thus observed the meridian up to the age of 76 years, for a period of 48 years, from 1743 to 1791. He died of a second attack on 31 May 1799.

After him the meridian was never used again for observations. The State purchased his manuscripts and part of the collection of instruments, which were taken to the Paris Observatory. His son-in-law, Lagrange, gave the clocks and lenses to the Observatory at Marseille.

THE JUDGEMENT OF ASTRONOMERS ON THE WORK OF LE MONNIER

J.B. Delambre, in 1810, had said in speaking of gnomons: *All that one can say in their favour is that, that if they had not determined the precise quantity of the diminution of the obliquity, they had at least placed this diminution beyond all doubt.* Le Monnier who had obstinately contested this, had been obliged to admit it, but this was the least he could do.

G. Bigourdon in 1919 resumed the work of Le Monnier on his meridian: Le Monnier there measured the solar diameter over several days, in December and January, for determining the moment when the diameter attained its maximum, that which corresponds to its perihelion [nearest distance between sun and earth]; and also determined the position of the great axis of the terrestrial orbit. Moreover, he compared the true noon, given by its passage over the copper strip, to the corresponding heights taken by the quadrant, and as with the latter, sufficient observations of the meridian subject to the variations of before and after noon were taken, to confirm also the inequalities of the refractions.

Le Monnier had hoped that this double gnomon, by the agreement of the results obtained in summer and winter, would allow confirmation that the obliquity of the ecliptic is actually variable, and to decide if the effects of nutation [which had not been noted on the largest sectors] affected also the solstitial height of the Sun.

One of the principal results obtained by Le Monnier is relative to the variation of the obliquity of the ecliptic, which he at first considered to be nil or very small. Later he found his variation much less than that indicated by Louville; and without giving a definite value, he believed it to be 30" per century, a very small quantity. Relative to the theory of the Sun, we add that Le Monnier attributed a variation to the great equation of the centre which did not exist.

THE MERIDIAN UNDER THE REVOLUTION

On 3 April 1791, the constitutional clergy was imposed at Saint-Sulpice. In Brumaire An 11 (November 1793), the facade of the church was surmounted by the inscription "Temple of Reason". The Philosophical Feasts held there gave place to acts of vandalism against

objects recalling the king and Christianity. But out of respect for Science, the gnomon was preserved. [This is strange because when the foremost French scientist Lavoissier was guillotined, 8 May 1794, it was stated that "The Revolution has no need of scientists"]. Only the inscriptions on the pedestal concerning the king were mutilated, plus those of the signs of the zodiac.

The gnomon also was the means of allowing the steps of the choir to be preserved, which it had been proposed to demolish. Two pharmacists of the district: MM. Charvais and Duchatel had convinced their fellow citizens that it was necessary to keep the ballustrade to preserve the meridian line intact. The Temporary Commission of Arts had emphasized the necessity of keeping watch on the preservation of the gnomon or meridian of the aforesaid church of Saint Sulpice, in which it happened that the meridian passed over the steps and across the marble ballustrade which separated the choir and the nave of the church of Saint Sulpice, and that it could not be removed without damage to the meridian, also that this ballustrade was a monument which merited preservation. And on 26 Fructidor An II (1793), the Committee of Public Instruction decided that the ballustrade should not be displaced and the meridian should be preserved until a decision had been made for the purpose intended for the former church Saint Sulpice.

THE WORK CONCERNING THE MERIDIAN IN THE 19th CENTURY

THE STATE OF THE MERIDIAN IN 1836

For the renewal of interest in the meridian, we have to thank the barrister Augustus Nau, member of the Fabric Council of Saint Sulpice. In his report of 10 July 1836, he certified that the meridian was in a good state of preservation, but it could not function because the objective [lens or pierced disc] was totally blocked by dirt. The Bureau of Longitudes on being consulted, pronounced the almost certainty of the perfect preservation of this line, and concluded that the meridian could no longer be used for astronomical observations, but that it could serve perfectly well as a superb sundial, since it could indicate true noon each day almost to the second.

THE SUGGESTIONS FOR THE RESTORATION OF 1836

M. Lerebours proposed to make good the deficiency of the two small apertures of 10 lignes each by which the image of the Sun reached to the Winter Solstice and the Equinoxes, and in setting up two conveniently adapted objectives, and in removing the large closed tube solely intended for the Summer Solstice. On then placing the three objectives in a different fashion in a less complicated way and controlling these by an apparatus fixed to the coping of the wall, at breast height, which would enable continual use and easy maintenance.

M. Nau, in a letter of 24 February 1837, suggested closing the large opening in the shutter, then with the aid of a more or less complicated mechanism, hermetically sealing the tube of the objective [lens]. These three operations could then be carried out with the help of a device fixed on the coping at breast height. It is impossible to determine the exact price of this equipment, but being well made, should not exceed more than 200 Francs.

In 1841, the restoration had not been carried out, since

the celebrated clock-maker André Lepaute, proposed to indicate the form of the old arrangement of the piece of mechanism removed and damaged many years before. He suggested at the same time of adding a mean time curve. In February 1841, the Fabric Council despatched the dossier to the City of Paris. No trace of the Prefect's reply or of the work being carried out has been found.

THE CLEARING OF THE WINDOW IN 1889

In 1886 the question of restoring the church arose and of regaining the clarity [of the window]. Perhaps the plates of metal could be removed from the stained glass window? The Curate of Saint-Sulpice church consulted C. Wolf, Member of the Academy of Sciences, Astronomer to the Paris Observatory, who replied that the gnomon of Saint-Sulpice and its meridian did not offer more than historic interest. It was not, in consequence, inconvenient to open the bay closed in 1744.

This operation could, furthermore, be carried out without displacing any of the pieces which constitute the

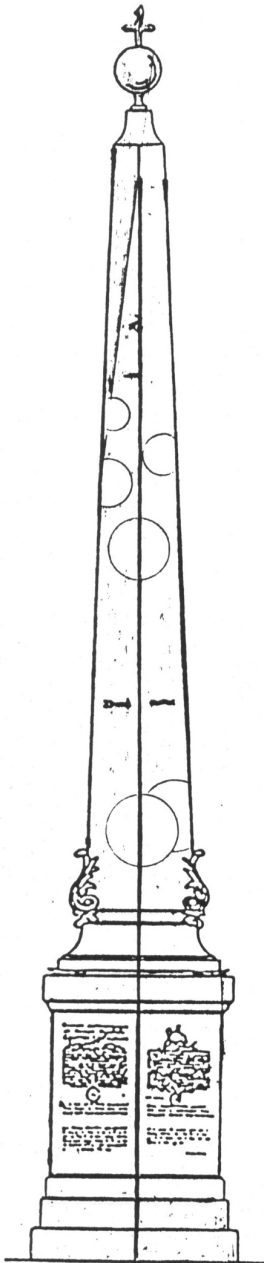


FIGURE 15: The pattern of the luminous discs formed on the obelisk

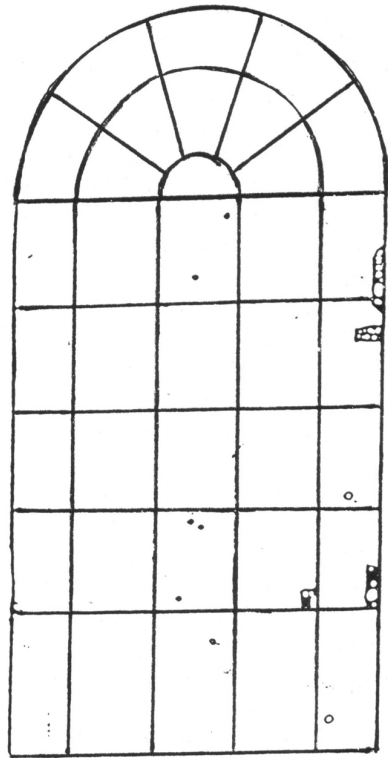


FIGURE 14: The numerous holes in the stained glass window which give false images

Le Monnier gnomon carried by the sealed supports at the right hand foot of the bay. This historic monument should thus be preserved in its entirety.

With the agreement of the Seine Prefect, the metal plaques were replaced by a window similar to those in the church and, in principle, the gnomons have not been touched up to the present time.

THE PRESENT STATE OF THE MERIDIAN

The meridian is still in existence today and partially functions. The window is no longer obscured as in Le Monnier's time, it therefore allows all the light to penetrate. Moreover it is sprinkled with holes, which at noon, allow rays of sunshine of the sun to form on the obelisk; it is therefore difficult to distinguish the true discs of the meridian from the false ones, Figs 14 and 15.

The two pierced discs are placed one above the other in the right side of the window, but the lower one no longer has the lens it once possessed. They [the aperture discs] are in the form of tapering metal boxes largely open on the outside but expanding on the inside to give the maximum opening, Fig 16. That of the lower one has not been placed where it came from [originally].

The lens of the aperture has been recovered from the Marseille Observatory. The journal *L'Astronomie* of 1921, pointed out that all the horary apparatus of Le Monnier were given by his son-in-law, Lagrange, to the Marseille Observatory. The Observatory services have been able to positively identify the lens used by Le Monnier at Saint Sulpice. It has a focal length of 78 feet [25.34m] and a diameter of $3\frac{1}{2}$ pouces [about 9cm], preserved in a cardboard mount composed of two cardboard discs, apertures of 2cm being cut out roughly and stitched together by gold wire. On the cardboard may be read "80 p foy, ouverture 2 pouces, amalric un ocu $8\frac{1}{4}$

pouces, grossit 114 fois, excellent”; [80 feet focal length (25.987m), aperture 2 inches (5.41cm), forms an image of 8¼ inches (22.3cm), magnification 114 times, excellent]. The meaning of amalric has not been found. (Figure 17)

The copper plaque of the Summer Solstice. Thanks to the archives of the *Monuments Historique* [Historical Monuments] concerning the copper plate, we have learnt that the services of *Beaux-Arts* has studied the half-effaced inscriptions from the “General Inventory of choice works of art” and decided to remove the plaque. On 4th May 1959, M. Toulouse, Bronzer and Restorer of Objets d’Art of Paris, removed the plaque to restore it. He thought of a temporary stopgap to replace it by a wooden or plywood plaque but he discovered the marble plaque underneath and concluded that it was not necessary to cover it again. He stated that the metal plaque carried the date 1744, whereas the marble is inscribed with the date 1745. The question of the different dates intrigued the *Monuments Historiques*. Since that time the repair or replacement of this plaque has remained in abeyance [ie nothing has been done].

The marble plaque of the Summer Solstice. Unprotected since 1957, the marble plaque is trampled on by the passers by and the worshippers, and is very worn. The inscriptions have begun to disappear, whilst the plaque itself is worn into irregular hollows.

THE PEDESTAL OF THE OBELISK

As already remarked upon, the inscriptions on the pedestal were mutilated in the Revolution, see Fig 18.

The paths of the two discs have been observed; they are well positioned on the meridian at true [solar] noon, to within almost a second [of time]. But as many luminous discs are cast by holes in the window around midday, it is necessary to identify the two good discs which pass together, one above the other. They were photographed 23 December 1986; the image of the Sun on the meridian is passing under the symbol of Capricorn, Fig 19. A

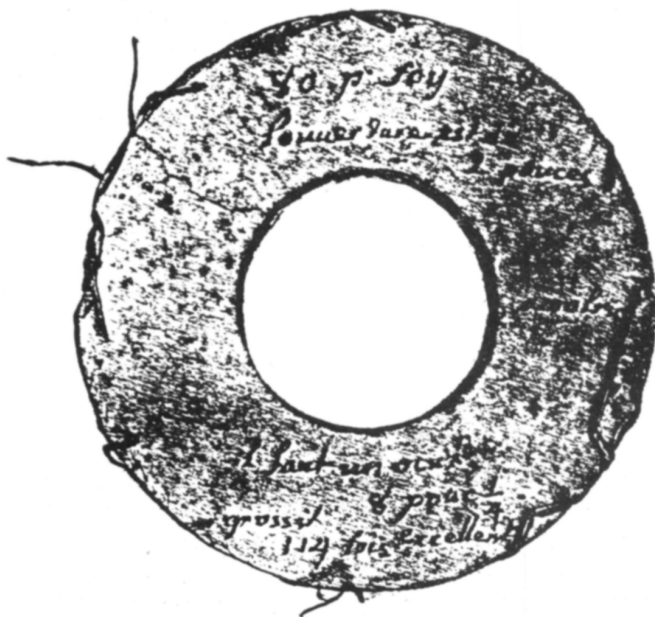


FIGURE 17: The lens which was found at Marseille Observatory

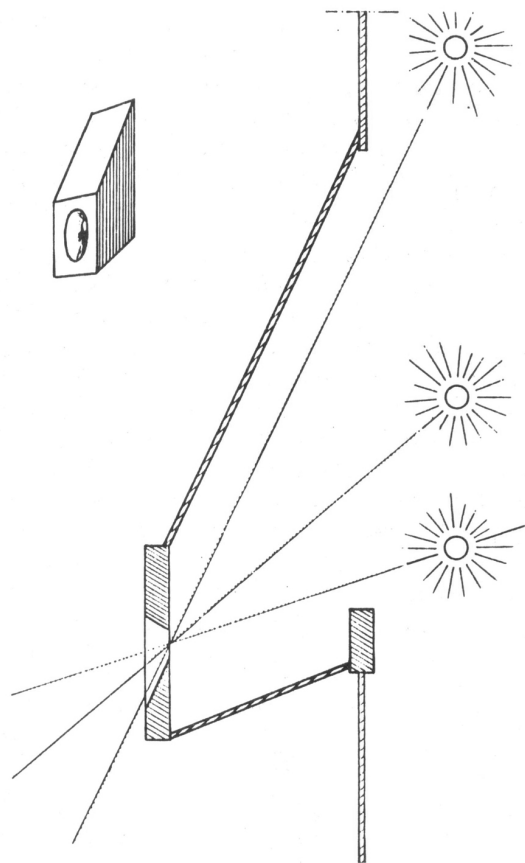


FIGURE 16: The two apertures for the sun's image on the meridian

precise observation was made by M. Sagot, 21 November 1987, who concluded the position in relation to Aquarius was satisfactory.

The two discs each become non-functional in their turn, that of the lower disc from April to September, that of the higher disc from 1 June to 12 July. Also, at the moment of the Summer Solstice, neither image is visible.

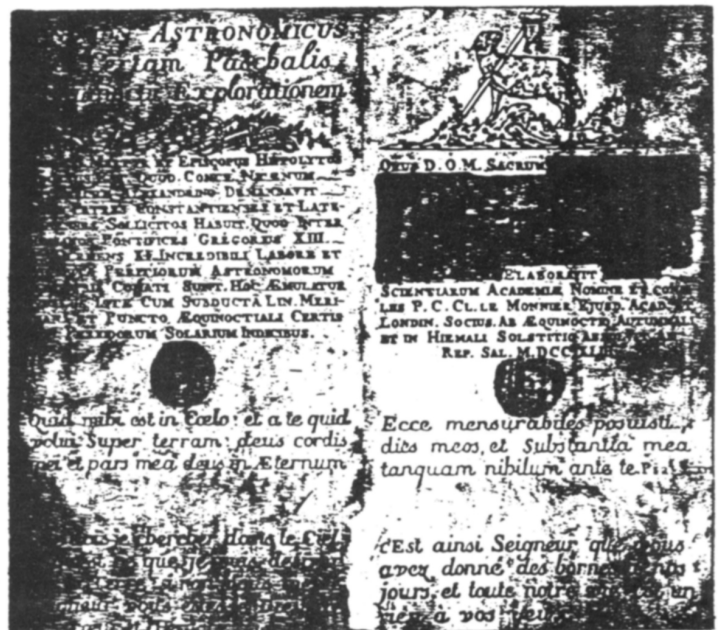


FIGURE 18: The appearance of the pedestal as it is today

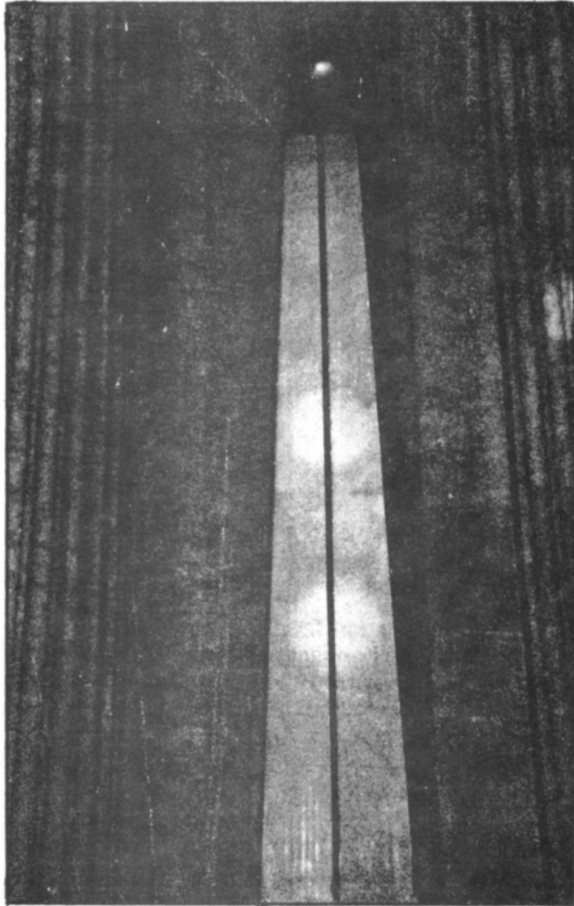


FIGURE 19: The discs of light on the obelisk 23 December, 1992

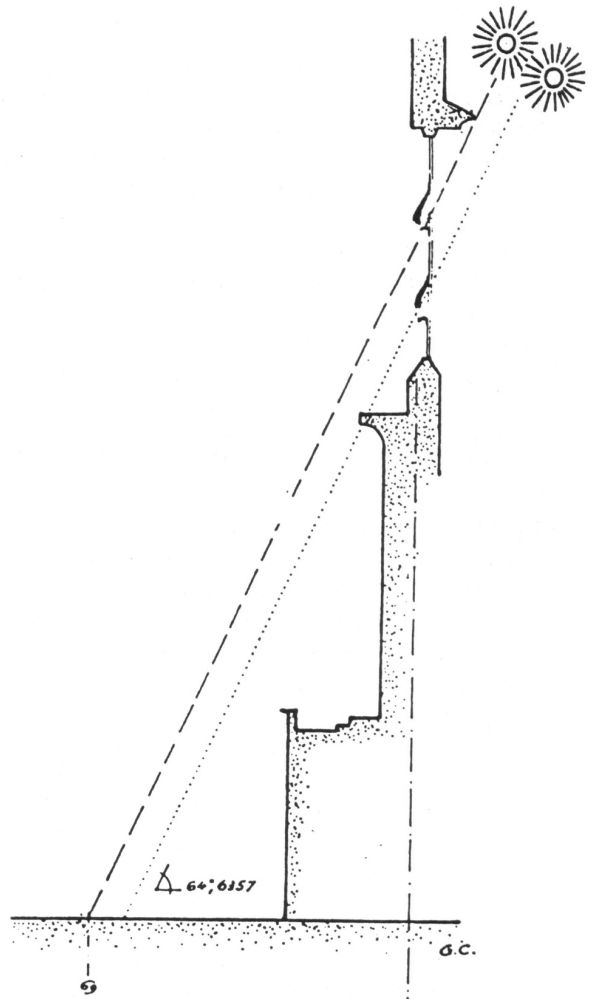


FIGURE 20: The lower aperture is masked by the interior gallery at the Summer Solstice so that the sun's image cannot reach the meridian

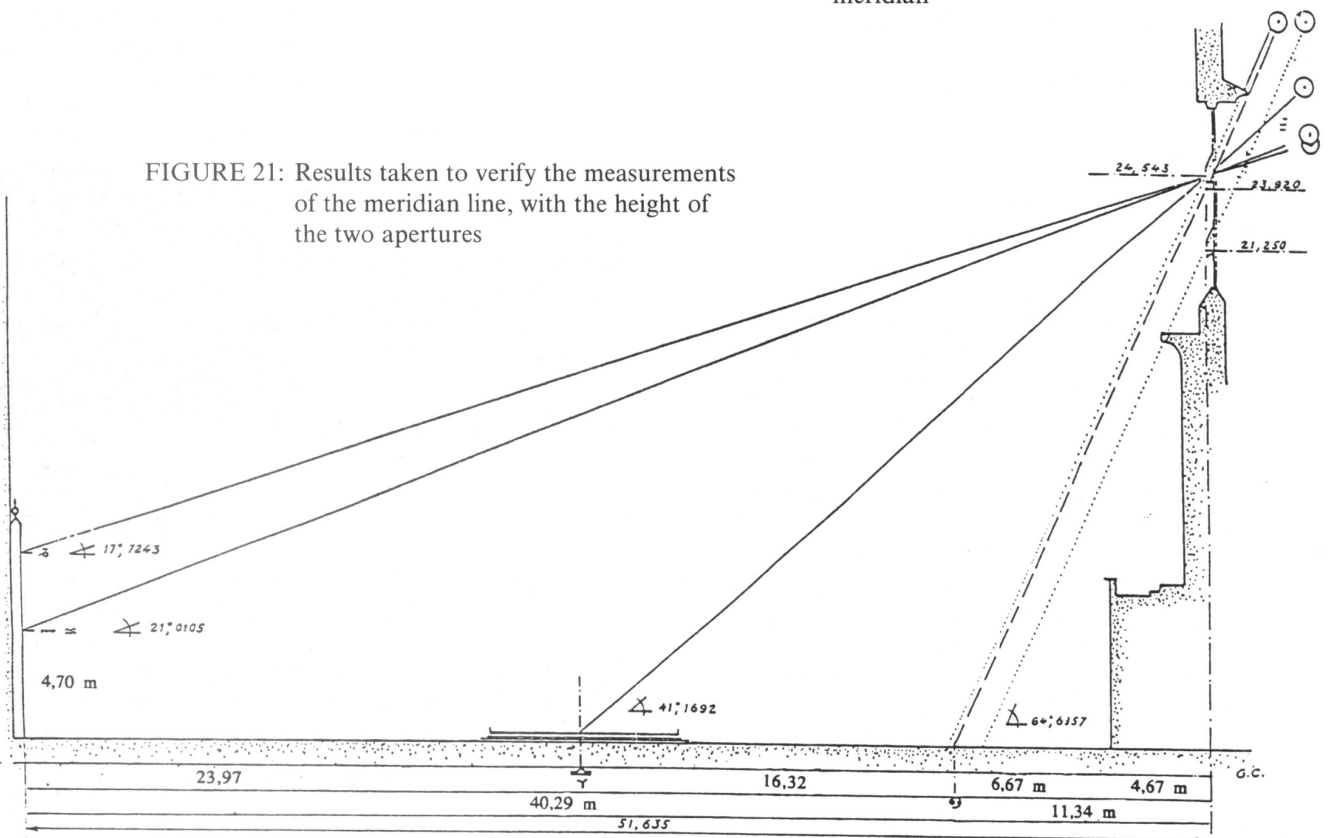


FIGURE 21: Results taken to verify the measurements of the meridian line, with the height of the two apertures

It has been remarked that the light passed by the lower disc is stopped by the inside gallery found underneath the window, a notch is moreover hollowed in the slope of this gallery at the place of the passage of the meridian; the light from the upper disc is obstructed by the exterior cornice which surmounts the window. The shadow of this cornice, descending little by little towards this disc, can easily be seen from the street, until it is completely obscured. It was this which has prompted Le Monnier to lower his disc in order to be able to observe the Summer Solstice, Fig 20. [The light then passed correctly through the notch in the interior cornice].

VERIFICATION OF THE MERIDIAN BY THE S.A.F. [S.A.F. - Société Astronomique de France]

VERIFICATION OPERATIONS

Measurements were undertaken of the height of the two gnomons. A measurement session was organised 13 June 1987, in which the participants were Mssrs. G. Camus, P. de Divonne, A. Gotteland and B. Tailleuz. It resulted in the measurements shown in Fig 21:

1. The upper disc is at 24.533m height and conforms well with the Equinox plaque and the sign of Capricorn on the obelisk, but the image of the hole is masked by exterior cornice about 18 days before the Summer Solstice.
2. The lower disc is situated at 21.25m, almost 2.67m below the position where it should be to make the Summer Solstice observation possible [ie the light would pass through the notch in the cornice. It is now masked by the interior gallery for a period of about 144 days].

Note: The report detailing the work carried out has been published in the review *Observations et Travaux* [Observations and Work], published by the Société Astronomique de France in the last quarter of 1987; dedicated to M. le Curé de Saint-Sulpice and the Architect-in-Chief of Monument Historiques.

STUDY OF THE SUMMER SOLSTICE MARBLE AND COPPER PLAQUES

AN EXPLANATION OF THE DIFFERENCE IN THE TWO DATES ON THE PLAQUES

It seems that Langlois carried out the work of constructing the meridian 1743-1744; the copper plaque was thus installed in 1744, the date at which it seems the ellipse had the dimensions which were engraved on the plaque. All the explanation is furnished by the phrase of Le Monnier which has been cited previously.

THE METAL PLAQUE

This has been studied in the workshop of M. Toulouse. It is perhaps not the original plaque because it is not of copper but of brass, and in two soldered parts, the engraving, is crude work, the lines superficial and uncertain, and there is no ornamental decoration. The two corners on the North Side are much worn, particularly the right hand corner [north-east] and the inscriptions scarcely visible.

The South part is in a fairly good state. On it may be read:

FAIT PAR CLAUDE LANGLOIS INGENIEUR
AUX GALLERIES DU LOUVRE A PARIS
M D CCXLIV

Made by Claude Langlois Engineer
to the Galleries of The Louvre Paris 1744

At the centre is an elongated oval, above which the inscription is traced, thinly drawn, with numerous attempts, of minor axis 256mm; and the major axis 230mm. These dimensions correspond with those given in Le Monnier's text.

THE MARBLE PLAQUE

It has been observed, not only of the effacement of the inscriptions and hollowing of the plaque itself, but also an irregular wearing of the brass strip [marking the meridian line], of the hollow to receive the flat board, the external border to the plaque, also the marble plaquettes 110mm width which it frames.

PROPOSITIONS FOR RE-ESTABLISHMENT OF THE MERIDIAN

Restoration of the meridian to be carried out in the following manner:

The window: The various missing glasses should be replaced in order to eliminate sunlight passing through the holes and forming parasitic discs which prevent recognition of the good images of the meridian.

The apertures: The upper aperture has never been modified. The lower one should be taken out and replaced at a height of 23.876m from the ground and 0.657m below the upper aperture. [To allow free ingress of the sunlight at all times].

This height has been calculated by an observation of the Summer Solstice, for a latitude of 48° 51' 03" [48.850833°] and an ecliptic in the year 2000 of 23° 26' 21" [23.439291°]. A short note with these values has been sent to the Architect in Chief, *Monuments Historique*.

The two Summer Solstice plaques: The poor state of the brass and marble plaques, which has worsened in the last thirty years, does not allow envisaging replacement [the metal plaque], except to make the rather delicate work secure against visitors. It is necessary, as a matter of urgency, to arrest the degradation of the marble plaque.

It is suggested that the placing of a new metallic plaque in stainless steel, which would be for the purpose of protecting the marble plaque against [the feet of] the faithful and visitors; recalling the observations made in the XVII century for measuring, at the Summer Solstice, the obliquity of the ecliptic, marking the renovation of the meridian, and terminating the meridian on the South side, as in former times.

After having served as the model for the fabrication of the new plaque, the old brass one could be deposited in a museum, or displayed on the wall nearby, accompanied by a short notice explaining the purpose of the meridian.

EDITOR'S NOTE: G Camus, P de Divonne, Mme Andrée Gotteland and B. Tailleuz, the authors of this article, are all members of the Commission des Cadran Solaires, Paris. The President of the Commission, M. Denis Savoie, and the authors have given their permission for the reproduction of the article in the *BSS Bulletin*. In addition Mme Gotteland kindly provided copies of the relevant line diagrams and also checked the translation from the French text made by the Editor. The article first appeared in *L'Astronomie* the official journal of the Société Astronomique de France, pages 195-214 of the May 1990 issue.

THE ANALEMMA OF VITRUVIUS

BY PETER I. DRINKWATER

It is perhaps difficult for 'moderns' to enter easily into the mentality of the diallist of the Ancient World. So much is so different: instead of the modern (obsolescent?) array of technical drawing instruments, with French curves, stylus pens and the like, we are allowed only a plain ruler and dividers/compasses; and the comforting scales of the protractor and graduated rule must be jettisoned for proportions and fractions of circles and lines. We have to do all sorts of things that 'can't be done', such as using our *dividers* to *divide* a circle into fifteen equal parts, or divide arbitrary arcs into six equal parts (the secret is to 'step out', using trial and error until it comes right). Instead of computers or calculators we must use our minds. Even the hours themselves are different.

Vitruvius was a Roman architect and military engineer who composed ten books on Architecture, of which the ninth is devoted to sundials and water-clocks: his liberal use of Greek terms indicating the source of his knowledge. Vitruvius himself claims nothing in the field as his own, but refers to numerous types of dials as if they were commonplace and well known to his readers. He assumes correctly however that it is to the fundamental geometry behind all sundials that the most detailed attention is most usefully to be given. Probably very many people could have done this better than Vitruvius but (with the exception of the later, and more rarified, Claudius Ptolemy) none of them did; or rather anything which they did write has not come down to us. But we don't do too badly in having something which dates from 'before AD 27'.

The name "Analemma", which Vitruvius gives in the vital construction, is composed from two words taken from the Greek, *ana* and *lemma*, which might be interpreted as elegantly as 'The most exalted piece of geometry', or more prosaically as 'The setting-up diagram'. It begins with a discussion of the different lengths of the shadows cast by upright gnomons on flat surfaces at noon at different places on the days of the Equinoxes. At Rome it is 8/9 of the height of the gnomon, at Athens 3/4, at Rhodes 5/7, at Taranto (in the heel of Italy) 9/11, and at Alexandria 3/5. Vitruvius proceeds as for Rome, his diagram has not survived (the oldest extant MS is Anglo-Saxon!); to make a tighter diagram I proceed as for Alexandria, (refer to Figure 1).

Upon a horizontal line representing the flat surface AB is the vertical 'GNOMON' of five parts. Upon centre A the large circle 'THE MERIDIAN' is drawn. (Vitruvius says that its radius is at point B, but leaves us to deduce that B is the root of the gnomon). Set out the three points of the gnomon shadow from B to C. Draw line CFAN from through centre A. Take AB with the compasses and set the distance along the prime horizontal both ways from B; from these two points set the distance up to the circumference of the meridian to determine E and I. Draw line EAI parallel to the prime horizontal; this is the 'THE HORIZON'. Step out the circumference of the meridian into 15 equal points and set this fraction both ways along the circle from point F, to mark points G and M; and from point N to mark points K and L. Draw line LAH through to meet the prime horizontal at T. NAFC is the Sun's Equinoctial Ray, LAHR his Midsummer Ray, and KAGT his Midwinter Ray: all, of course, at noon.

Draw LG for the Tropic of Cancer and KH for the Tropic of Capricorn. (Vitruvius's $\frac{1}{15}$ th gives the Zodiacal band a width of 24° , which may originally have been correct, (the value goes back to Eudemus of Rhodes in the fourth century BC) and was retained in popular use throughout the Middle Ages: nowadays the popular value is $23\frac{1}{2}^\circ$ although the actual value is little more than 23° ! Divide both GL and HK in half to determine points O and M: through these points and centre A draw QOAMP for the 'AXIS' of the universe. Upon centre O draw the semi-circle GL, and on centre M draw the semi-circle KH. Note where line GOL crosses EAI and mark that point V. Note where line KMH crosses EAI and mark that point S. Draw SY parallel to the axis QOAMP; and VX parallel to both. Line VX is important enough to have a name 'THE LÆOTOMUS' (but the name, transliterated from the Greek, merely means 'that which cuts to the left: this is probably because in some sloppily made Direct South Dials of antiquity, the line which it cuts (that of the Summer tropic) is the only one to be regarded and made use of.

The arc XL represents one half of the Sun's visible track at mid-summer and is to be stepped out into six equal parts for one symmetrical half of the twelve hours of daylight at midsummer. Arc YK represents one half of the Sun's visible track at mid-winter and is likewise to be stepped out into six equal parts for one symmetrical half of the twelve hours of daylight at midwinter. A series of lines parallel to XV (and to the axis) is to be drawn from the points on the arc XL to the line GVOL. Another series of lines parallel to YS (and to the axis) is to be drawn from the points on the arc YK to the line HMSK. Vitruvius hints at this last step without actually describing it: presumably because it is geometrically obvious, and because no lettered points are involved.

At this point Vitruvius, or his scribe, or some later copyist, or the source from which Vitruvius obtained his Analemma, makes a boob; stating that the 'circle of months' or 'MANÆUS' (another Greek term) is to be drawn with its centre on point D, *where the Equinoctial ray crosses the circumference of the circle*, and a radius to point H, where the Midsummer ray crosses the circumference. Common sense tells one immediately that there can be no point D on the circumference at this place: that point is already lettered F. Geometrical logic compels one to place point D on a chord line drawn between points G and H.

The Manæus, correctly drawn, is one feature of the Analemma which appears to have been transmitted intact down the centuries; it certainly occurs in medieval Astrological tradition. The Manæus circle is divided into twelve equal parts by natural geometry and the twelve points of its circumference linked together in pairs by lines parallel to the Equinoctial ray. These lines cut the circumference of the meridian circle at the places where the Sun passes from one sign to the next, moving up and down: they have many uses, but none that are vital to the construction of an ordinary planular dial, hence, perhaps, Vitruvius's somewhat cursory treatment of this feature. If his instructions about the location of D are taken literally, and it is identified with point F, the resulting falsely placed Manæus circle, if it is taken as

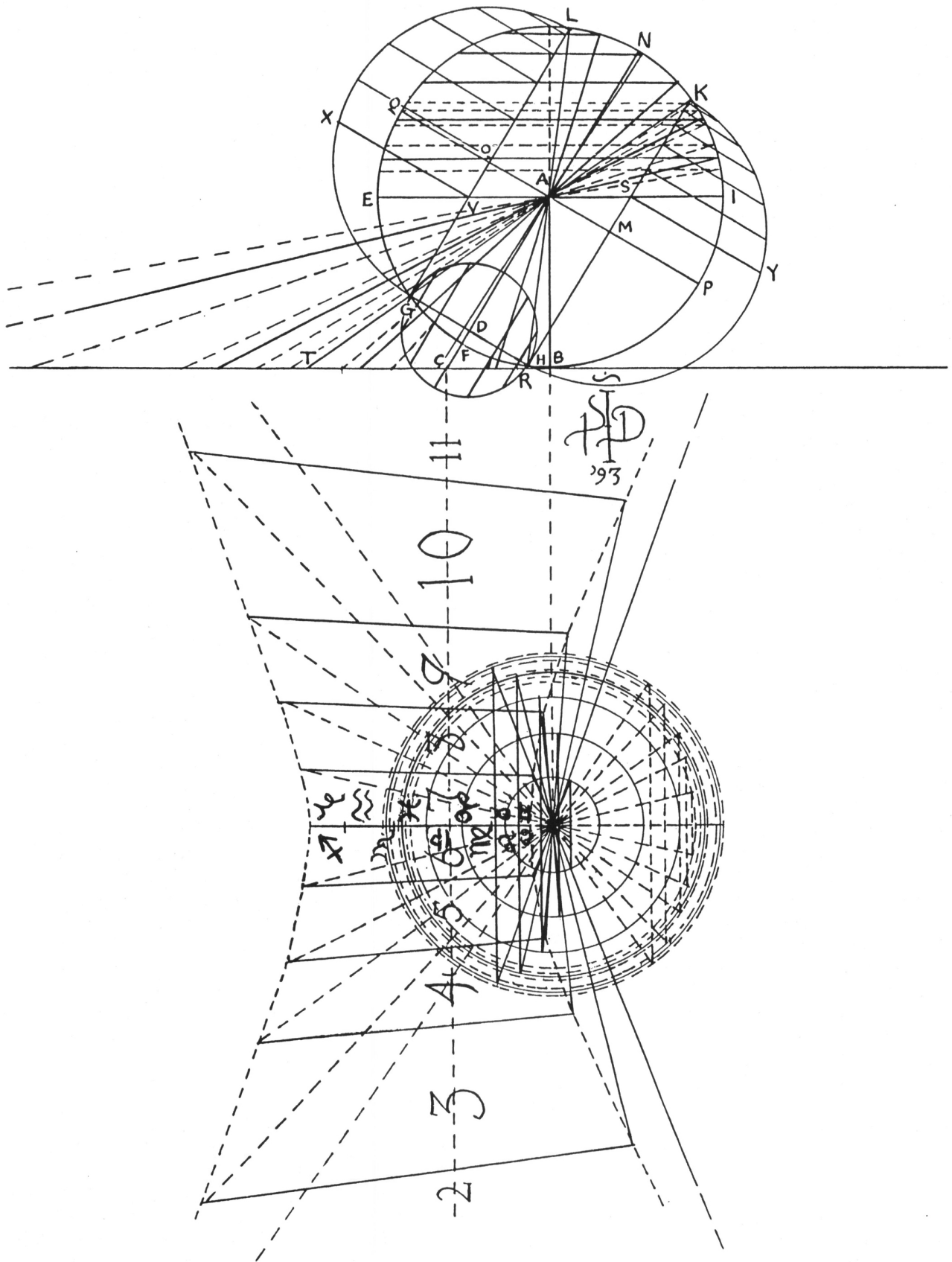


FIGURE 1

dividing a short tangent line, rather than the arc, will yield results not far from the accurate: it is easy therefore to see how a mistake, once made, would readily be perpetuated; the small diagram (Figure 2) shows the difference between the false (solid lines) and the true (dotted lines). A similar mistake is sometimes found in late medieval tracts, but appears to have been made there independently. Vitruvius leaves the Analemma at this point, assuming (probably correctly) that anyone who had followed him thus far would be able to continue under their own power.

Let us do so: since we started with a vertical Gnomon on a horizontal plane, mark up that plane as a Horizontal Sundial showing the old Temporal Hours. Through each of the hour points along line GVOL, from V to L, draw a series of lines parallel to the horizon EVASI, ending each line at the circumference of the meridian circle. Divide each line in half and make these halves the radii of a series of concentric circles around the root of the gnomon on the plane to be calibrated (these are all done with solid lines). Using these circles in the time-honoured way to establish true North by the gnomon's shadow, draw the meridian line straight through the root of the gnomon.

Returning to the Analemma, take the distance from the centre each of the horizontal parallels to the point where it is crossed by the diagonal GVOL. Set each distance along the meridian line of the plane, in the appropriate direction, from the root of the gnomon. Draw lines through these points, at right angles to the meridian line, to the circumference of each respective circle: thus each of the concentric circles has two points marked on it by these lines. Draw lines of adequate but non-specific length, from these points through the root of the gnomon. Returning to the Analemma; note where each of the horizontal parallels meets the circumference of the meridian circle. Draw a line through the centre A from each of these points until it meets the prime horizontal (or tangent line). Take off each distance along this line from point B and set it along each corresponding pair of 'adequate but non-specific' extensions from the root of the gnomon on the plane. Thus will appear a series of hour points for midsummer, forming a hyperbolic curve. All of this is drawn with solid lines, the outermost pair of points is omitted to save space. Do exactly the same, as shown with the dotted lines, starting with the hour points between S and K on the line HMSK: the constructions, being more spread out, are probably clearer. Thus will appear a series of hour points for midwinter, forming another hyperbolic curve. If these two sets of points are connected together with straight lines, then the appropriate hour lines will emerge. You can then draw the hyperbolic curves in with an approximation of straight lines, and the arcs of circles (as on ancient examples), the equinoctial track is a simple straight line.

Vitruvius writes airily of also dividing the equinoctial of the Analemma and (apparently) projecting. For the more elaborate dials this may well have been done, but surviving ancient dials on the horizontal and other planes indicate that a division and projection of the Midsummer and Midwinter tracks only was by far more usual, and indeed the rule. This is probably because a division of the equinoctial track also would have indicated that which

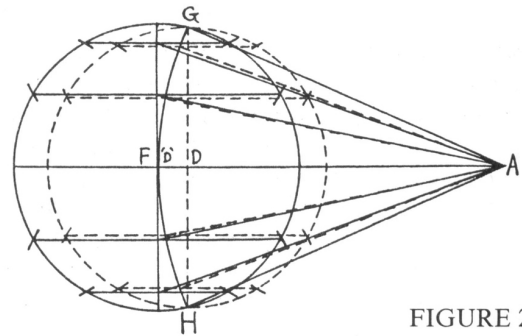


FIGURE 2

no one at that time wanted to know, that the old Temporal Hour lines were not true great circles and should not really appear as simple straight lines on the gnomonic plane!

You might use the Manæus Circle to mark the points of the Zodiac along the meridian line, simply by projecting through the places where it marks the meridian circle from the centre A to the prime horizontal and transferring the distances to the meridian line: this was done on some ancient dials. It is, of course, anachronistic to use the medieval emblems for the Signs, as it is to number the hours in Arabic; in classical times simple abbreviations were used, usually in Greek. Survival of the Analemma in its entirety through the 'Dark Ages' and Medieval period is problematic and cannot be proved, although all or most of its features certainly survived as part of Astronomy. It was designed to project the old Temporal Hours, but could readily be adapted to project modern hours, its basic appearance may well have suggested the popular 'Tangent and Circle' method of drawing these hours on a sundial.

The old Italian Hours (numbered equally from sunset) and Babylonian Hours (numbered equally from sunrise), both apparently introduced as a response to mechanical clocks, suggest an even more tangible link. Sixteenth century writers on dialling consistently present a method of drawing these hours which involves the use of an Azimuth angle and a tangent length, exactly as outlined above, a method which was quietly dropped in the seventeenth century and is now forgotten. Much more research into this could be done and is perhaps possible. It may well be that the tradition of geometrical dialling is continuous from the most ancient times to the present, surely no other Art has lasted so long!

Continued from page 10

What is one to make of this? Did Kratzer really labour under the delusion that this would work: that you could somehow get a correct reading from a gnomon made for one latitude and a set of hour lines made for another? Or did the painter err, is this a case of mere artistic license? One hesitates to think that such a carefully finished instrument as this is really another Kratzerian nonsensical, or a meaningless, non-operative device produced for mere effect. It is perhaps fortunate that the other example of this dial, that included in Kratzer's portrait, see Fig. 3, lies in his hands in an early stage of construction, with the hour lines as yet undrawn; that at least enables us to give him the benefit of the doubt in this matter.

HIGH NOON

BY CHARLES K. AKED

For several centuries, whilst the mechanical clock imperceptibly but gradually imprisoned mankind in its metallic grip, the only time standard available to superintend the accuracy of this potential autocrat was the rotation of the earth. Implicit in the use of the earth as a standard was that its diurnal rotation was constant over any observable period, and that the observation of a given star would, by successive crossings of a given meridian, indicate the exact moment when the period of one rotation ended and the next began. It was, however, a very great assumption without knowing the exact details of the celestial machine forming the solar system and whilst the assumption was accurate enough for all the mechanical clocks ever made; modern science has been able to show that the earth is far from being a perfect timekeeper in its own right. Nevertheless the use of the earth's rotation to provide a time standard up to quite recent times was undisputed until quartz crystal oscillators appeared which were accurate enough to measure the small fluctuations in the earth's period of rotation. It was the task of astronomical observatories to determine, from observations of chosen stars, the exact mean time for civil use. All kinds of refinements were made in the observations to eliminate such things as the reaction time of the observer, and improve the accuracy by taking the mean of several close readings, and eventually the use of electrical methods to transfer these exact moments to clock movements. For the majority of clock-keepers there was no ready access to such results, especially in the early period of domestic clocks, and generally reliance was placed on a noon mark. Many such noon marks from the early years have survived to modern times and served as the time standard for many mechanical clocks, with the result that the clock was really adjusted to read solar time unless an Equation of Time table was also employed to correct the varying error between solar and mean time. In France, in spite of all the public mechanical clocks, solar time was still used until 1838, and there were many sundial cannons, which sounded about noon, serving as time standards, which in the absence of an Equation of Time correction, were valueless in providing a true time standard for use with mechanical timekeepers.

Without special instruments or methods, the observing of the exact moment of noon by a sundial is virtually impossible, first because the sun, being of a magnitude of about 0.5° , casts a fuzzy shadow, and secondly the almost imperceptible motion when the shadow is closely observed. Eventually clockmakers who required really accurate time for such purposes as rating marine chronometers, employed transit instruments for the purpose. One ingenious solution for determining the exact instant of noon by optical means was invented by a Barrister-at-Law, James Mackenzie Bloxham, who was greatly interested in horological problems, and the deviser of the gravity escapement for turret clocks which was the inspiration for the gravity escapement later devised by Lord Grimthorpe.

The instrument devised by Bloxham might never have appeared except that around 1840 Edward John Dent mentioned to Bloxham that he had devised a meridian instrument using shadows (hardly an invention since the

method had been known for centuries), upon which Bloxham informed Dent that he too had been thinking about the same problem for many years. A few days later Bloxham brought along a small instrument containing two small prisms cemented to an optically flat glass plate. Dent himself wrote that as the instrument was not within the scope of the clockmaker's art, he recommended Bloxham to Simms and also to Dolland, both in the optical instrument trade, but these two failed to see the commercial possibilities in the new instrument and, after almost a year, declined undertaking the task. Dent therefore attempted to make these instruments in his own workshop, but it took two years and the expenditure of about £600 to produce the first practical model. (About £50,000 at present-day values.) As the construction would be readily apparent to any optician and would have been copied as soon as placed on the market, Dent proposed to Bloxham that he should take out a patent on the invention. Bloxham was unwilling to do this after consultation with his peers, as being unacceptable within the profession, but he agreed to a patent being taken out on his behalf by Dent. Bloxham's rights to the invention were then sold to Dent for £75. Dent wrote a short description of the invention in the 27th July 1843 issue of the *Literary Gazette*, taking all care to give the priority of invention to Bloxham.

The patent applied for on 20th June 1843 is now known as Patent No 9743, the number being given by the reformer Bennet Woodcroft when he re-organized the British Patent Office. The patent specification was enrolled on 20th December 1843, ie when full protection was granted to the rights of the inventor of the device in the patent specification. The drawing accompanying the specification shows a long telescope for viewing the instrument, whereas Dent's own arrangement had no telescope, hence both simpler and cheaper to produce.

The instrument in the patent specification is given the name "Dipleidoscope", derived from the Greek words

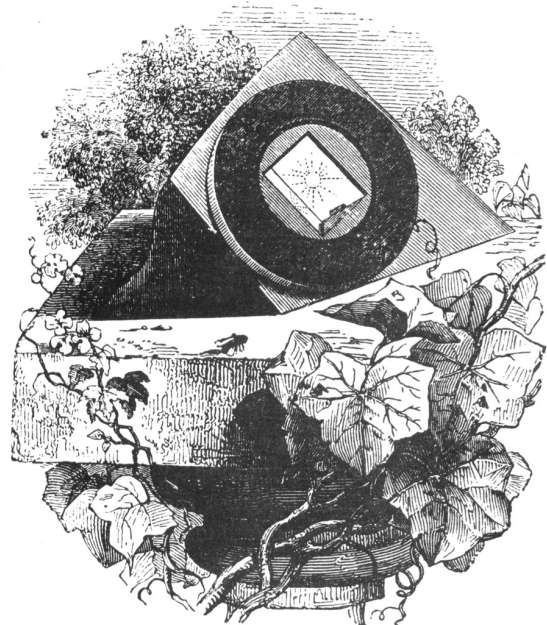


FIGURE 1: Dent's Fixed Dipleidoscope

for double, image, and viewer - διηλύος - double, εἶος - form or image, and σκοπος - viewing, or a watcher. The term was most likely coined by Bloxham. Dent rather pre-empted the granting of the patent since he published his first booklet on the Dipleidoscope, in which the principle of the instrument was clearly expounded, in 1843; together with simple instructions for its use by the owner. Two forms of the instrument were provided, one for permanent fixing outside, and a portable one for travellers.



FIGURE 2: Dent's Portable Dipleidoscope

PRINCIPLE OF OPERATION

In the original form of the instrument, two prisms were employed to provide the reflecting surfaces, but as these required optical techniques, later instruments made use of much cheaper mirrors, see the accompanying figure, placed behind an optically flat plain piece of glass. This glass, by the setting of the instrument, is turned until its bottom edge is at 30° to the meridian, towards the observer, with the junction of the two mirrors lying along the celestial polar axis, and one mirror plane vertical in the meridian.

Rays of light from the sun meet the plain glass at an angle, as in the figure, and are partially reflected and partially penetrate the glass to be reflected by the two mirror surfaces and again out through the glass at a different angle to the glass reflected rays at all time except at true solar noon. To an observer, the result is that he sees two separate images of the sun. The images can be made to coincide by turning the instrument around its axis, however the sun in its rotation around the earth results in a similar effect to turning the instrument, so that at true noon the two images coincide. Looking at the instrument just before noon shows two images of the sun approaching each other, they coalesce briefly at the instant of precise noon, then separate and move away.

To improve the accuracy of the observations, the moment of the two sun images making contact on approach has to be noted, plus the moment of complete superposition, and the moment when contact is broken on separation. By taking the mean value of these three readings, the exact moment of noon can be calculated

more precisely than that from the noon observation alone. By use of the Nautical Almanack or Whitaker's Almanack with its listing of the times of apparent noon, and knowing the time difference between the place of observation and Greenwich, the true time for noon would be known, and if the observer's own watch had been used to take the three time readings, the accuracy of the watch could be checked to the nearest second. A watch or clockmaker would then transfer the observed true noon to check his regulator as soon as possible to minimise any possible errors between observation and checking. For this short period the rate of the observer's watch was of no importance in affecting the accuracy.

Unless the observer possessed what is now known as a 'Doctor's Watch', it was not possible to correct the watch since there is no stop mechanism fitted to the ordinary watch. The 'Doctor's Watch' has a lever which acted on the balance to stop it just before the observation, and at the exact instant of noon the lever was operated to start the watch again - giving, in theory, the exact time shown on the watch. In practice the exact instant of noon could not be observed to the nearest second, there was also the personal reaction time of the observer in restarting the watch, and in general the stopping of a watch introduces errors in the rate of the watch. The use of such a watch could not replicate the accuracy of the three-readings method.

The necessary observations required the owner to be present a few minutes before the expected time of noon at the locality, and also up to a few minutes after, so it was only convenient for those who must have accurate time. The instrument was only useful for a few minutes around noon each day, so either a protective cover was placed over the instrument or the instrument was removed and taken indoors. The full sun was not essential to take readings as long as the cloud cover was thin enough to allow the sun to be seen, but the accuracy was reduced by the degree of the haziness of the image.

SETTING THE INSTRUMENT IN PLACE

To set the instrument accurately on the meridian after the base plate had been levelled accurately and firmly secured in position, the actual instrument having been set for the precise latitude of use, the user had to obtain the accurate Greenwich mean time from somewhere - by 1843 it was being telegraphed to many railway stations once a week. This time was transferred to the observational station and having ascertained the exact time of local noon from tables and allowed for the difference in time of the local meridian from Greenwich, the base of the dipleidoscope was turned to give coincidence of the images of the sun at the exact time of noon. Once done, this adjustment was permanent. The portable instrument had a magnetic compass to set the instrument on the meridian with sufficient accuracy, allowance being made for magnetic variation.

In the use of this instrument utilizing the sun's powerful rays, it was expedient to use darkened glass to protect the observer's eyes. Today there are protective filters, the most common method in those days was the use of smoked glass [glass with a thin film of soot deposited from a flame], but this did not filter out the harmful infra-red rays which damage the eyes. Fortunately the observer only had a few seconds of viewing at each of the three observations.

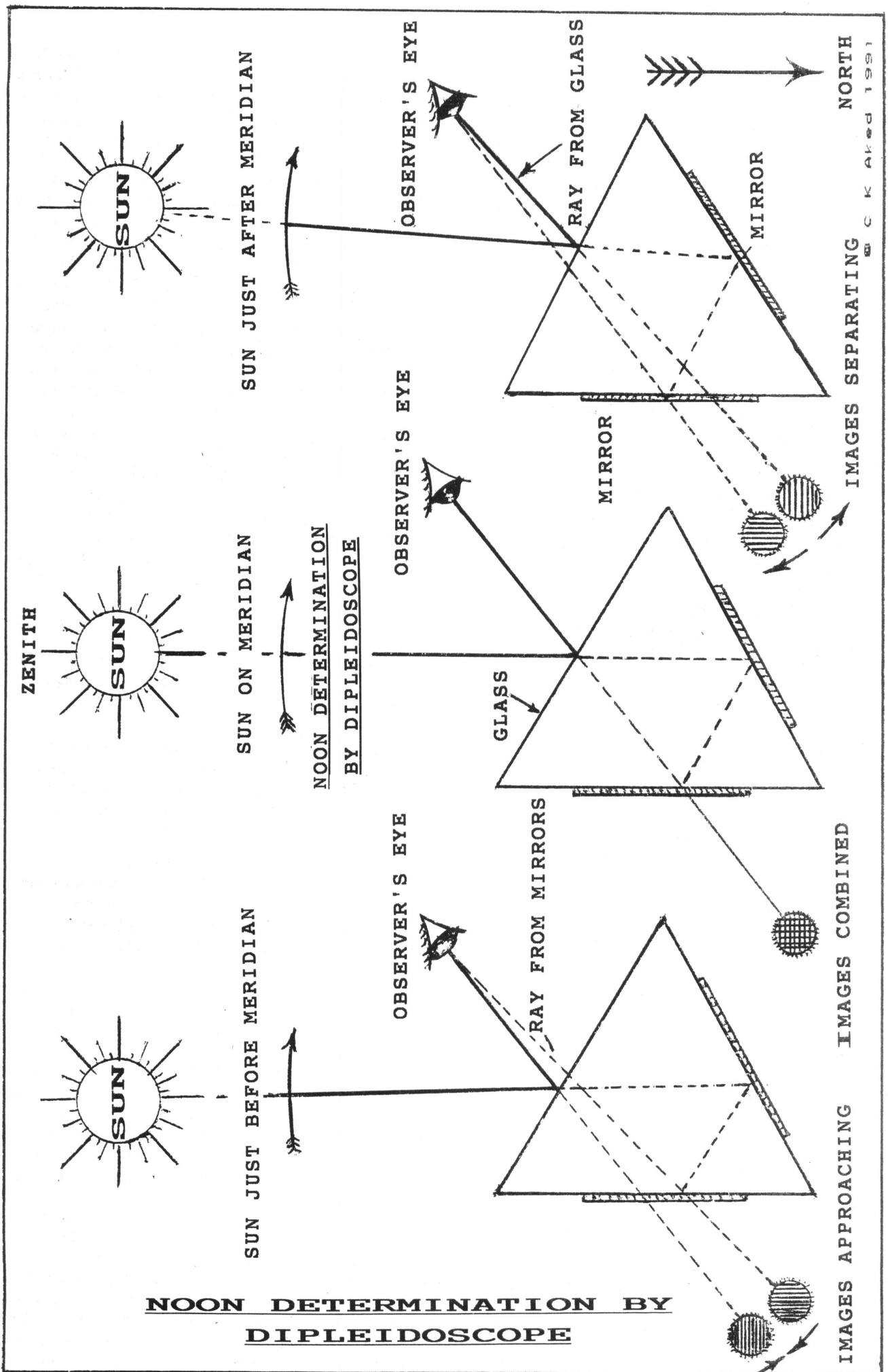


FIGURE 3:

These instructions and precautions were set out by Dent in his booklet, part of which is reproduced here:

SETTING UP THE DIPLEIDOSCOPE

In choosing a position for the instrument care must be taken that its support is firm and rigid, that its surface is perfectly level, and that it must as a matter of course command a southern aspect.

After a position has been selected for the instrument the observer, before proceeding to the fixing, cannot do better than go through the following preparatory practice:- Place the instrument upon its base-plate, the side marked East being in that direction. Hold a sheet of paper opposite the front glass at about two feet distant, taking care not to obstruct the rays of the sun from passing into the instrument: the reflected image from the front of the glass will be immediately seen upon the paper.

The instrument should then be gently turned either to the right or left, until another image appears on the paper; these will mutually approach, until one is seen to cover the other. If the observer then looks into the instrument (having its lower side towards him, and his eye protected by means of a darkened glass), he will perceive the sun reflected in it as one luminous circular object. The principal advantage derived from previously throwing the images on the paper is, that it indicates to the observer the direction in which he is to look into the instrument. By keeping his eye upon the sun, as exhibited in the instrument, he will, after the interval of a few moments, perceive a second sun appear to pass away from the former:- these will presently be entirely detached, and two distinct suns will be seen. If he turns the instrument very gradually towards the west, the images may be so regulated as to re-approach, coincide and separate again; and thus afford the opportunity of practising the complete observation described lower down. This experiment may be repeated at the pleasure of the observer until he has acquired the requisite skill for the permanent fixing of the Dipleidoscope: which, it needs hardly to be remarked, must be effected at apparent, or solar noon.

To appreciate the actual functioning of the instrument easily really requires a three-dimensional model. Dent's own diagrams in his pamphlets do not show the sun near its zenith. At precise noon the plain glass must be presented at an angle of 30° rotation around the axis of



FIGURE 4: Illustration of the simple mode of taking an observation with the Dipleidoscope

the mirror junctions towards the observer's eye. The sun's rays then meet the front surface of the plain glass at an angle of 60° and after reflection leave at 120° into the observer's eye. The sun's rays which are transmitted through the glass meet the first mirror surface at 60° and leave at 120° to meet the second mirror surface at 60° and leave at 120° , and this passes through the plain glass in precisely the same direction as the rays reflected from the front of the plain glass, thus the two images are blended into one. The internal mirrors or the reflecting planes of prisms (if used) must therefore be accurately located at 60° to each other and the plain glass, and the surfaces have to be optically perfect or errors will be introduced. At each reflecting surface any angular difference is doubled, hence the angular displacement of the image formed by the mirrors moves four times as fast as that from direct reflection from the plain glass, greatly increasing the accuracy of the observations.

ACKNOWLEDGEMENT - The engraved plates were supplied by Mr. J.R. Millburn.

A QIBLA LINE CONSTRUCTION

Continued from page 25

9. Draw a horizontal line through point G; its intersection with the left side-line is point H.
10. Draw a line through points E and H; the intersection of this line with North-South line is point I.
11. Draw a horizontal line Φ through point I.
12. Draw a vertical line through point C; its intersection with line Φ is point J.
13. Draw an arrow from point J through the origin. Point J is the *back* of the arrow. Extend the arrow to the

circumference of the larger circle.

If the North-South line is properly placed in the meridian on a horizontal surface, the arrow will point to Mecca.

As a final point, note that this graphical procedure can be modified to produce the azimuth of any other location. Besides making the appropriate change in the longitude difference, the reflector line must be moved. The reflector's angle with the East line must equal the latitude of the target location. Reflectors for North latitudes will be in the south-east quadrant; South latitudes will have reflectors in the north-east.

A JAPANESE SUNDIAL BY ROBERT A MILLS

Figure 1 shows the layout of a sundial erected in a public park in Tokyo, Japan, in Latitude 35°N. It is a very large structure comprising a horizontal dial with a gnomon AB consisting of a massive wedge of concrete with a slope of 35° to the horizontal. The tall pillar and its stepped profile are only attractive embellishments as far as I can judge, could they be associated with the solstices?

The photographs were taken by my son-in-law and sent by my daughter, who appears in photo 1 on the Eastern side, the time being about 10.30 am local solar time. This was taken from the top of a nearby tall block of flats and is indicative of the size of the structure, showing the tall vertical pillar and what appears to be a symbol of the sun which perhaps serves as a noon mark fixed in the position of 11.40. As the longitude of Tokyo is about 140° East of Greenwich, its solar time is GMT (UT) plus 9 hours 20 minutes. The National time Zone for Tokyo is UT + 9 hours, this would account for the "Noon Mark" being 20 minutes or 5° off the XII hour line to give the true local solar noon.

The shadow angles of the gnomon are given by the relation:

$$\tan \delta = \tan HA \sin \phi$$

$$\text{ie } \tan HA \sin 35^\circ$$

These are given in the figure and the following table.

Sun Time	Hour Angle (HA)	Shadow Angle (δ)
12 h	0°	0.00°
11/13 h	15°	8.73°
10/14 h	30°	18.32°
9/15 h	45°	29.83°
8/16 h	60°	44.83°
7/17 h	75°	64.96°
6/18 h	90°	90.00°

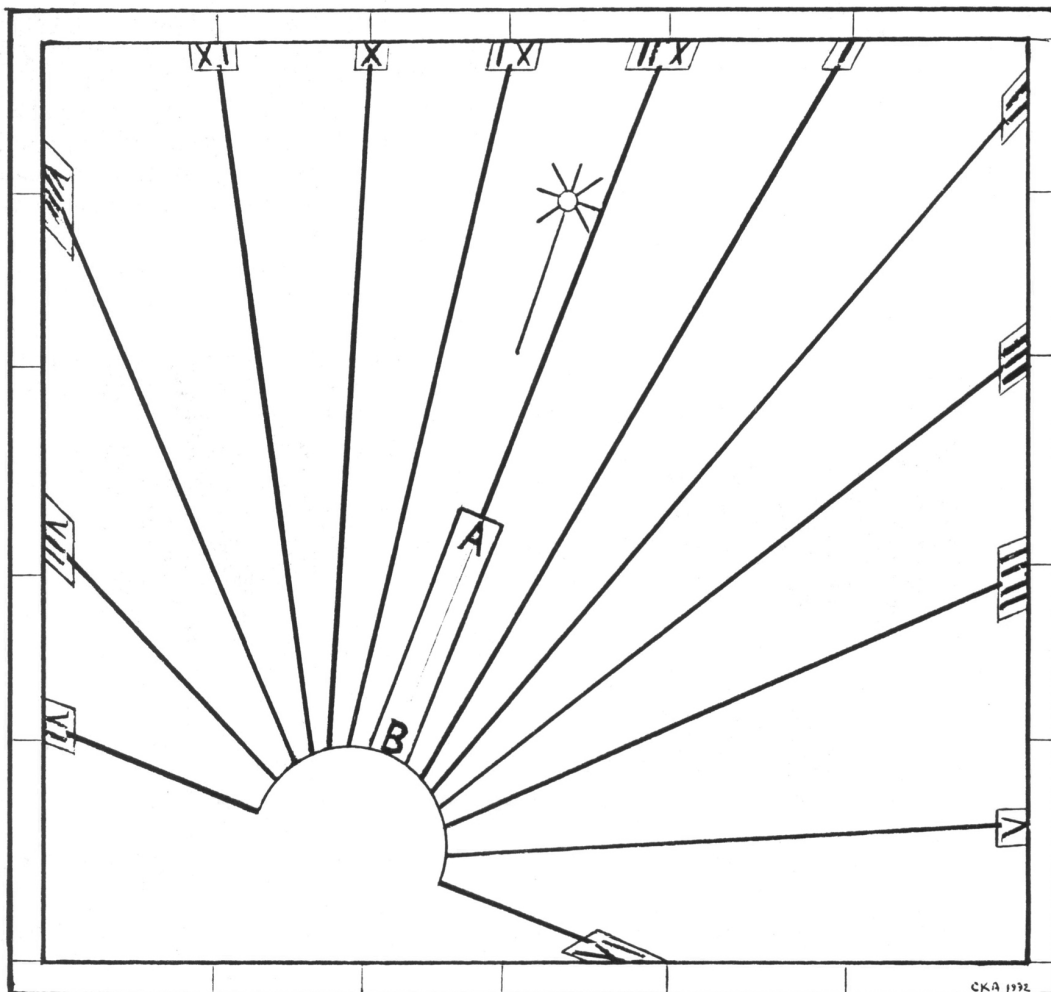


FIGURE 1

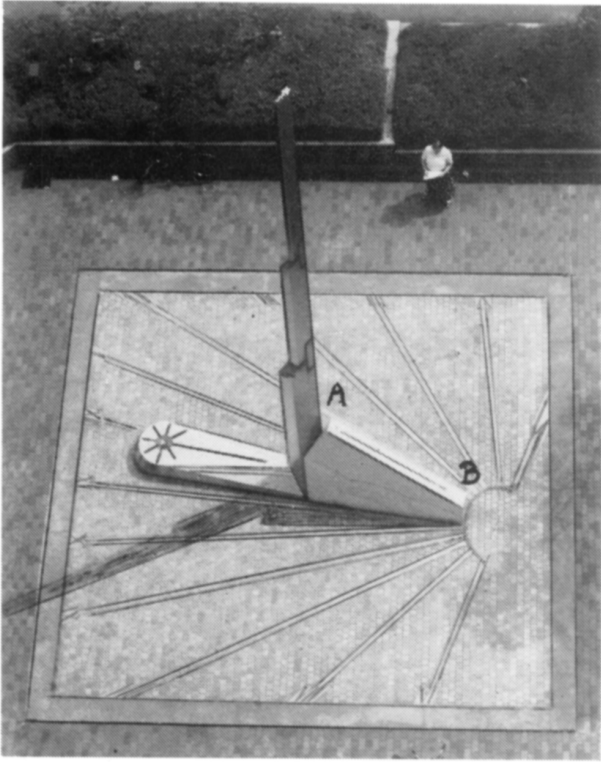


PHOTO 1

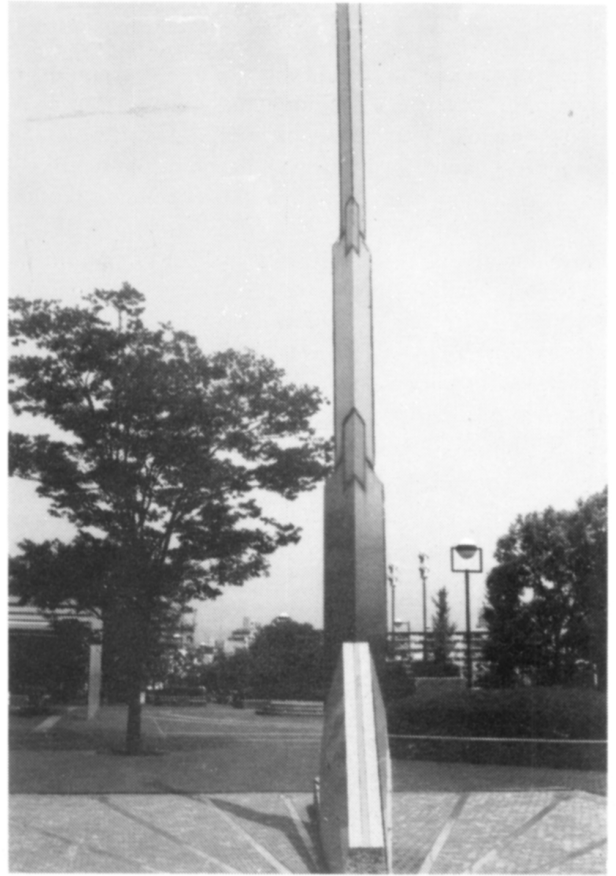


PHOTO 2



PHOTO 3

A Japanese Sundial - Tokyo

LAYING OUT A VERTICAL DECLINING DIAL

BY COLIN McVEAN

The following is an explanation of the description of laying-out a vertical declining dial taken from F.W. Cousin's book *Sundials*, see page 115 onwards.

Figure 1 shows a vertical wall declining West, BE is a line at right angles to the wall, and the declination of the wall from the South is $\angle CBE$. AB is vertical to BE and the triangle ABC is the style of a horizontal dial for the latitude, erected on the N-S line. CD is at right angles to the wall. The triangle ADC will now be the style for a vertical declining dial for the wall. AD will be the base of the style, CD will be the style's height, FG drawn at right angles to AD will be the equinoctial line and AB will be the Noon line.

Using this system, a declining vertical dial may be drawn as follows, having first found the declination angle for the wall. Figure 2 shows a vertical dial declining West 30° at Lat 50° N.

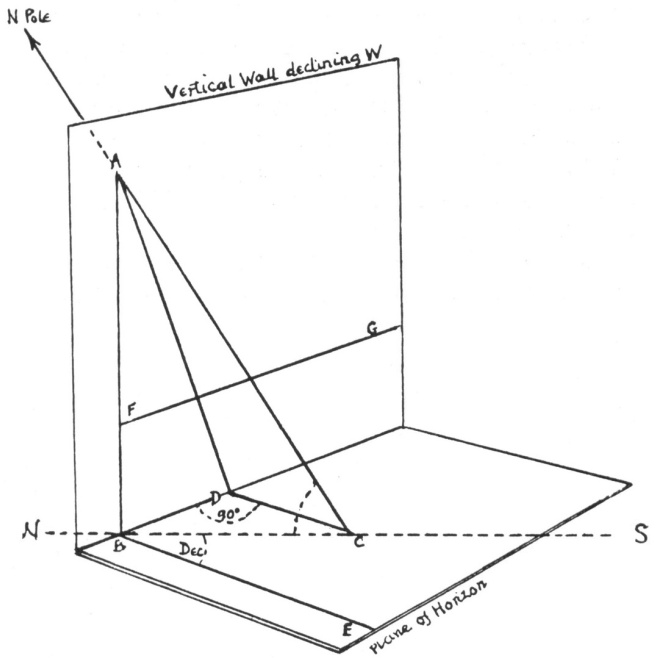


FIGURE 1: A vertical wall declining West

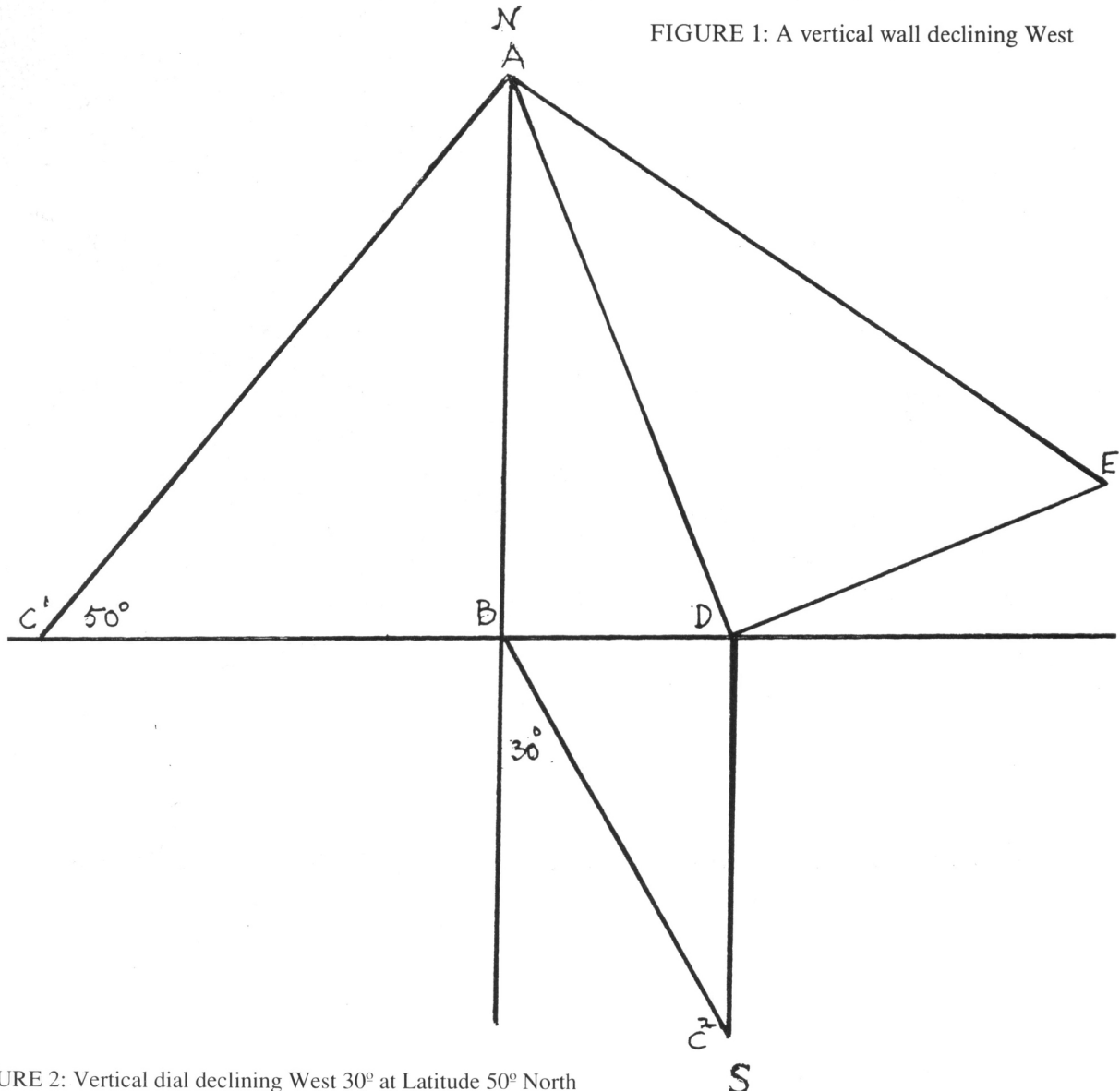


FIGURE 2: Vertical dial declining West 30° at Latitude 50° North

Draw a vertical line AB through B and at any convenient point C through B and at right angles to AB. Draw the horizontal dial ABC to the left for West decliners. For East decliners draw the dial to the right of AB. The angle AC¹B must equal the latitude, shown here as 50°N. From B mark off the declination to the right of AB to the South, here 30° and make BC² equal to BC¹. From the horizontal line C through B drop a vertical from D to C² and join AD. At right angles to AD from D make DE equal to DC. Then AD will be the Style base, DE the Style height and AB the twelve o'clock line.

To draw in the hour lines, take a fresh piece of paper (Fig 3) and to it transfer the perpendicular AB through B,

the lines AD and AE, keeping the same angles BAD and DAE. Through D and at right angles to AD produce the equinoctial line FDG. From AE drop a perpendicular to cut D, then produce AD to O making DO equal to ED.

Using O as a centre, and with any convenient radius, describe an arc. Join O to the point where AB crosses the equinoctial line. Label this point 12. Each side of the line 0-12 mark off 15. arcs. Draw lines from O through these points to cut the equinoctial line. From A draw lines to meet these points. Label these lines from left to right - 10, 11, 1, 2, 3, 4, 5, 6, ADO will be the sub style line, DE will be the style height and AB will be the noon line.

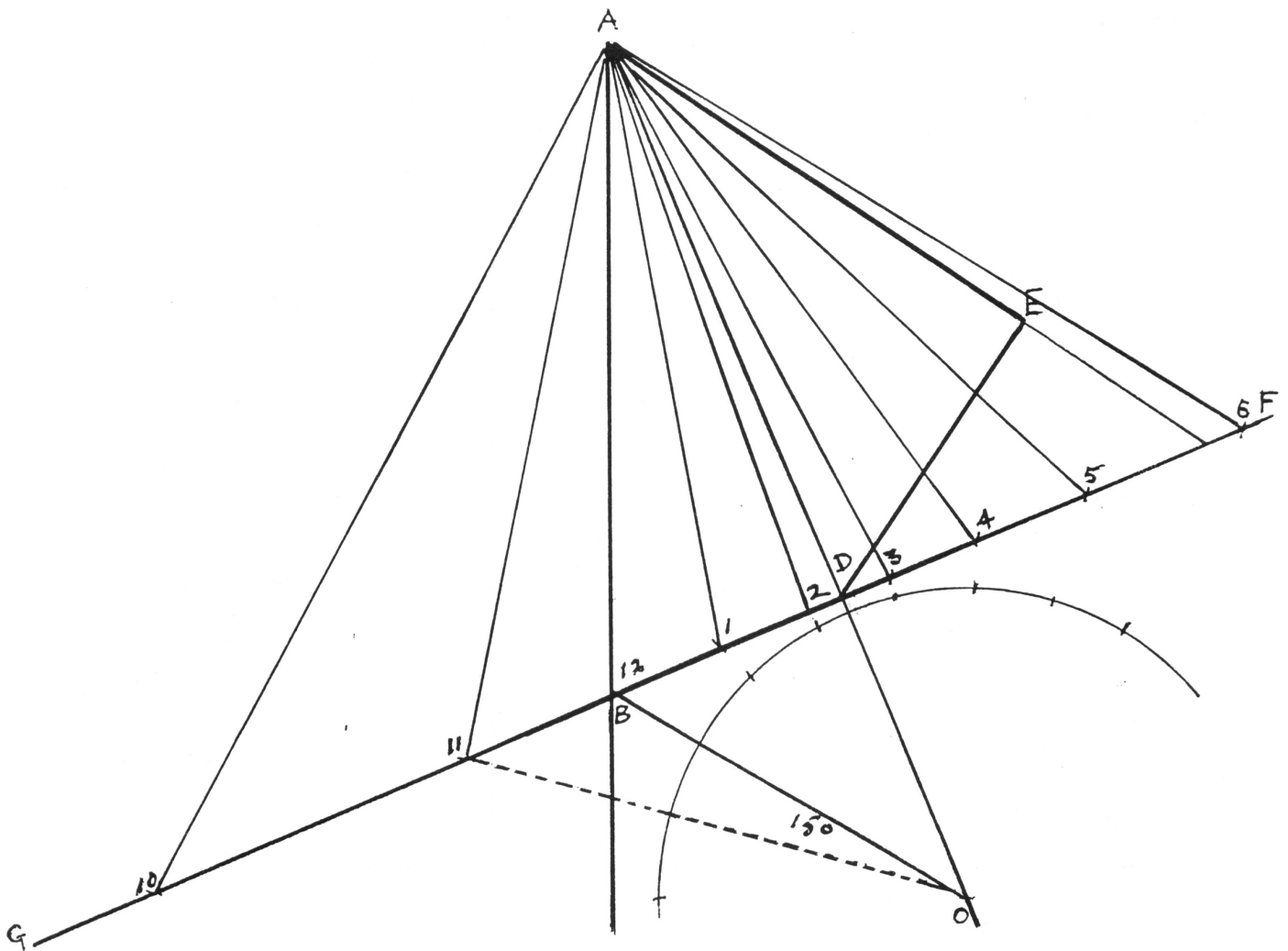


FIGURE 3: Drawing the Hour lines on a vertical dial declining West 30° at Latitude 50° North

From the Chairman's pen ERRORS AND MISCONCEPTIONS

His Royal Highness, Prince Phillip, Duke of Edinburgh is quoted as having said: "The person who made a mistake never made anything". I believe that this remark was originally made by Isambard Kingdom Brunel but it is an apt comment for those engaged in the *art of dialling* and in promoting the subject. "To err is human", but human-beings do not like to be embarrassed by the discovery of an error or an omission in their work, more particularly as they begin to gain status in their chosen field. Consequently, there is always the dangerous temptation to conceal the truth or to 'make a stand' to defend 'one's position', so as not to appear foolish. I am sure that we have all done this at one time or another, for whatever reason. Nevertheless, in the long run, one gains far more respect by the admission of one's mistakes and failures, even if the short-term consequences are to one's disadvantage.

I remember, many years ago, when I was a junior Research Assistant at the National Maritime Museum, answering an enquiry from a school-girl as to what was Blagrove's *Mathematical Jewel* by telling her quite emphatically that it was a *book*! Indeed, it is the title of a book, see opposite page, but the 'Jewel' itself, which the work describes, is a form of astrolabe, 'invented' by John Blagrove, the author. It was quite some time later that I discovered my own ignorance; but by the time it was too late to remedy the matter. My unfortunate reply to this young lady has never been called into question, since, until now, it has never come to light.

More recently, in one of my 'sundial page' articles in *Clocks* magazine, (*Antique Clocks* November 1989, p.44) I described the declination curves on a vertical wooden sundial, delineated to indicate the length of the day, longitudo dierum, expressed in terms of the number of equal hours in the day and measured from sunrise to sunset, as representing the zodiacal signs. Despite the fact that, at about that time, I was engaged in the design of a number of vertical 'furniture' sundials for Larne in Northern Ireland, including an 'Hours in the Day' dial, I could not conceive the thought that an 18th century 'country' diallist would have delineated anything but the most common pieces of 'furniture'. So familiar was I with this sundial that I had never really bothered to examine it in an impartial manner! Only on reading the published article did it really dawn on me as to what I had done, but it was too late. For my carelessness I was quickly picked up by two of my readers, including Dr. Marinus Hagen. In a subsequent article, I apologised to my readers and to the 18th century diallist, whom I had maligned and thought to be a provincial artisan rather than a skilled mathematical practitioner. One of my friends thought that it was unnecessary to make such an apology in print, that it carried things a bit too far, "sack-cloth and ashes" and all that; but, to me, it was important to put the record straight.

Of course, sometimes one takes responsibility for mistakes which are beyond one's control. In my article on the 'sundial page' of the January 1993 issue of *Clocks* magazine, the photograph of my vertical sundial at the Tower of London is printed upside down. More irritating is the consistent printer's error in my article on the 'sundial page' of the January 1992 issue of *Clocks*, concerning the earliest delineation of the equation of time. The name of the German instrument-maker Johann Michael *Vogler* is

printed as 'Volger' on each occasion, despite the illustration of a sundial on which the name *Vogler* is clearly visible! However, even this pales into insignificance beside the plaque on the west wall of the Church of St. Margaret's, Westminster, indicating the equation of time correction to be applied to the sundials to obtain mean-time. The plaque was placed in position sometime after the sundials were set up in 1982. Although the art-work for laying out the plaque and delineating the equation of time correction curve was accurate, the engraver somehow managed to invert the curve on the plaque itself. This was a fact which I failed to notice when I paid a hasty visit to inspect the finished article *in situ* some while later. It is true that the plaque didn't appear quite as I expected it to be; but I couldn't imagine that it could possibly be wrong. It was not until a few years later when I was actively planning to take a record photograph of the plaque, that I received a disconcerting note from David Brown. He wished to know why the equation of time diagram on the plaque differed from that in my *Shire Sundials* album! Why indeed? There can be no doubt that I should have checked the plaque before it was placed in position, despite the fact that it was a straightforward operation to reproduce the approved art-work on the plaque itself. Thus, regardless of the onus on the makers to produce the specified goods, as the designer the responsibility for this unfortunate error must rest with me.

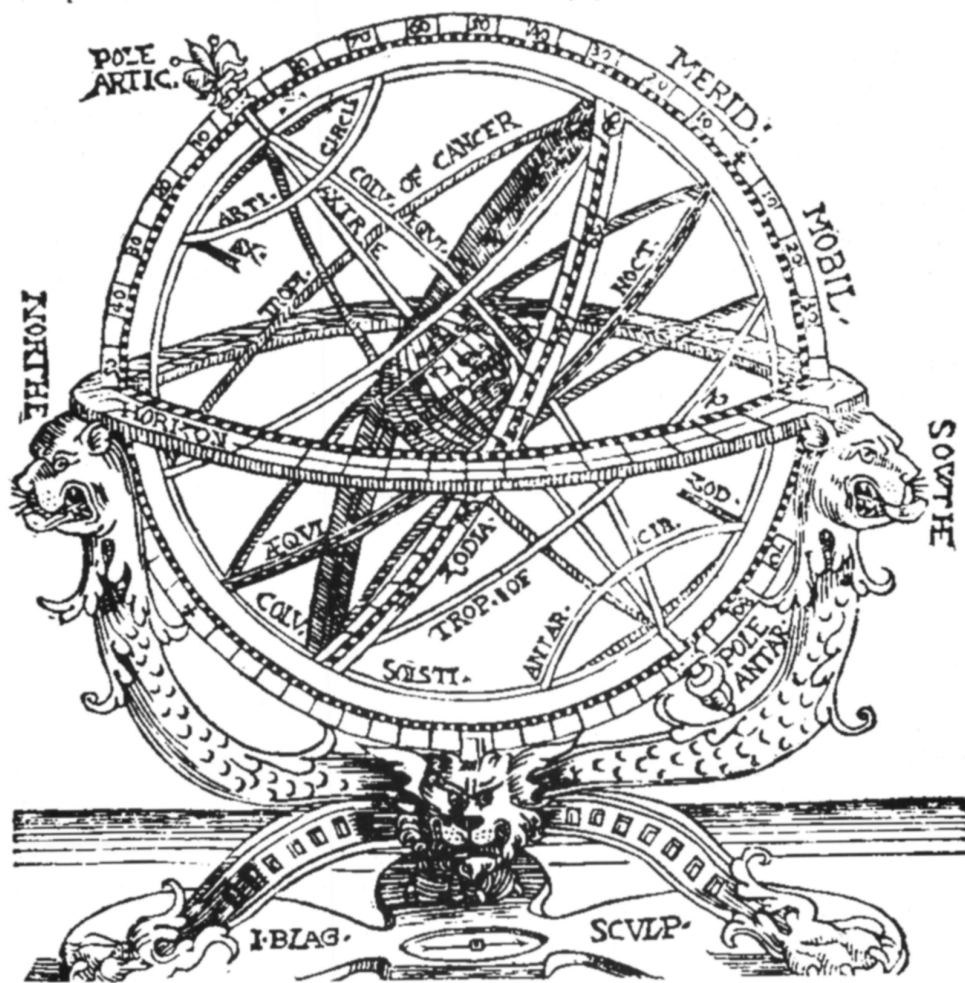
As Chairman of the British Sundial Society, having declared my own human frailties, I believe that I have a responsibility also to the membership to maintain and improve the standards of the Society, to strive for excellence in all that we do. This may relate to historical research, to the construction or restoration of sundials, to the publication of books and articles, or to the education of the general public. We should endeavour to aim for the best results possible. In many respects we have already achieved this and the *Bulletin* in a singular manifestation of this achievement. Our conferences and meetings, as well, are an example to all, whilst our Education Section is forging links and making our name with *How to Make a Sundial* in schools and educational establishments throughout the country. Moreover, apart from those engaged in the construction of sundials, many individual members are actively contributing to our various common causes in their different ways, some recording sundials, some computing, some writing and publicising the subject, bringing the Society to the notice of the public. I cannot express my appreciation enough for these individual activities and for the most part I have nothing but praise for them. The scaphe sundial at Holker Hall, designed by a member, which featured in the October issue of the *Bulletin*, is an outstanding example of excellence, not only in its design, but in its making, which, by association, reflects credit on the Society. In another category, the delightful books of 'Solar Horology' by Oronce Fine, 1494-1555, (Diallist to the great Renaissance Prince of France, Francis I), 'Interpreted in English' by a member and published within the last three years in Shipston-on-Stour, are also notable examples of individual achievement, which again by association, give credit to the Society. *Cambridge Sundials* and *Cumbrian Sundials* deserve a mention too, as do the articles, written

THE MATHEMATICAL JEWEL,

Shewing the making, and most excellent vse of a singular
Instrument so called: in that it performeth with wonderfull
dexteritie, whatsoever is to be done, either by Quadrant, Ship, Circle, Cylinder,
Ring, Dyall, Horoscope, Astrolabe, Sphere, Globe, or any such like heretofore
devised: yea or by most Tables commonly extant: and that generally
to all places from Pole to Pole.

The vse of which Jewel, is so abundant and ample, that it lea-
deth any man practising thereon, the direct pathway (from the first stepp to the last)
through the whole Artes of Astronomy, Cosmography, Geography, Topography,
Navigation, Longitudes of Regions, Dyalling, Spherical triangles, Setting figures, and
briefely of whatsoever concerneth the Globe or Sphere: with great and incredible
speede, plainesse, facilitie, and pleasure:

The most part newly founde out by the Author, Compiled and published for the furtherance, as well of
Gentlemen and others desirous of speculatiue knowledge, and priuate practise: as also for the turn-
ishing of such worthy mindes, Nauigators, and traueylers, that pretend long voyages or new discoveries:
By *Ioim Blagrawe* of *Reading* Gentleman and well willer to the Mathematicke, who hath cut all the prints
or pictures of the whole worke with his owne hands. 1585.



Imprinted at London by Walter Venge, dwelling in

by members, that have recently appeared in certain institution periodicals and commercial magazines, particularly in *the Valuer* and in *The Antique Collector*.

Alas, not all the enthusiastic output by members has been free from errors or misconceptions, that are bound to occur where the fundamental principles underlying the art of dialling or its history are not wholly understood or appreciated. As in many other fields, in the art of dialling, sometimes called the science of gnomonics, "a little knowledge is a dangerous thing ...". Just as the finer examples of individual achievement may reflect credit upon the organisation, so there are certain cases that are less likely to favour the Society's interests. In a recent publication, the author of which is a member, the vertical stained-glass sundial at Leigh Hall is described as a 'reclining' sundial, whilst the Silver Jubilee dolphin dial at 'the Maritime Museum' at Greenwich, albeit an equinoctial mean-time sundial, is described as being 'horizontal'. A printer's error may have been responsible for 'reclining', as opposed to declining; but this could hardly apply to the description of the dolphin dial as 'horizontal'. These are small errors in themselves, but they are errors nevertheless.

Misconceptions are another matter. When they appear as statements of fact, in a reputable publication, without any qualifications or supporting evidence, they become a liability to the subject of their cause. "It was the sun, or rather the lack of it that brought about the rapid disappearance of the working dial in Britain" is just such a statement, that might have been acceptable as a joke, if it were not for the fact that it appeared as a serious remark in a periodical in the autumn of 1990. If one takes this comment at face value, why were sundials used so extensively in Britain over so many hundreds of years? The author gives us the answer in the very next sentence: "As soon as the earliest clocks ... were widely obtainable in the country, the days of the sundial maker were ended". The author continues to compound the misconception: "But a few centuries later, in Queen Victoria's reign, the sundial staged a revival. It returned as an ornament". I have no doubt that the common or garden horizontal sundial was indeed popular as an ornament in the Victorian garden; but in the 'few centuries' preceding, after 'the days of the sundial maker were ended', how were clocks regulated and how was time determined? One might look at another statement in another periodical that observes that "Sundials continued to be in demand until the coming of the Railway Age when the necessity for some form of standard time finally made them redundant". There are, of course, half-truths in some of these statements. Certainly, the sundial's use as a utilitarian instrument declined with the coming of 'the Railway Age', but not because of the need to establish some form of standard time. The dramatic improvement in physical communication between towns and cities, brought about by the advent of the railways, was accompanied by an even more dramatic improvement in communications in methods of signalling over long distances. It was the introduction of the electric telegraph, by which national astronomical observations could send time-signals to railway stations and post-offices of town and city centres along the route, that, in fact, was the 'beginning of the end' of the sundial as a valued instrument. Even so, in remote areas, away from centres provided with this facility, sundials continued to serve as useful function until the coming of wireless-telegraphy, or radio, at the beginning of the 'Electronic Age'. As late as 1934 there appeared in the

Nautical Almanac for that year an advertisement for a 'Solar Chronometer' or equinoctial mean-time sundial, when it would still have been of practical use in isolated regions of the world without radio reception facilities.

The final example of a misconception, which actually caused me to write to the author, was a statement that appeared in a periodical this last year. It reads "as the sundial's time-keeping properties became more and more obsolete, the faces of dials, where previously only the hour lines were marked, became ever more cluttered with extra information". The author replied that this was an opinion, but it reads to me like a statement of fact. In fact, the sundial does not have time-keeping properties as such, since it is not a time-keeper, ie. it is not a 'clock' in the horological sense: it is an astronomical instrument, the purpose of which is to determine the time by the apparent motion of the sun. The clock, on the other hand, is a machine which conserves, or 'keeps' time by a mechanical means, whether clock-work, electronic, or otherwise. What is more, for centuries sundials were used to regulate clocks, (which "often go wrong"), until communications became 'instant' through the medium of the electric telegraph. Thus sundials and clocks were very much complementary devices in the measurement of time. It is true that the term 'sun-clock' is sometimes used erroneously to describe a sundial; but this is a misnomer, which, in part, might be remedied if the sundial were to be constructed using photo-electric cells that would signal the hour by sound, ie. by the use of a bell. (The word 'clock' is derived from the word meaning 'bell' in a number of Continental languages).

On the question of sundials becoming evermore 'cluttered', the historical process was quite the reverse. In the 17th century, when the art of dialling flourished not only as a necessary science but as a mathematical pastime, sundials were indeed often cluttered with extra information. The use of such 'furniture', as it was called, was something of a 'conceit' to show off the skills of the diallist, but in most cases the furniture also provided much useful astronomical information, which nowadays we take for granted. As clocks improved in accuracy and become more readily available, and as fashions changed, so the sundial tended to be furnished with less and less of this information. Thus, in due course, the sundial became a simple utilitarian instrument, by which clocks and watches could be regulated.

Readers will be aware that I have not mentioned any names in this article, in so far as Members are concerned in the design, making or authorship of the works cited. It has been my purpose specifically to illustrate some of the errors and misconceptions that have recently occurred and which might well occur again, not to embarrass by praise or reprimand the individual responsible. I have made a study of sundials since 1967, when I was given direct responsibility for the sundial collection in the Old Royal Observatory at the National Maritime Museum at Greenwich. Although I designed the Nautical Institute armillary sundial symbol in 1972, it was, in fact, not until 1977 that I seriously started designing sundials. Nevertheless, I have been interested in every aspect of the sundial for some 26 years. Despite this experience, I am mindful that I still have much to learn, for the science of dialling is extensive, and that I can always benefit from the advice and criticism of others.

THE CELESTIAL SPHERE
A TALK AND DEMONSTRATION GIVEN AT THE BSS CONFERENCE,
BATH SEPTEMBER 1992
BY C. PHILIP ADAMS

INTRODUCTION

To "an observer viewing the heavens on a clear night... the appearance will be just as though he were surrounded by a vast sphere, to the surface of which the stars are attached, the observer himself being at the centre". Furthermore, "The imaginary sphere, at the centre of which the observer seems to be placed, is known as the Celestial Sphere. Although the sphere has no material existence, the conception is of fundamental importance in astronomy". (H Spencer Jones 1961).

The conception is also important for gnomonics as the apparent movements of the sun in relation to the earth are made comprehensible by regarding the sun as being attached to the celestial sphere in the same way as the stars and moving around the earth with the stars from east to west. The sun, of course, also appears to move round the starry background once in the year from west to east due to the orbital movement of the earth.

Another conception that is fundamental and helpful in thinking about the apparent movements of the sun is that of Mean Solar Time.

"We imagine a fictitious Sun which moves in the celestial equator at a uniform rate and completes its passage round the equator in exactly the same time that the true Sun takes to pass round the ecliptic. Then the time given by this fictitious Sun will be such that every day is of exactly the same length and equal to the average length of the apparent solar day" (H Spencer Jones 1961). It is convenient to refer to this fictitious Sun as the Mean Sun to distinguish it from the True Sun.

Textbook explanations are hampered by the necessity to describe and explain complex phenomena that occur in three dimensions by the use of two dimensional diagrams.

While the writer has found the text of Spencer Jones (1961) the most lucid of all in explaining the relative motions of the sun and the earth, it was Spencer Jones' very clear line drawings that suggested that rendering them into three dimensions by means of a model of the celestial sphere might make the conception still clearer.

THE CELESTIAL SPHERE MODEL

The celestial sphere shown in Fig. 1 is just less than 12 inches in diameter and consists of the following elements:-

1. 12 great circles spaced at 15° intervals.
2. An axis which points to the north and south poles.
3. An earth at the centre. The earth is equipped with a plane representing the area at which an observer stands; a celestial horizon; a zenith pointer which indicates zenith position on the celestial sphere. The position of the observer on earth can be adjusted from equator to north pole by tilting the plane, the celestial horizon and the zenith pointer which all move together.
4. An equator and an ecliptic are attached by two quarter-circular arms pivoted below on the axis. The equator is fixed rigidly to the ends of the arms, the ecliptic is pivoted to the ends of the arms and its inclination can be adjusted to the normal 23.5° to the equator or to any other angle as shall be later noted. The equator and the ecliptic rings fit as closely as practicable round the sphere consistent with their

free rotation around the sphere. This rotation simulates the daily apparent movement of the sun around the earth from east to west.

5. A separate loose ring is provided. This ring can be placed around the sphere and outside the equator and ecliptic. Its purpose is to draw lines on the sphere to connect points and delineate angles as may be required.

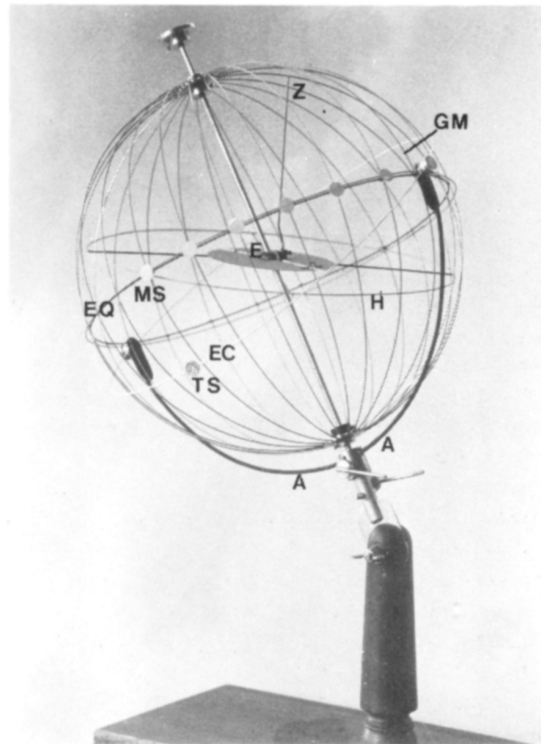


FIGURE 1: The Celestial Sphere, general view.

There are 12 great circles spaced at fifteen degree intervals. An equator is fixed to all the circles on the inside to strengthen the structure.

A movable equator, EQ and an ecliptic, EC are attached to the curved arms A, A. This equator is rigidly attached, the ecliptic can be tilted and locked at any desired angle to the equator. This equator and the ecliptic can be rotated round the sphere to simulate the daily rising and falling of the sun.

A series of mean suns, MS from the winter solstice to the vernal equinox are in place at slightly over 15 day intervals corresponding with the great circles. A true sun, TS is shown on the ecliptic at the winter solstice.

The earth, E, the zenith indicator Z and the plane on which an observer stands and the celestial horizon H can be seen. The observer is at about 55 degrees latitude and at the Greenwich meridian, GM.

Colours are used to distinguish various important features of the model. The plane on which the observer stands is green, the horizon ring is blue. The Greenwich great circle is red as is the great circle at right angles, at which the winter and summer solstices occur. The equator also is red and the ecliptic is yellow. The loose ring also is

yellow.

In Fig. 1 an observer is at latitude 55° and on Greenwich meridian.

The true sun, coloured yellow, is shown on the ecliptic and at the winter solstice. A series of mean suns is shown, coloured red, situated on the equator and starting at the winter solstice. The mean suns are at 15° or 15 day intervals.

The celestial sphere can be used to illustrate and explain numerous astronomical and gnomonic phenomena.

RISING AND SETTING OF THE SUN

Fig. 2 When the sun is at the winter solstice and therefore below the equator, the sun appears above the horizon well southward for only a short time and low in the sky each day. Fig. 2a, sunrise, 2b, sunset.

Fig. 3 When the sun is at the summer solstice and above the equator, it rises and sets much farther northwards along the horizon and is much higher at midday. Fig. 3b, sunset.

THE EQUATION OF TIME

The equation of time arises from two factors in the earth's relationship to the sun. The first is the ellipticity of the earth's orbit and the second the fact that the axis of the earth is inclined at 23.5° to the plane of its orbit. This results in the apparent plane of the sun's movement, the ecliptic, being inclined at the same angle to the celestial equator.

The effects of these two factors can be considered separately and then added together to derive the actual equation of time.

ELLIPTICITY OF THE ORBIT

To explain the influence of the ellipticity of the earth's orbit, let it be arranged that the celestial equator and the ecliptic coincide, the earth's axis being upright or at right angles to its orbit. Fig. 4.

At the winter solstice the true sun moves faster than the mean sun so that over a 15 day period the true sun will have moved ahead of the mean sun. Fig. 4a

By means of the model the daily rotation of the earth is simulated by rotating the combined celestial equator and ecliptic from east to west when it can be seen that the true sun crosses the meridian later than the mean sun so that a sundial will read slow. Fig. 4b.

This effect will continue until the true sun begins to slow down until at the summer solstice the two suns again correspond. Thereafter, the mean sun moves ahead of the true sun and the sundial begins to read fast.

This effect continues until the true sun begins to gather speed and, reversing the trend, and at the winter solstice the two suns correspond once more.

The effect of these speed variations can be seen in Fig. 5a, the two suns corresponding twice per year.

OBLIQUITY OF THE ECLIPTIC

The influence of the obliquity of the ecliptic can be separated out by postulating that the earth's orbit is circular and that the true sun moves at a steady speed.

To exaggerate the effect let the obliquity of the ecliptic be greater than normal, for instance about 60° , Fig. 6. Σ

It can be seen that in their annual movement the mean sun and the true sun are moving along the equator and the

ecliptic respectively over the same distances in the same time, and both starting, let us say, at the winter solstice.

While in 15 days the mean sun has moved from one great circle to the next, the true sun has moved from the same starting great circle over two great circles because at the area at which the true sun is moving, the circles are converging towards the pole and are closer together. The true sun is, therefore, very much ahead of the mean sun and as a result, the true sun will cross the meridian much later than the mean sun as the two suns come round from east to west and the sundial will read slow.

It must be understood that this effect is greatly exaggerated by putting the ecliptic at 60° to the equator but the effect is the same when the correct degree of obliquity is observed.

As the first quarter of the year draws to a close and the spring equinox approaches, the great circles in the path of the true sun become more widely spaced and the true sun becomes less and less ahead of the mean sun until at the equinox approximately the two suns correspond.

Over the next quarter the opposite effect occurs and so on over the remaining two quarters. The total effect over the year is shown in Fig. 6b, the two suns corresponding four times per year.

When the effects of ellipticity and obliquity are combined, the familiar equation of time graph results. Fig. 6c.

THE HOUR ANGLE AND THE AZIMUTH

A matter which puzzled the writer for some time was the connexion between the hour angle of a body, such as the sun, and its azimuth. Both these attributes are made clearer by means of the celestial sphere model.

In Fig. 7, the sun, on its ecliptic, is shown in an hour angle of 30° , two hours before midday. A vertical is dropped through the sun to the horizon using the extra great circle provided with the model.

The azimuth is the angle at the zenith between the vertical, which of course passes through the zenith, and the meridian and it is quite clear that this angle is much greater than the hour angle of the sun.

CONCLUSIONS

It is unfortunate that, in a paper, the illustrations of a model designed to take explanations into three dimensions, have of necessity been shown in two dimensions again which may have robbed this exposition of some of its force. It is hoped that photographs of the model have conveyed more of its significance and helpfulness than line drawings would have done.

The writer believes that there is much more to be learned and understood from a model of this kind than it has been possible to include in this paper. Spherical trigonometry, for instance, would seem to be a fruitful area for investigation using a piece of equipment of this kind.

REFERENCE:

General Astronomy. 6th Edition. Sir Harold Spencer Jones. London Edward Arnold Ltd.

NOTE:

It was not possible to place the appropriate text under Figures 4 and 6. Please turn to page 37 for further details in explanation of these figures.

FIGURE 2a

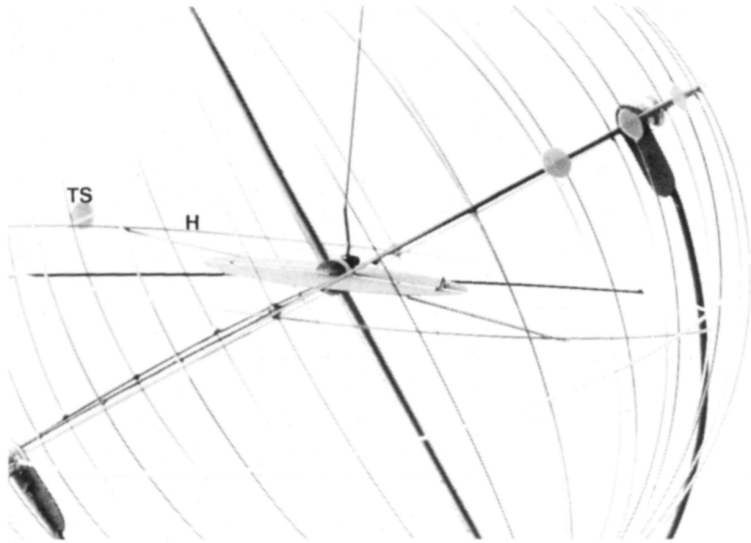


FIGURE 2b

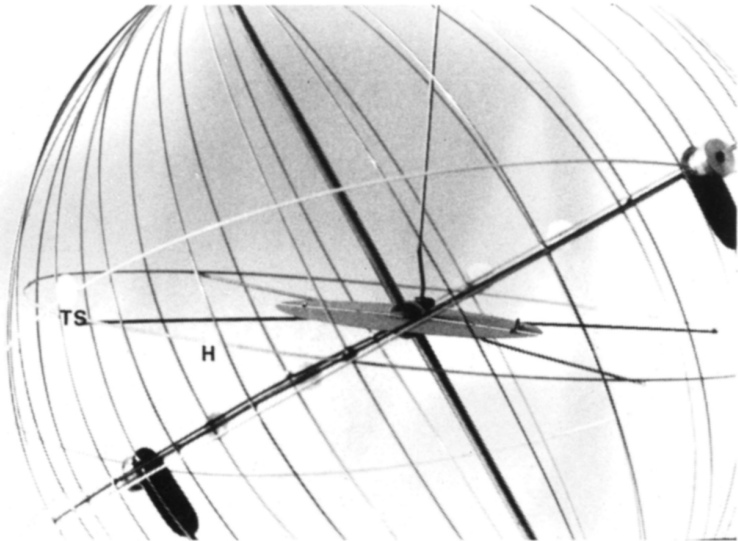


FIGURE 3a

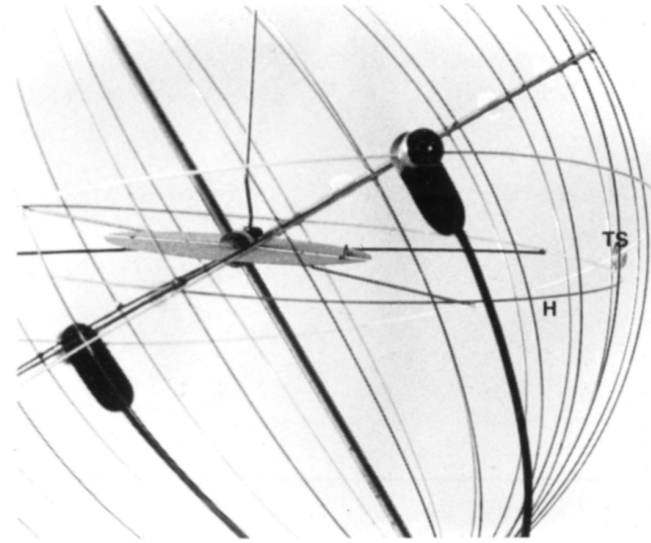


FIGURE 3b

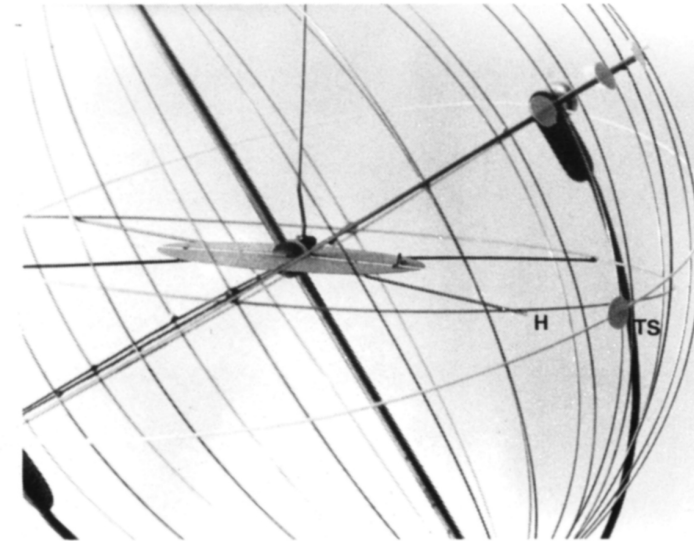


FIGURE 2: In midwinter when the sun, TS, is at the winter solstice it rises, a, and sets, b, above the horizon H, not far from the meridian.

FIGURE 3: In midsummer when the sun, TS is at the summer solstice, it rises, a, and sets, b, above the horizon much farther north than in winter.

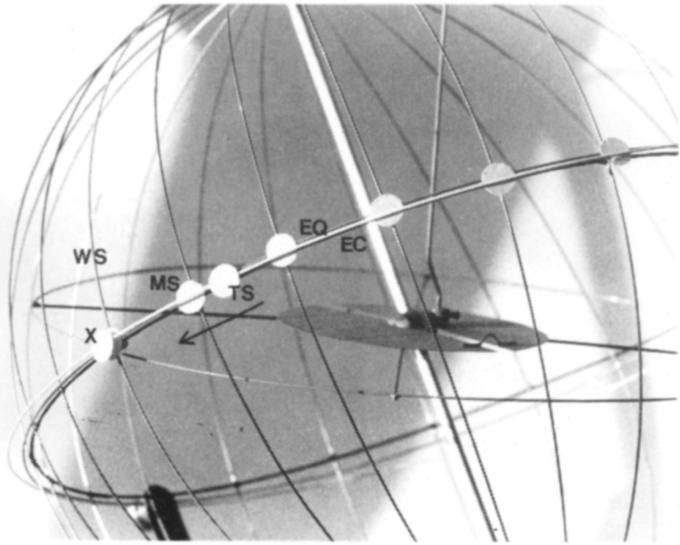


FIGURE 4a: The Equation of Time, the effect of ellipticity of the earth's orbit.

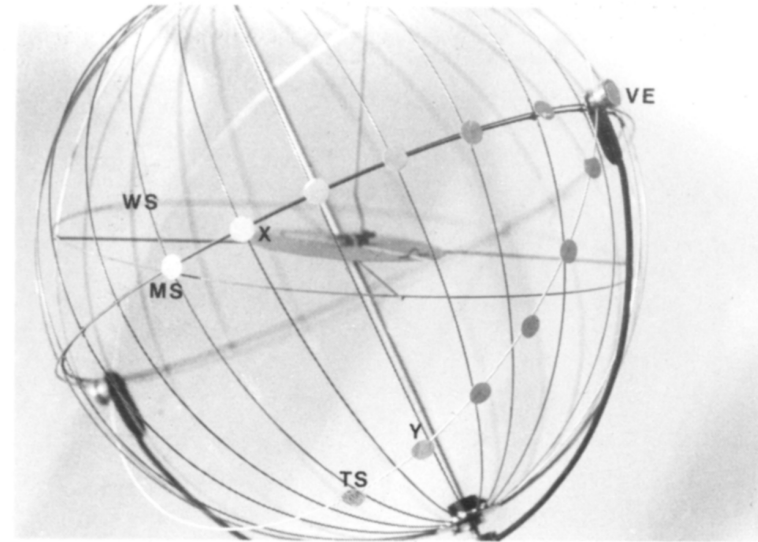


FIGURE 5: The Equation of Time, the effect of obliquity of the ecliptic..

36

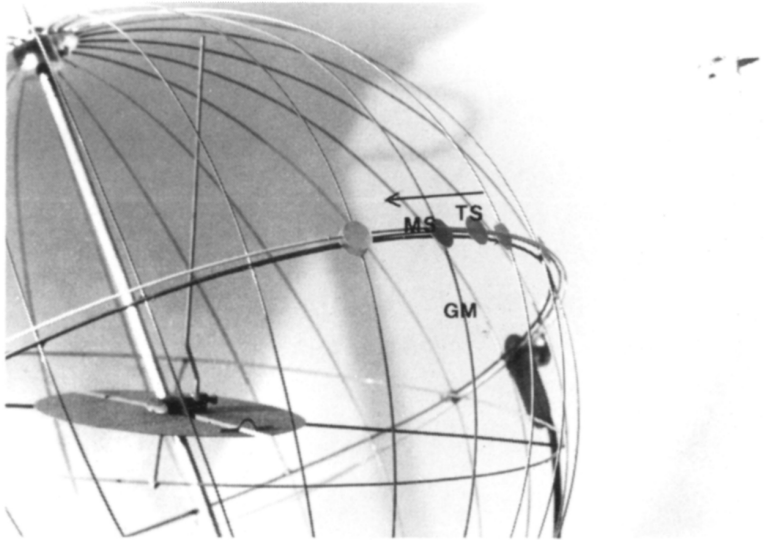


FIGURE 4b: The Equation of Time, the effect of ellipticity of the earth's orbit.

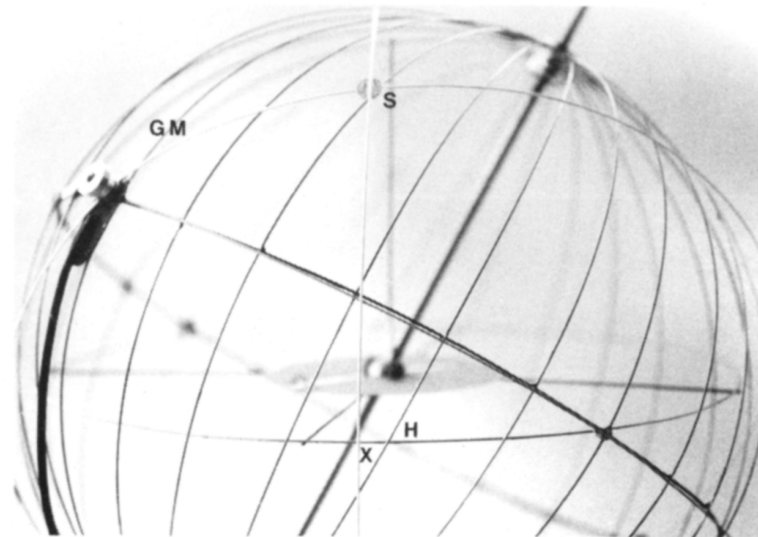


FIGURE 7: Hour angle and azimuth. The sun S is at an hour angle of 30° . A vertical through the sun passes through the zenith and crosses the horizon, H, at X. The angle between the vertical and the meridian is larger than the hour angle.

EXPLANATORY NOTES FOR FIGURES 4 AND 5

FIGURE 4: The Equation of Time, the effect of ellipticity of the earth's orbit.

a. To study this effect the ecliptic is made to coincide with the equator so eliminating the effect of obliquity of the ecliptic. At the winter solstice, WS, the mean sun and true sun coincide at X.

A little over 15 days later the mean sun, MS has moved 150° round the equator from west to east. In the same time the true sun TS has moved a little farther in the same direction. The rotational effect of the earth is simulated by rotating the equator/ecliptic assembly in the direction shown by the arrow.

b. A little over fifteen days after the winter solstice the mean sun, MS and the true sun, TS approach the Greenwich meridian as shown; the mean sun crosses the meridian first followed by the true sun which gives a slow reading for midday on a sundial.

FIGURE 5: The Equation of Time, the effect of obliquity of the ecliptic.

To study this effect, the influence of ellipticity of the earth's orbit is removed by considering the earth to have a circular orbit so that the true sun will move around the ecliptic at the same speed as the mean sun. To render the effect of obliquity of the ecliptic more dramatic, the degree of obliquity is increased to about 60° .

It can be seen that the mean and true suns start at the winter solstice but that after about 15 days the mean sun has only moved to the next hour line, at X, 15° eastwards but the true sun has moved over two hour lines, at Y, and so has gained on the mean sun. The true sun will, therefore, cross the meridian much later than the mean sun and sundials will read slow. This effect increases further and then reverses as the two suns proceed towards the equinox when they coincide again, VE. The effect continues in reverse over the next quarter year. Over the next two quarters the whole process is repeated from the beginning.

VARIATION IN THE SUN'S TIMEKEEPING DUE TO ELLIPTICITY OR ECCENTRICITY OF ITS ORBIT AND OBLIQUITY OF THE ECLIPTIC

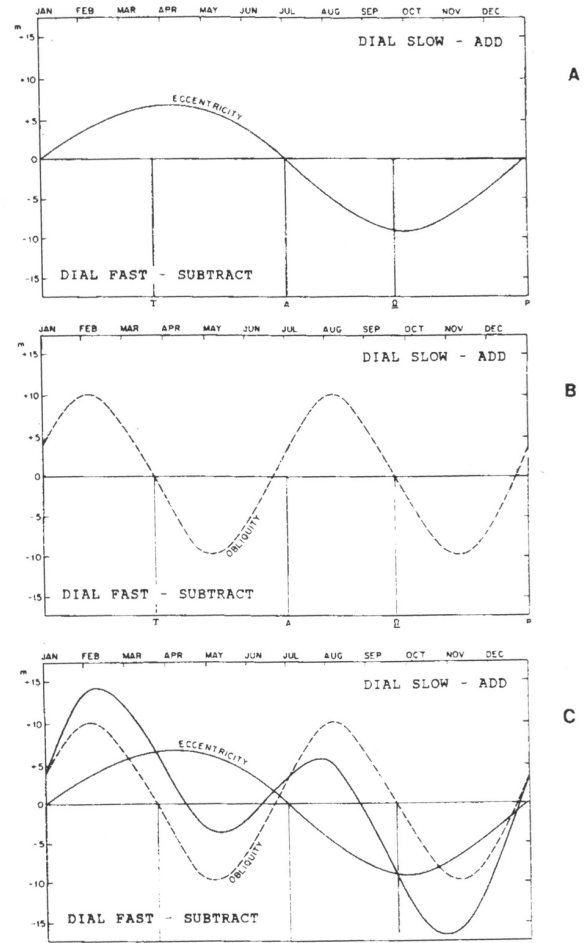


FIGURE 6: A graphical representation of the factors giving rise to the equation of time.

- The effect of ellipticity of the earth's orbit.
- The effect of obliquity of the ecliptic.
- The combination of a and b gives the equation of time.

AN APOLOGY

The Editor has been working under some difficulties because of his medical condition, and although the present issue was prepared as long ago as September 1992, the material was mislaid in February 1993 and has only just emerged. It is entirely the Editor's fault who was under the impression that the issue was in the printer's hands and the delay was caused by the change in publishing methods. For the late publication of this issue, the Editor can only present his humble apologies.

Members will be pleased to learn that the BSS Council has approved the reprinting of the first three issues of the BSS Bulletin. Those who joined the Society in the first year will remember that these were published as photocopied

texts since there was so little money to spare for this purpose. The present Bulletins which are so splendidly produced by Stratford Repro, are the best of their kind in the world and universally admired, so it seems fitting that the early material, which is of some considerable importance, should be reproduced in the same form. It is hoped to get the three issues into one Bulletin (there was much less material in these early issues), and so have the entire published in the uniform format. It will then be the most complete reference to dialling available, and future issues will build up into a most invaluable and complete reference source.

BOOK REVIEW

MANUSCRITOS RELOJEROS by José Luis Basanta Campos, paginated 277-326, with 37 illustrations of extracts. Reprint from *Academia Boletín de la Real Academia de Bellas Artes de San Fernando*, No 74, First half of 1992, Madrid, 1992. Spanish text. Paper covers 26 x 19 cm.

José Luis Campos is the author of *Relojes de Piedra en Galicia*, discussed by the reviewer in *Antiquarian Horology* some years ago (the book was published in 1987 before the founding of the BSS). This is an excellent treatise on the stone sundials in Galicia which every sundial enthusiast should possess, and worth mastering the Spanish language just to be able to read it. Over the years Dr Basanta has published little pamphlets in connection with the bibliography of horology and sundials books and added much to the knowledge of horological subjects.

This present contribution is reprinted from the Academy Bulletin of the Royal Academy of Belle Arts of San Fernando and consists of listing the details of 45 manuscripts dealing mainly with dialling, presented in the following format:

Title, Description, Author, Present Location, and Bibliographical details, with an illustration of part of the manuscript in most cases. Some of the manuscripts are detailed rather less than this, for example if the manuscript is in a private collection, the location details are omitted, the majority are in major libraries, often Royal Palaces such as El Escorial in the beautiful Library in which no student can remain oblivious to the surroundings and the impressive ambience of centuries.

The majority of the texts are in Spanish, a few in Latin. The influence of Jesuit priests is indicated by the number of their tracts, nine of those listed. In some cases the work is unsigned, even when of magnificent proportions such as example 28 which has 610 pages and many illustrations, written in the second half of the eighteenth century. Its title is "Tratado de los relojes de Sol", Treatise of Sun Clocks, the first page being headed Chapter Ist of Time. There are 16 unsigned manuscripts in the list.

This work is invaluable to researchers and students of dialling history but will not be of great interest to those who disregard the bibliography of dialling. Of course many of the tracts will, as in England and elsewhere, be copies of other dialling works made for personal use by the writer. This was the best way of becoming familiar with the design, making, and use of sundials. There must be very many dialling tracts in England which are hidden away, prepared by students for their own use and part of the curriculum of the dialling course they attended. Often these were expanded in the following years to become dialling treatises in their own right. Here then is a virgin field of endeavour for someone looking for a thesis dialling subject.

The book ends with an Index of authors and sources, plus those who have contributed to the bibliographical material. In the main the quoted references are Spanish works and not easily accessible to English readers. The original manuscripts are scarcely susceptible of reading or translation by those unused to ancient Spanish handwritten texts.

Dr. Basanta is to be congratulated on presenting such a valuable addition to the bibliography of dialling, and this work indicates just how much effort is required to undo the neglect of previous centuries in ignoring the subject of dialling. The reviewer hopes to be able to provide an English translation of the relevant data in the future if the author will allow permission to do so.

"Se Ne Va Il Tempo Come L'Ombra" - MERIDIAN IN PROVINCIA DI ASTI, (Roughly 'Time Changes as the Shadow' - Sundials in the Province of Asti); presented by Gianmarco Rebaudengo, text by Mario Tebenghi, Guido Tonello, and Tiziana Valente; photographs by Giulio Morra. 57 pages, 73 colour illustrations (2 on book cover), 2 line diagrams, outline map and one b & w photograph. Thin card glossy covers. Published by the Amministrazione Provinciale di Asti, 1992. 21½ cm width. Italian text.

Enquiries have revealed that there are no copies left of this catalogue for sale. Asti is about halfway between Turin and Genoa in Italy.

There is a short introduction to the catalogue by Gianmarco Rebaudengo, followed by two pages of text by Tiziana Valente on the colour illustrations. Mario Tebenghi outlines the graphical construction of a wall sundial on page 10, the map of the district surrounding Asti is given on page 11, whilst Guido Tonello gives a geometrical construction of a vertical dial taken from *Gnomonices Libro Octo* by Christophorus Clavius Bambergensis, Rome, 1631.

Without further preamble, page 13 commences the catalogue of colour illustrations of wall sundials in the Asti region. Many of the dials are old but there is a fair sprinkling of modern creations which are not out of place. In general the data accompanying the dials is limited to the fairly obvious, dates of construction being mainly given with the modern examples. The photography and the colour illustrations are excellent.

There follows a four page listing of other dials which are not illustrated, probably because these are either remnants of dials or in poor condition, some being mere traces almost effaced by time. The only b & w photograph in the book is in this listing and shows a dial being restored. Page 51 gives a form for recording the details of dials, it seems a very simple and logical means of recording the multifarious details of dials.

A three page glossary of terms is given by Guido Tonello and Tiziana Valente, it is a greatly simplified technical glossary intended for lay persons. There are 54 books and articles listed in the bibliography, a complete list of all the illustrated dials and finally the index to the whole book.

The work was been sponsored by United Technologies Gate of Asti.

All in all a very pleasant presentation of Italian sundials but perhaps somewhat lacking in respect of the details which a serious student of dialling requires. As a pictorial record of the dials it can hardly be bettered, unfortunately the gnomon shadow has not reproduced well with many of the dials, this is merely a mention in passing.

C.K. AKED

BOOK REVIEW

STEVEN A. LLOYD. Ivory Diptych Sundials 1570-1750. With introductions by Penelope Gouk and A.J. Turner. 169 pages, very profusely illustrated. Harvard University Press, 1992. ISBN 0-674-46977-1. Price 50 dollars (In America).

This is a splendid new catalogue devoted to the ivory diptych sundials in the Collection of Scientific Instruments at Harvard University, America. Following an explanatory foreword by William Andrewes, the David P. Wheatland Curator in charge of the Collection, there is a preface by the author Steven Lloyd which explains the *modus operandi* of the treatment. The author emphasises that his book is intended as a catalogue, thus readers must refer to scholarly texts to supplement the information given in his book.

Section 1 of the book commences with the use of the Diptych Sundial, and details the Unequal or Planetary Hours, followed by explanations of earlier and later hour systems. Dial Furniture is the theme of the conclusion of this first section. For some unknown reason, this text is divided by the inclusion of illustrations of the work by N.C. (1653) and its English translation, so one has to jump from page 19 to page 23 to continue the main text. The treatment is simple but effective.

In the next section we move on to Nuremburg Diptych Sundials, with an historical introduction by Penelope Gouk. English diallists will be familiar with her treatise - *The Ivory Sundials of Nuremburg 1500-1700*, published Cambridge 1988, a delightful book for those interested in the subject. Those familiar with Dr. Gouk's own work will need no reminding that her work is a model of presentation, thus she is well qualified to write on these devices. Opposite the opening of the section is an illustration of a sundial maker at work, with a diptych sundial of crude construction just managing to get into the scene.

Page 48 begins the cataloguing and illustration of Diptych Sundials from Nuremburg. In this section the author comments that the number of photographs may seem excessive. As these show all the surfaces of the dials, plus as overall view, this means at least five illustrations for each sundial. The reviewer considers this an excellent approach which allows the reader almost the privilege of handling the dial itself. Colour would have been the ideal medium, for looking at the colour plates in Dr Gouk's book, these show just how beautiful the dials are. As it is, colour was ruled out on the grounds of expense, the illustrations are given in "duotone", giving black on an ivory background, and the clarity of the illustrations is commendable.

Whilst the measurements of the dials are meticulously recorded in the heading to each example, it is not easy to visualise the actual size from looking at the illustrations since no comparison scales are given. Adjacent to the illustrations are full descriptions of each surface depicted.

Details of Nuremburg workshops are included at intervals.

Section 3 deals with French diptych sundials, opening with an authoritative historical introduction by Anthony Turner. It is illustrated with about 37 examples.

Moving on to Section 4, Flemish and Italian diptych dials are again introduced by A.J. Turner. Since the Flemish output was exceedingly small, it is surprising that almost two pages are written on these, whilst the Italian examples are covered in only six and a half lines. The Harvard Collection has one Flemish and three Italian examples.

This concludes the catalogue proper, in which there are a few illustrations from dialling treatises included, not always quite in tune with the sections in which they appear.

The expected Appendices cover: 1. Museums with significant collections of diptych sundials (five in England); 2. The dating of sundials made by Hans Ducher and Leonhart Miller.

The glossary is terse but adequate, although not everyone will agree with the definitions. For example under "compass needle" it is stated "A magnetized iron or steel needle with a metal (usually brass) central pivot . . ."; the central part is usually an inverted brass cup resting upon a pointed iron pin, a combination which is long-wearing. Again the compass needle must be of steel to retain its magnetic properties, iron is unable to act as a permanent magnet.

Many of the listed works in the Bibliography will be unfamiliar to the average diallist. The entry *La Mesure du Temps . . .* seems to have gone astray in the listing. Concordances in catalogue and inventory numbers are included to help the reader locate a particular example: leading finally to the four-page Index. Obviously this is intended for those with good eyesight for the typeface is small, and the italic phrases are difficult to see. It seems a comprehensive data aid, a pity the index was not printed in larger and bolder type for ease of reference so that the reader could skim through in searching instead of having to read closely.

The book jacket has a superb illustration of a windrose face of a diptych sundial made by Hans Drucher, c1642; the front inside cover and rear inside cover pages carry a medieval map of Europe and the Mediterranean area. The title page and opposite is under-printed with face IIb of a diptych dial by Charles Bloud. An excellently produced book which more than adequately details the Harvard Collection. The price will probably be in pounds by the time it reaches the English purchaser, but the book has been heavily subsidized by sponsors in America. For all those who have the remotest interest in these remarkable relics of a bygone age, this book is a must for their library, no sundial enthusiast should be without his own copy. It is a magnificent reference source.

STOCKISTS OF DIALLING BOOKS

Rogers Turner Books Ltd., 22 Nelson Road, London, SE10 9JB. Tel: 081-853 5271.

Rita Shenton, 148 Percy Road, Twickenham, TW2 6JG. Tel: 081-894 6888.

THE MERTON COLLEGE CHAPEL DIAL

BY CHARLES K. AKED

Members of the British Sundial Society who attended the first Conference held at Exeter College, Oxford, March 1990; and who had the physical ability to go on the tour of the sundials, may recall the unusual sundial on the east side of the last buttress of the north wall of the Merton College Chapel. It is described shortly in *The Sundials of Oxford Colleges*, the brief guide produced for delegates to the Conference. The form and function of the dial is obscure to an uninitiated eye, and when one considers that R T Gunther could not explain the form of the dial in 1923 in spite of his considerable knowledge of dialling, it is not surprising that the dial functioning is obscure to the majority of observers, even when the modern viewer has the advantage of it now being in its entirety, an advantage denied to Gunther.

The Chapel was refaced about 1972 to renovate the decaying stonework, and the sundial was restored to its original state. How long ago one of the essential features was removed - the gnomon, is not known. Illustrations of the dial before the refacing operation do not show this feature, without which the dial loses its significant shadow indications.

Oxford was one of the principal scientific research centres in the early seventeenth century, mainly because of the number of those who were interested in mathematics. This was largely due to the enthusiasm and encouragement of Sir Henry Savile, Warden of Merton College. He was born in 1549 at Bradley near Halifax, travelled on the Continent, and was Queen Elizabeth I's tutor in Greek and Mathematics, becoming Warden of Merton in 1585. In 1619 he founded the two Savilian chairs of Geometry and Astronomy at Oxford, dying a few years later in 1622. It seems that the chapel dial was executed during the tenure of the first holders of these chairs, the dial being painted on the stone of the chapel wall. Tradition has it that the dial was the work of Henry Briggs who was the first holder of the chair of geometry, or that of John Bainbridge, the professor of Astronomy. Both men are buried in the Chapel, where there is an eulogistic memorial to Bainbridge. Henry Briggs was a mathematician of talent who was instrumental in introducing logarithms to base 10 in conjunction with John Napier.

There is a passage in John Aubrey's *Brief Lives* which actually mentions Briggs as the dial maker: "He lived at Merton College in Oxon, where he made the dials at the buttresses of the east end of the chapell with a bullet for the axis". This chance observation was the vital clue to the restoration of the dial to a working instrument again. On the other hand Pointer in his *Oxoniensis Academia* of 1749 ascribes the dial to Bainbridge, whilst agreeing with Aubrey - "a dial . . . which has only a little bullet on the edge of each side pillar for its gnomon".

THE MERTON COLLEGE DIAL

The chapel itself is not aligned accurately east-west, and so the dial itself actually declines almost 15° north of east. Thus the sun can cast a shadow over the limited period of the day from approximately 5.30 to 10.00 in the morning only. Evidently there was an extension on the wall south of the buttress, now long disappeared, which worked in summer from about 3.30 to 5.30 am, when the cast shadow passed round to the northern side. Of course

these indications would be so if the dial was placed in an unencumbered space and the sun could reach the dial so soon as it appeared on the horizon, whereas the site contains many buildings preventing this and the sun must rise in the heavens for some little time before reaching the dial itself.

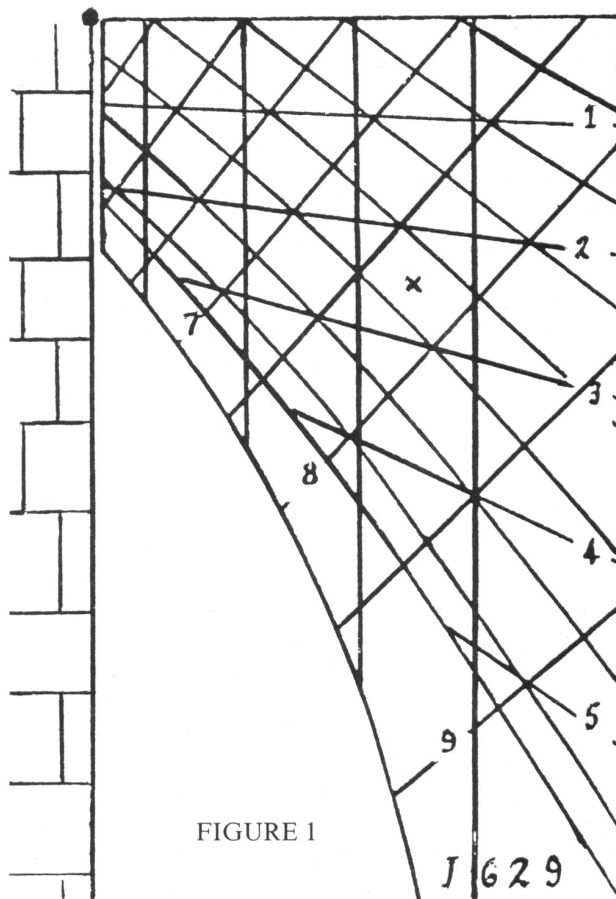


FIGURE 1

An initial glance at the dial (see Fig 1), reveals a rather confusing set of lines which on closer examination can be broken down into four separate sets, of which three are quite straight, the fourth being curves inclining downwards to the right. These lines are merely painted upon the surface of the stone, none of the lines are engraved. There seems to be no gnomon, however a more careful search reveals a short projection on the corner of the nearby buttress to the left of the dial. Since this is so short it must be regarded as only one part, or the tip, of a gnomon whose indicating edge is parallel to the earth's axis. In addition the edge of the buttress itself casts a shadow, this will be referred to later in this outline. Note also that the dial is on the north facing wall of the chapel and therefore the sun will rise on the left of the dial, and the following explanation will be rather confusing since most of us think in terms of south-facing dials with the sun rising on our right to the East.

Supposing the site to be clear to the horizon, the shadow of the projecting bullet will be thrown horizontally across the dial face at each dawn when the sun reaches the horizon providing the sun is rising north of the dial face. As the sun climbs in the sky, the shadow descends, reflecting inversely the motion of the sun. The only position of the projection to meet these

requirements is at the same level on the nearby buttress as the top line on the dial. It follows, therefore, that the curved lines are declination lines, so that at the Summer Solstice about 21 June, when the sun reaches its maximum zenith height in the northern hemisphere, the shadow falls upon the declination line nearest to the buttress, i.e. on the far left. After this the shadow will move in the course of the year towards the Winter Solstice and the furthest excursion to the right of the dial, these indications reflecting the change of the sun's declination from $+23\frac{1}{2}^{\circ}$ to $-23\frac{1}{2}^{\circ}$ because of the inclination of the earth's axis relative to the plane of the sun. The complete pattern is not shown simply because the orientation of the dial only allows shadow indication during the summer months, the dial is non-functional in winter.

During the course of a single day, the shadow commences at the horizontal line and descends along (or parallel to) one of the curved lines until the shadow of the gnomon no longer falls on the wall. In actual fact one of the set of curved lines is straight and corresponds to the indication at the time of the Equinoxes when the sun's declination is zero and the day commences at 6 am and ends at 6 pm. Referring to Fig 1, the six o'clock line meets the upper horizontal line, and the declination line also meeting this point is seen to be uniquely straight, and furthermore it is inclined at 38° to the horizon line, the co-latitude of Oxford.

Thus the sequence of diagonals correspond to the hour and half-hour lines on a sundial, the position of the shadow in respect of these lines therefore gives the local solar time for Oxford. These are numbered 7, 8 and 9, with each alternate unnumbered line being the half-hour. In the actual dial, the hour lines are gilt to make it easier to distinguish them. The sixth hour is unnumbered, and there is no distinguishing mark against each half-hour either. It can be seen from the photograph that the edge of the buttress helps the eye of the observer to the gnomon indication although the shadow of the protruding cornice above rather spoils the clarity of the indication. To obtain Greenwich mean time from the dial it is necessary to add five minutes because of the displacement from the Greenwich longitude, and also the Equation of Time correction.

The third set of intersecting lines, numbered 1 to 5 are declination lines corresponding to a particular sunrise on the hour or half-hour. This is rather different to usual dials where the declination lines are shown against months or the position of the sun in the Zodiac. These lines sloping gently downwards therefore show the time from sunrise on that particular day.

Finally there is the set of vertical lines, parallel to the edge of the buttress, these are not used for time indication, when the shadow of the edge of the buttress falls on each in turn, this indicates that the sun is at a particular point in the sky with respect to the four cardinal points of the compass. These are, moving from inner left to outer right, 80° east of south, due east, 80° east of north, 70° east of north, and the edge of the dial corresponds to 60° east of north.

In order to make the azimuth lines fit in with the time and declination lines, it is necessary to have a bullet or gnomon of just over one inch diameter. A temporary gnomon of plaster was used in 1972 to verify all the

previous points, and for the first time, possibly for over two centuries, the dial had meaning for the observer again. This was about 343 years after the first construction (for the dial bears the date 1692 at its lowest point), and after a whole series of repainting over the many years since; however a 1906A ICL Computer (long since extinct) was used to verify the line positions, and this showed that the delineation of the dial was still essentially correct. The present gnomon is a brass bullet.

In the diagram the point marked with an "X" indicates the local solar time of 7.45 am, the sun having risen about $2\frac{1}{2}$ hours previously, the declination is approximately $+7^{\circ}$, and the sun is almost 75° east of north.

This account is based upon that of Geoffrey Bath who wrote an article which appeared in 1972 in the Merton College Magazine - *The Postmaster* under the title of "The Chapel Dial".

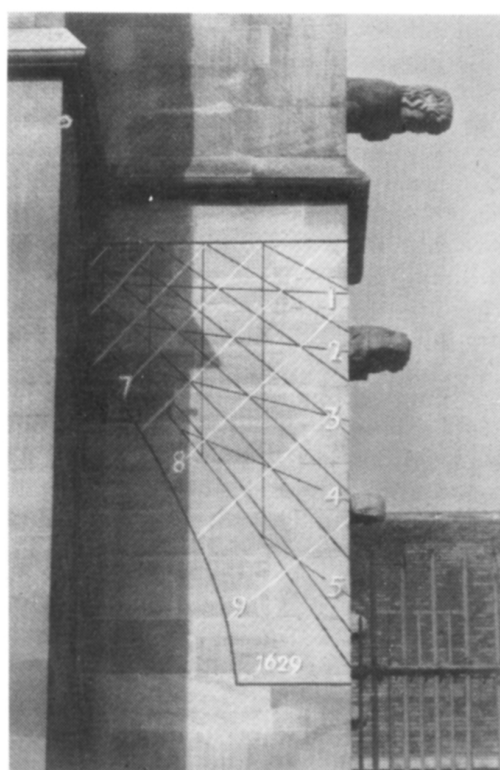


FIGURE 2

In this article the author speaks of the sun rising at each dawn to throw a shadow horizontally across the dial, this can only occur whilst the rising sun is to the north of the plane of the dial, and is the reason why the dial cannot give an indication at all in the winter months, for the sun remains behind the indicating plane all the time during that period. The dial can only show the time under the best circumstances between 5.30 am at the first appearance of a shadow and 10.00 am when the shadow finally leaves the dial. As a time indicator this sundial is therefore of very limited application and appears to be the result of a purely academic exercise to prove some point rather than a desire to produce a practical time indicator to serve a community. Even the intended service is limited by the nearby college buildings which make the sunrise a non-event for the sundial, for the sun must rise above these obstructions before it can begin its work on the dial.

KIRCHER'S SUNFLOWER CLOCK

BY JOHN BRIGGS

Use is often made today of the term “suncllock” in connection with sundials, especially of the analemmatic variety. If this name is brought into common usage, it may well become an entry in the standard English dictionaries, for English is a constantly changing and evolving language; at present it is not to be found even in the largest compilations. From a technical and etymological viewpoint, the word “suncllock” is quite incorrect when applied to a sundial; for the term clock should in all strictness apply to a device which signals given times by means of a bell. There are a few such true clocks to be found even today, for example if you are standing in the road outside the Imperial College of Science and Technology just off Exhibition Road, South Kensington, you will hear the striking of the hours but will search in vain for the dials of a public timekeeper, the mechanism is in St George’s tower which carries no dials. Similarly in the Close outside Salisbury Cathedral, the hours are struck as they have been for the last six centuries, but no dial will be seen below the spire to indicate the hours. These are the true clocks, a name derived from the word signifying a bell, and the link with the bells used in monastic houses to signal the times of prayers, meals and other activities. The time to sound the bell was first given by sundials, later water or sand clocks, and much later by small weight-driven mechanisms, known as monastic alarms, which warned the keeper of the “clock” or bell that it was time to strike the bell. Eventually the mechanism was improved so that it could strike the bell automatically without the intervention of a man and thus eliminate the drudgery of the task.

By common usage, the term clock is now applied to any mechanical or electrical timekeeping device which is not carried on the person, the term watch being applied to time-keepers small enough to fit in a pocket or be worn on the wrist, or even as a fob, pendant or ring. Yet originally the term “watch” was used for the time train of a clock, since the early use of such a device was for those charged with keeping the watch or vigil, even today we refer to night watchmen.

Although there is a thin dividing line between technical correctness and practical use, we generally regard a clock as some mechanism devoted to time measurement. Clepsydrae which use the flow of water to measure periods of time are also referred to as water clocks, yet sand glasses or hour glasses, or time glasses as the writer prefers to call them, are never called sand clocks because there is a distinct series of devices which are referred to in this way. “Sand glasses” often do not have sand in them, and many of them run for much less than an hour, so these generic terms are strictly incorrect, hence the preference for “time glass” for devices involving the solid flow of particles to indicate the end of a given period of time. As such a device cannot measure time continuously, although it may be arranged to sound a bell at the end of its measuring period, it cannot be classified as a timekeeper or a clock, although some have been arranged to turn over automatically and drive an indicating pointer over a dial. These just about creep in as somewhat inadequate timekeepers.

KIRCHER'S SUNFLOWER CLOCK

Athanasius Kircher (born 2nd May 1601 at Guisa near

Fulda, died 28th November 1680) was a German who was professor of philosophy, mathematics and Oriental languages at Würzburg. He took a very great interest in devices for time measurement. In 1641 he wrote a treatise - *Magnes: sive de Arte Magneticum. Opus tripartitum* “*The Magnet: or on the Magnetic Art. In three parts*”. The text was in Latin, and the first edition published in Rome, for at that time he was teaching mathematics at the Collegio Romano in Rome; the second edition was published in Cologne. He was a Jesuit, having been educated at the Jesuit college at Fulda.

In this book many water clocks are described, some of quite imaginative appearance, in which the various actions are moved by magnets. More interestingly to BSS members are the items on page 508, these refer to “plant clocks”, amongst which is the “Sunflower Clock” shown in the accompanying illustration.



Before going into detail with the illustration, it is necessary to know something of the plant “sunflower”. Most of us are familiar with these tall annual flowers, often one may reach a fantastic height and be recorded in the newspapers. The sunflower is any species of the genus *Helioanthus*, and the one with which we are most familiar is the *Helioanthus Annuus*. It is also known as a heliotrope (from the Greek *Helios* - sun, and *trepein* - to turn), because the leaves and flower of the plant turn to present the maximum area to sunlight, essential if such a large plant and flower are to be synthesised in a short growing season. Such action comes under the heading of photokinesis, photoperiodism and phototaxis. Since the flower head turns to point at the sun, it is possible for a short period in the year to make use of this turning phenomenon in a “flower clock”.

Kircher's engraving shows a large sunflower growing in a circular trough, to the centre of the flower is fixed a light rod or pointer, and the daily motion of the flower in following the sun moves this pointer against a circular scale uniformly divided into hours, a somewhat optimistic scheme of things. The scale is held by two hands, from where these spring is difficult to understand, although the two cloud-like objects at the sides of the scale are actually two cherubs, looked at from above their heads. The sun's rays should, of course, be at right angles to the flower head (the sun is depicted at the top lefthand corner), but artistic licence is necessary to be able to show both fully. The two smaller sunflowers at the side are obviously being trained since they have not learned to turn their heads fully to the sun.

Under the flower, on the scroll, are the Latin words "Artis et Natura corriugium", roughly art and nature improved. Further below, on the trough is the message "Annos circitie Sol tempora Signat et horas. Omni Solisequataea, Sunia Solis agit", roughly "the year's turning of the sun indicates the time and hours". Above the whole is the Greek inscription ΩΡΟΣΚΟΡΙΟΝ ΕΑΙΟΤΡΟΝΚΟΝ, the writer's erudition does not extend to translating this.

In spite of having grown many sunflowers and observed the daily movement of the flower heads (these return to the starting position during the night to be able to greet the dawn sun), the writer has never thought of using one to indicate the time, and so cannot comment upon the practicality of the idea. The period during which the flower head is available for such use is so limited that it seems it was intended as a mere whimsy rather than a practical clock. As soon as the flower head is fertilised

and the seeds develop, it no longer follows the sun because the great weight bends the stalk so that the underside becomes an umbrella to protect the seeds from rain.

So here we have a device which is motivated by the sun and can act as a timekeeper, yet it is not a sundial. Kircher went on to publish another book in 1646 under the title of *Ars magna Lucis et Umbrae. In X Libros digesta. . . .* This is a very large book of about 800 pages in ten sections, of which parts III, IV, VI and VIII deal with dialling, not surprising since the title of the book is "The Great Art of Light and Shadow". An earlier book by Kircher, *Athanasius Kircheri primitiae gnomonicae catoptricae* was published in Avenione, 1636; the translated title is "Athanasius Kircher - primitive shadow gnomons". These books are quite difficult to find and for most members it will be necessary to visit the British Library to consult a copy.

If anyone is considering the making of such an ornamental clock for the garden, it would be better to make an artificial sunflower of suitable dimensions and turn it by means of a mechanism in the base rather than depend upon the uncertainty of availability of a real flower and sunshine. Where the cherubs with adult hands can be obtained today for the purpose of holding the scale is not known to the writer, possibly slender rods could be used to support it, or the "flower" stem be made of a fixed tube with a rod going up the centre to turn the flower head. Three short supports from the top of the fixed tube would then be adequate to secure the circular scale, and the cherubs dispensed with if thought desirable. Or perhaps it would be better to put the effort into making a true sundial.

A WORD FROM THE EDITOR

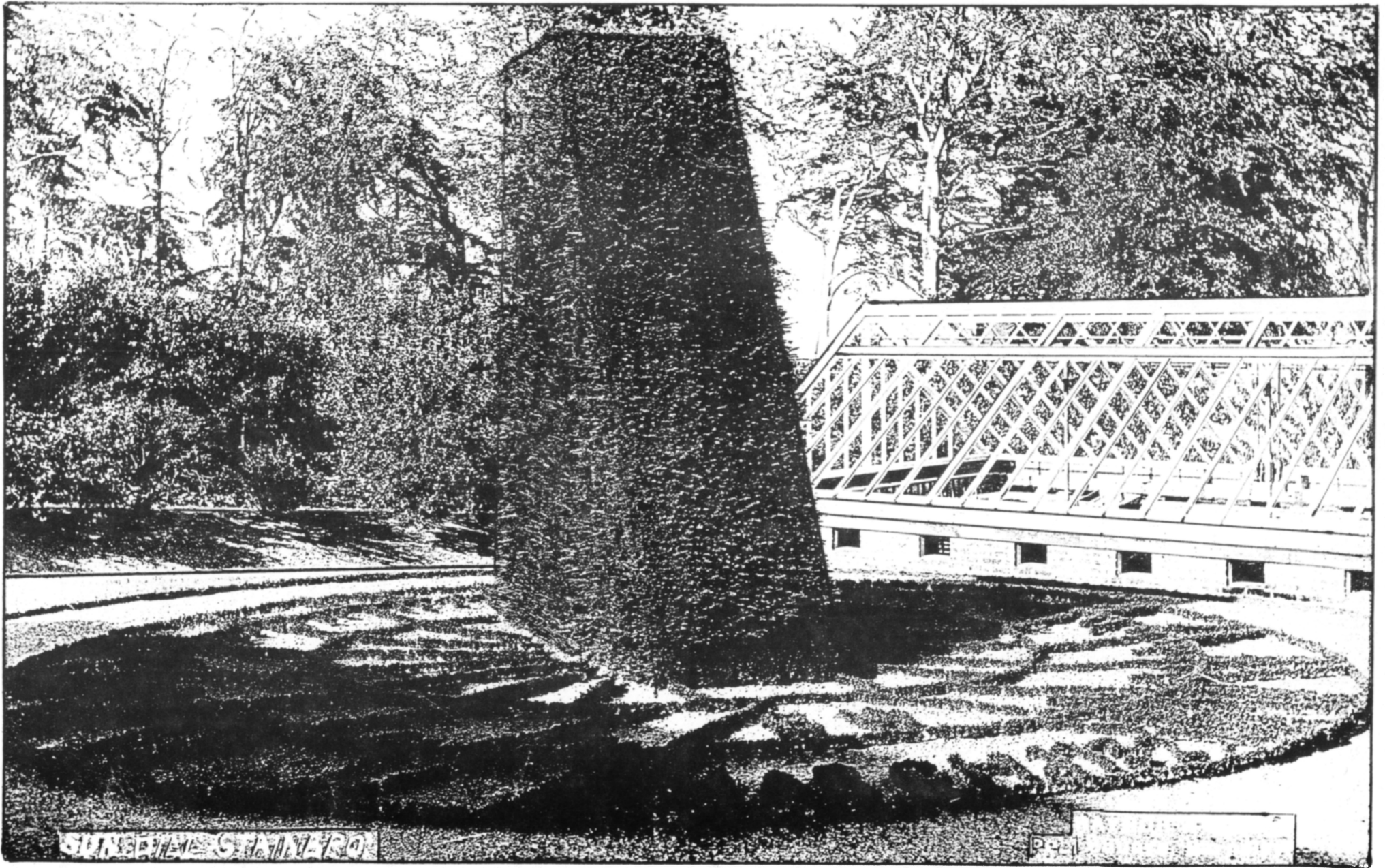
Articles and letters from BSS members are welcomed. Our authors, sadly, are only rewarded by the prestige of appearing in an authoritative journal, now read throughout the world. Since most of the BSS funds are devoted to publishing the *Bulletin* there is nothing left to pay authors for their work. Authors may request additional complimentary copies of the *Bulletin* in which their work appears, or arrangements can be made for multiple copies at cost.

Letters are a particularly easy way of entering the field of authorship, but remember there may be brickbats if you are in error, so check your facts carefully. Some people spend a great deal of time looking for mistakes. If your letter grows too long, it may well become an article in its own right. Editors welcome concise letters which are to the point and informative. Controversy adds excitement and spice as long as it remains impersonal.

Submitted material should preferably be typed with double spacing between lines, on one side only of A4 sheets, with a generous space above and below to allow the Editor to exercise his skills. If this is not done, it means retyping, since the text gets so mangled with changes and additions that the person setting the text for printing has a most difficult task. Mathematical sections are particularly difficult if not set out clearly and well

spaced, the presentation should be unambiguous so that the Editor also may understand it; normal conventions and symbols must be used. Illustrations - black and white photographs are the ideal, line diagrams and engravings - ok, less preferable are colour prints, especially if lacking contrast, but can be dealt with if there is nothing better. Drawings should be set out clearly and be of an adequate standard with fairly thick lines, poor drawings and smudgy photocopies require work to be done to make them presentable - this has to be done by an unwilling Editor.

At present there is a queue for material to appear, a newly submitted article may have to wait for a few months before space is available for its publication, letters should appear in the first available issue. The combined talents of the publication team can deal with French, Italian, German and Dutch texts, but the Editor prefers English if at all possible. Authors need not worry about perfection of literary style or punctuation, but accuracy of facts and figures is absolutely essential. With the increased sensitiveness in respect of copyright, do not use other people's material without first securing written permission, it is permissible to quote from a source, but better to be safe than sorry. If you are using IBM word processor, a disc may be sent.



This topiary sundial was featured on a picture postcard published by Ray Noble of Barnsley, Yorkshire. The “Stainbro”, which may be visible at the lower left of the illustration, is Stainborough, a small locality 3 miles ESE of Barnsley. The postcard was loaned to Mr. Chris Ketchell and sent to the Editor by our member Mr. John Lynes.

USEFUL ADDRESSES

Mr. Charles K. Aked 54 Swan Road WEST DRAYTON Middlesex UB7 7JZ	[Editor]	Tel: 0895 445332
Mr. C. St. J.H. Daniel 57 Gossage Road PLUMSTEAD COMMON London SE18 1NQ	[Chairman]	Tel: 081 3178779
Mr. R.A. Nicholls 45 Hound Street SHERBORNE Dorset DT9 3AB	[Treasurer]	Tel: 0935 812544
Mr. P. Nicholson 9 Lynwood Avenue EPSOM Surrey KT17 4LQ	[Sponsorship]	Tel: 037 27 25742
Mrs. Anne Somerville Mendota Middlewood Road HIGHER POYNTON Cheshire SK12 1TX	[Library, Archival Records & Sales]	Tel: 0625 872943
Mr. Robert B. Sylvester Barncroft Grizebeck KIRBY-IN-FURNESS Cumbria LA17 7XJ	[Membership]	Tel: 0229 89716
Mrs. Jane Walker 31 Langdown Road Little Sandhurst CAMBERLEY Surrey GU17 8QG	[Education]	Tel: 0344 772569
Dr. I.D.P. Wootton Cariad Cottage Cleeve Road GORING-ON-THAMES Oxon RG8 9BD	[Registrar]	Tel: 0491 873050
Mr. D.A. Young Brook Cottage 112 Whitehall Road CHINGFORD London E4 6DW	[Secretary]	Tel: 081 529 4880