The British Sundial Society

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BULLETIN 94/2 - JUNE 1994 - CONTENTS

Cover Illustration - A German Chalice Cup Sundial in an unusual six-pointed star shape. It is fitted with a polar gnomon. Within the three supporting arms beneath the cup is a magnetic compass to enable the dial to be aligned correctly on the meridian.

DIALOGUE

DE ZONNEWIJZERKRING

The General meetings are now held in Amersfort as it is a central spot for the whole country. At the September meeting reports of various activities of other societies were given and various suggestions were made by members, including that important articles from the Bulletin should be translated into English and widely circulated. A number of ideas were illustrated which it is hoped will form the subject of articles in future issues.

A description is given of an interesting dial in Snellegem, West Flanders. It shows the time in a number of places with all gnomons pointing the same way with the dials turned to allow for difference in longitude. There follows a description of how the dial is constructed, and the author comes to the conclusion that it does not work correctly.

The definition of time by atomic vibration has led to differences with other systems which are discussed in an article with some mathematical details. Then follows an article on the path of the sun and another on a sundial that will show sidereal time.

The various lines that can be drawn on sundials are then discussed and many diagrams are included to show the types of information that can be indicated. A page from an almanac of 1829 is reproduced showing the length of the day at 52° 23′ N through the year. An interesting sideline is a reproduction from a comic of 1972 showing a system of time measurement devised by the Chippewa Indians using two sticks. There follows a list of Dutch people involved with sundials and the periodicals in which they are mentioned. There is a short discussion on the analemmatic and the equiangular hybrid dials and a short article on dials discovered in Israel relating to the reign of Herod.

A member reports on plans to restore the dial at the Janskerkhof in Utrecht and an idea from the BBC Gardeners' World is reproduced on how to make a sundial in one's own garden using twelve strategically placed plants and oneself as a gnomon.

A patent is expensive but there is now a system of registering designs in the Netherlands that is cheaper. It corresponds to the old system in Britain "entered at Stationers' Hall".

E.J. TYLER

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IN MEMORIAM - JOSÉ ANTONIO GARCIA-DIEGO

The death of José Antonio Garcia-Diego of Madrid on 27th January 1994 has been reported to the Editor.

He was a civil engineer and noted for several hydraulic projects, one of which was the reconstruction of Turriano's device in Toledo for lifting water to the city from the river Negus. He also founded the company of Onuba which introduced nuclear technology for civil application in Spain, and many societies dedicated to engineering and nuclear technology. He was a member of eighteen associations, including the British Sundial Society.

He created the Fundación Juanelo Turriano, a privately funded foundation and was its first President; a Vice-President of the Spanish Society of History of Sciences and Technology, a member of the International Academy of the History of Science. He was a corresponding member of the Real Academia de Bellas Artes y Ciencias Históricas de Toledo.

He was outstanding in his lifelong work as a historian of technology, and wrote many articles, reviews, and forewords for the works of others. He organized numerous international exhibitions and attended many more. He wrote many books, mainly on medieval hydraulic engineering.

The writer found him a most kindly and considerate man during several meetings with him both in Spain and England. His passing is a great loss to research in medieval technology.

CHARLES K. AKED

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IN MEMORIAM - GEORGE ROBERT HIGGS 1900-1994

In British Sundial Circles, George Higgs was something of a legend - a 93 year-old with the enthusiasm and ability of someone a third of his age.

He spent much of his time abroad - India, South Africa, Brazil and Argentina, working for Metropolitan Vickers Electrical Company. When World War II came he was working in Brazil. It was there that he met and married Peggy Colson.

Retirement, in 1966, to the Kirkcudbright area brought him nearer his birthplace. A pair of farm cottages were skilfully converted into a comfortable dwelling with a capacious lounge looking out on to an attractive garden, which was crying out for a sundial. He built an armillary sphere on a plinth set in the lawn, and installed a large mural dial above the lounge window.

Sick sundials started to come to him soon after, the 51-face lectern from Culzean Castle, a 57-face lectern from Hensel House, even a humble cube dial from Meadowbank. Mr. Heane of the National Trust for Scotland sought his advice, whilst a rewarding and long-lasting friendship began when George replied to a letter, published in the May 1984 issue of *The Scots Magazine*, asking for information on Scottish sundials. Through this he met Andrew and Anne Somerville, joining in their sundial safaris until Andrew's sad death in 1990, and explains why George was in at the founding of the BSS in 1989.

In 1979, after his wife's death, George moved to a house in Kirkcudbright itself, where he quickly earned a place in the heart of those around him.

His memorials will be the 100 or more dials which came to life under his skilled craftsmanship. Many are the "window dials" of which he was justly proud, designed by him and executed in glass as true works of art by his friend and neighbour, David Gulland.

KEN MACKAY

Editor: A more detailed appreciation of George Higgs will appear in the next issue.

OF ANALEMMAS, MEAN TIME AND THE ANALEMMATIC SUNDIAL - PART 1

FREDERICK W. SAWYER III (U.S.A.)

There is an interesting irony in the fact that the analemma ('Figure 8') curve has become a familiar feature on the classical sundial over the last century and a half, but has only rarely been seen on the analemmatic sundial.[1] One might expect the similarity in names to suggest more of a kinship between the dial and the curve. The purposes of the present article are (in Part 1) to consider this irony - a consideration which requires something of an etymological journey - and (in Part 2) to elaborate on the design of a standard-time analemmatic sundial which reinforces the kinship by reuniting the dial and the curve.

HISTORY AND ETYMOLOGY

In order to proceed, we need to understand the concept of the analemma in a more general setting. Not only is the word *analemma* seldom used today outside of the 'gnomonic community', but when it is used, its meaning tends to be only a narrow derivative of its original sense:

> The word *analemma* means much the same as *lemma;* the analemma is for graphical constructions what the lemma is for geometrical demonstrations; it is a subsidiary figure which is *taken up* to shorten and facilitate the construction of the principal figure.[2]

The particular analemmas which in ancient times proved to be of most use in the design of sundials appear in the works of Vitruvius and Ptolemy. Writing in the first century BC in *De Architectura,* the Roman engineer Marcus Vitruvius Pollio noted that "in order to understand the theory of these dials, one must know [the theory] of the analemma".[3] However, the analemma to which he referred was not the now familiar curve relating apparent and mean time. What Vitruvius alluded to was a *graphical procedure equivalent to what is known today as an orthographic projection.* Although he did not provide instructions for its use,[4] Vitruvius made it clear that the analemma was at the core of the ancient practice of sundials.

Early in the second century AD, Claudius Ptolemaeus wrote *De Analemmata,* a more detailed presentation[5] of a method for projecting the principal circles of the celestial sphere onto a plane - the projection being from a point at an infinite distance along a line perpendicular to that plane. After describing the coordinate system resulting from his projection, Ptolemy presented two distinct methods for determining the coordinates; one method was trigonometric, the other was nomographic - basically, he invented an instrument. This instrument - Ptolemy's analemma - was composed of two pieces: a carpenter's square[6] and a plate of wood or metal with inscribed scales and curves. It allowed one to read values of coordinates directly from the analemma diagram by use of the carpenter's square as a straight-edge.

The analemma is thus also *an instrument which implements a graphical procedure.* This sense of the word is apparent in such references as Regiomontanus' 15th century introduction of a "universal rectilinear analemma"[7] - now generally implemented as an altitude dial on a card; St. Rigaud's publication of his version of that dial as a *New Analemma,*[8] and John Twysden's 1685 *Use of the Great Planisphere called the Analemma.* Note also Valentin Pini's 1598 discussion of Ptolemy's work, in which he introduced his own analemma - a simple armillary dial.[9]

The analemmatic sundial we know today was probably invented some time in the period[10] between 1532 and 1640. The timing could not have been more unlikely for the introduction of a modern sundial based on an ancient analemma:

> [The ancient] type of dial has fallen into disuse, since we stopped dividing the day into temporary hours. The Ptolemaic theory would therefore be perfectly useless to us today, if his constructions could not be equally adapted to the new system . . . When the book of the Analemma was published for the first time by Commandin, in 1562, gnomonics had already been founded on totally different principles. See the Horologiographia of Munster, of which the first edition is of 1531, and the second of 1533.[11]

Whoever invented the dial managed to combine the three senses of *analemma*[12] into a single accomplishment which not only bridged the centuries but transformed an old concept so that it made sense in a world of equal hours - the new paradigm of time measurement.

> [The analemma was] applicable to the ancient dials which, as everyone knows, have their style perpendicular to their face. It had lost all practical utility with the modern dials, based since the 15th century on the inclination of the style parallel to the axis of the world. But the analemmatic dial, with perpendicular style, appearing in the texts of the 17th century, revived the use of the analemma through its geometric construction.[13]

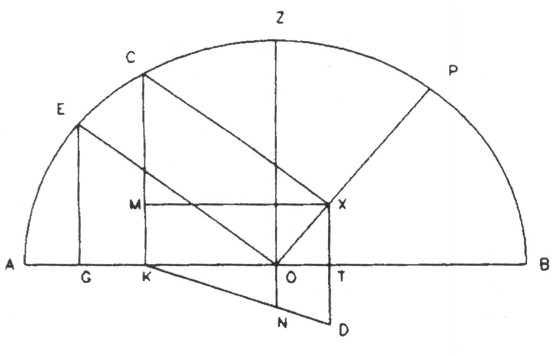
The analemmatic dial is little else than the *graphical procedure* we know as *orthographic projection* turned into an *instrument* to tell time. Its ellipse of hour-points results from an orthographic projection of the sun's path from the pole onto the horizon circle. Authors ranging from Vaulezard[14] in 1640 to Lalande, more than a century later, derived its distinctive declination scale for the placement of the vertical gnomon directly from the traditional analemma drawing.

The 18th century astronomer J.J. de Lalande was born in Bourg-en-Bresse (Ain), France, near the church of Brou, in whose grounds is found the oldest analemmatic sundial in existence.[15] In 1756 he was concerned that the dial was deteriorating, so he had it reconstructed in stone at his own expense. The next year, he communicated to the Académie des Sciences a letter which identified the task of drawing and justifying an analemmatic dial as "one of the most complicated in all of Gnomonics".[16] Lalande complained that earlier treatments of the dial either gave no demonstration that it was correct or gave an unsatisfactory, incomplete demonstration. Although his survey of the prior literature was far from complete,[17] Lalande noted that he was forced to find his own demonstration of the correctness of the dial. In doing so, he "formed an extremely simple rule for finding the place of the style in all the months of the year".[18] But what was the basis of this rule? As he noted himself, it was the ancient analemma.

This figure[20] shows an orthographic projection onto the meridian plane AZB. The horizon is AB, the pole P, the zenith Z, EO the projection of the equator, and CX the projection of the minor circle representing the sun's orbit on the given day. By selecting point D so that the lengths

J.J. DE LALANDE

This dial has been called analemmatic because it is traced by means of the figure known as the *analemma*:[19]



KD and GO are equal, Lalande shows that ND is the correct displacement (*ie.* cos φ tan δ) of the vertical gnomon or style from the dial centre for the given day.

The analemmatic sundial thus relies on the ancient analemma to divide the day into modern solar hours. But what does this have to do with the analemma curve? So far, nothing. Our next task, then, is to consider the modern meaning of *analemma*.

We begin by returning once again to the ancient analemma, which generally was drawn as a projection onto the meridian plane, thus lending itself to the representation of noon time shadows.

> The analemma's relation to dialling is evident in the first step of its construction. Two perpendicular lines are drawn to represent a gnomon . . . and its equinoctial noon shadow.[21]

By projecting the daily circles of the sun's path onto the meridian plane, the analemma naturally registered the various positions of the noon time sun by the length of the gnomon's shadow. Implementing this graphic scenario as an instrument or analemma would be a natural evolution. Indeed, we find reference to such an ancient instrument at least as early as 1753:

> *Analemma* in ancient writers denotes those sort of sun-dials which shew only the height of the sun at noon, every day, by the largeness of the shadow of the gnomon.[22]

If, then, *analemma* once referred to an instrument which focused on the recording of noon time shadows, the transition to an instrument which does the same under the "new" definition of the time is an easy one to make.

The analemma curve which is familiar to us today was conceived in 1740 by Jean Paul Grandjean de Fouchy, secretary of the *Académie des Sciences* in Paris.[23] The curve provided a graphic representation of the equation of time and was intended for use on meridian lines; indeed, it was called the *meridienne de temps moyen* (mean time meridian).[24] As such, it was clearly useful in the design of sundials, providing an easy graphical method of showing the difference between apparent and mean time. The curve was not restricted to the meridian, and appropriate variants of it found their way to each hour-line of the classical sundial. Consider, for example, the 1876 sundial by Father Ildéphonse at the convent of Cimiez-sur-Nice in France.[25] This dial superimposed an analemmatic curve on each hour-line; the dial carried the legend *Temps Vrai et Temps Moyen* (True Time and Mean Time). Now, more than a century later, this technique still plays a prominent role in many of the modern sundials available for purchase today.[26] As early as 1826 the analemma curve was incorporated into a dial by the Abbot Guyoux as the target for a spot of light;[27] this approach was improved and patented by Paul Fléchet[28] in 1860 and 1862. Just five years later, on 21 May 1867, Lloyd Mifflin was granted the first US Patent[29] for a gnomon incorporating the shape of the analemma curve. The innovation of shaping the gnomon so that it reproduces the analemma and registers mean time on an equatorial hour-ring has since appeared in many popular sundials; in 1966 the three winners of a *"Sundial of the Year 2000"* contest all benefited from this device.[30]

And yet, analemma curves are rarely to be found on an analemmatic sundial. Our etymological investigation has tracked them both to a common ancestry; we need now to effect a reunion.

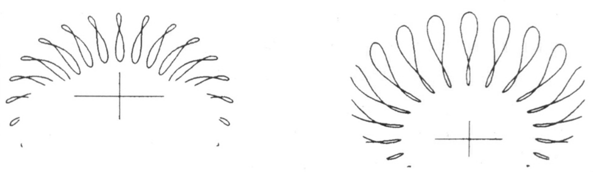
POLYANALEMMATICS

In 1970 Hermann Egger of Zurich Switzerland published a brief description[31] of one method for adapting the analemmatic sundial to register mean time. The resulting dial, which Egger referred to as a polyanalemmatic, associates each of the hour-points on the elliptical hour ring with an analemma curve. Egger eliminated the declination scale along the meridian line and arranged the analemmas so that if, at mean time *T*, the vertical gnomon is placed at the appropriate date on the analemma curve for *T*, then the gnomon's shadow will fall on the *T* hour-point.

As Egger suggested, this dial might be of primary interest as a large installation in a public park, where passers by might be enticed to walk among the analemmas to find the correct one to use by observing how close their shadows come to the hour-point associated with the curve. Unfortunately, this arrangement does not lend itself well to an instrument to be used as a sundial. Instead of being able to position the gnomon and then watch the time pass by as its shadow progresses through the hour-points, this dial effectively requires a new placement of the gnomon every hour; and the diallist may try a number of the analemmas before discovering the right one to choose. It is also very difficult to obtain any reasonable reading between the hour-markers, since the gnomon is properly in two different positions when it records the two times at either end of the interval and should in fact be at neither of those positions in the interim.

Figure 1

POLYANALEMMATICS FOR LONDON



$F_S = 1.25$ $F_W = .625$ $F_S = 1.0$ $F_W = 2.0$

A more useful dial results if the model provided by Father Ildédhonse, as noted above, is followed more closely. To accomplish this, replace each hour-point by an analemma curve, and retain the normal declination scale on the meridian line. In this way, the vertical gnomon is stationary throughout any given day and time is read by the intersection of its shadow with the proper date points on the analemma curves representing the hours. In operation, this is similar to the Ildéphonse dial. The additional requirement of moving the gnomon each day is a trade-off for the resulting convenience of not having to distinguish the exact end-point of the gnomon in order to read the time - the intersection of the shadow and the curve suffices.

Given this general description, there are many different ways in which the analemmas can be calculated and arranged. Two examples are given here[32] in Figure 1.

COORDINATES

Given constants F_s and F_w for a polyanalemmatic sundial and the equation of time ε_δ depending on the solar declination δ, determine the coordinates (x_δ, y_δ) of the analemma curve for mean time T.[34]

* * *

$$S = .5 \times \sqrt{(\cos T \sin \varphi - .44343 \cos \varphi)^2 + \sin^2 T}$$

$$W = .5 \times \sqrt{(\cos T \sin \varphi + .44343 \cos \varphi)^2 + \sin^2 T}$$

$$D_\delta = SF_s + WF_w + 2.30718 \tan \delta (SF_s - WF_w)$$

$$\cot Z_\delta = (\cos(T - \varepsilon_\delta) \sin \varphi - \tan \delta \cos \varphi)/\sin(T - \varepsilon_\delta)$$

$$x_\delta = D_\delta \sin Z_\delta \qquad y_\delta = D_\delta \cos Z_\delta + \cos \varphi \tan \delta$$

In these equations, the values of F_s and F_w, chosen to be constant for each dial, significantly affect the layout. A value of 1.0 for F_s will place the summer solstice date for each analemma curve at approximately[34] the same location the hour-point would have occupied on the traditional elliptical hour ring. A greater value moves this date farther out on the defining shadow, and a smaller value brings it within the perimeter of the ellipse. The choice of a value for F_w has a similar impact on the placement of the winter solstice date for each analemma. The equations then position all intervening dates at appropriate points so that at apparent time $T - \varepsilon_\delta$ the shadow of the gnomon will correctly intersect the analemma corresponding to mean time T.

Unfortunately, this dial continues to suffer from the difficulty encountered when trying to read the time between analemmas. It is possible to add more curves, but they quickly begin overlapping and the decorative dial becomes more and more confusing. We will look elsewhere for a more practical approach.

EXPERIMENT WITH ANALEMMAS

The ancestor of all existing analemmatic sundials, the dial which Lalande rebuilt in 1756 at the church of Brou, was restored once again in 1902. The craftsman charged with its restoration was an amateur diallist who decided to overlay an analemma curve on the meridian line. The dates were not marked on a linear declination scale; they were noted only on the curve itself. This situation quickly resulted in the common belief that the vertical gnomon or erect visitor should be stationed on the curve rather than the meridian in order to cast a shadow on the hour-ring.[35] There is of course no justification for this arrangement; it introduces significant error into the dial design.

In Kennet Square, Pennsylvania USA, not far from Philadelphia, there is a 1050 acre horticultural park, Longwood Gardens.[36] The park is on the former country estate of Pierre S. duPont (1870-1954). The park's last construction project overseen by duPont was the design of a 37 by 24 foot analemmatic sundial in what is now a Topiary garden in the park. The dial was completed in 1939 after more than six years of daily noon-time observations:

> After about eight months of trying to see [calculated] measurements, Mr. duPont got disgusted and said we would build the sundial ourselves after working out our own measurements. Both Roland Taylor and I [Knowles R. Bowen] began the task of taking actual observations on the sun at 12 noon every day, after checking our time with the Naval Observatory at Annapolis. If the sun was not out, we could not get that day's sighting until the following year, or maybe two years later, which explains why the project took so long.[37]

At some point during this long process, a visit was made "to France to check out a sundial there; we copied some details, but the dial was not too accurate . . .[38] - presumably this was the dial at Brou. Some years later, in 1946, duPont commissioned additional work on the dial, to reposition the hour-markings on the ellipse. One can only wonder if the purpose behind this change was to attempt to correct the errors which no doubt were becoming obvious in the dial readings. The errors would have resulted from placing a standard analemma at the centre of an analemmatic sundial, thus perpetuating the design flaw begun at Brou - a flaw which could not be corrected by a change in the hour-markings.

In the late 1960's another analysis was done on the Longwood Gardens dial, enlisting the assistance of P. Kenneth Seidelmann of the U.S. Naval Observatory. Measurements showed that the hour-points were positioned for standard time readings, but the double analemmas then at the centre of the dial[39] proved to be little more applicable to a proper design than a single analemma. To address this problem, Seidelmann developed a weighted average approach to defining substitute analemma curves which resulted in a close approximation to mean time.[40] The engraving of a new pair of analemmas was undertaken in 1978, and the Longwood Gardens dial was thus corrected in a novel way.

Part 2 of this article will be dedicated to developing the mathematics behind the Longwood Gardens adaptation.

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1. This article assumes a basic familiarity with the traditional analemmatic sundial. On a horizontal plane with coordinates pointing to the cardinal point, x increasing to the east, and y increasing to the north, the dial point corresponding to apparent time t is ($\sin t$, $\cos t \sin \varphi$). These points lie on an ellipse with an east-west semi-major axis of 1 and a north-south semi-major axis equal to $\sin \varphi$, where φ is the latitude of the dial. The gnomon is a vertical rod which is positioned daily at the point ($0, \cos\varphi \tan\delta$), where δ is the solar declination for the given day.
2. Delambre 1817, p. 458. English translations of excerpts from Delambre, Janin and Lalande, here and elsewhere in the present paper are by the author. Note the italicized *taken up;* the etymology of the word is ultimately from the Greek *ana* (up) and *lemma* (taken). Louis Janin alludes to the same sense of *analemma* as does Delambre: "en employant alors ce mot, comme beaucoup d'anciens auteurs, dans la sens de procédé de résolution graphique". Janin 1974, p.8.
3. The reference is to *De Architectura 9.8:* Ex quorum libris, si qui velit, subiectiones invenire poterit, dummodo sciat analemmatos descriptiones.
4. Gibbs 1976, pp. 107-108 cites the work of modern commentators such as Gustav Bilfinger and Joseph Drecker who have provided detailed instructions for the use of the orthographic projection in the design of specific types of sundials. For a more recent study culminating in the development of a horizontal sundial showing temporary hours, see Drinkwater 1993.
5. For a discussion of Ptolemy's analemma see Gibbs 1976, pp. 109-117, and Delambre 1817, pp. 458-503. Unfortunately, not all of Ptolemy's work survives, so even this more detailed discussion of the analemma does not yield specific instructions for dialling. Thus: "nowhere in the preserved part of the analemma does Ptolemy explain why his six angles . . . might be of interest to diallers". Gibbs 1976, p. 116.
6. A carpenter's square is the etymological origin of the word *gnomon.*
7. See Delambre 1819, p. 326.
8. See Delambre 1819, p. 330.
9. See Delambre 1819, p. 626. The reference is to Valentin Pini's publication of *Fabrica de gl'horologi solari* in Venice.
10. The oldest texts on the analemmatic sundial are Vaulezard 1640 and 1644; the earliest treatment in English is Foster 1654. Foster also considers a number of interesting variants, including a dial with nonvertical gnomon and equispaced hour-points, and a retrograde dial whose hour-points are all on a finite segment of a single straight line; see Sawyer 1991 and 1992. The oldest known analemmatic is the famous dial at the church of Brou, in Bourg-en-Bresse (Ain), France. Virtually every discussion of this topic in the literature makes an obligatory reference to the Brou dial. Verbal tradition suggests that the dial is as old as the church, which dates from 1506; but there seems to be no real evidence for the tradition. Janin 1974, p. 14 points out that the first written mention of the dial does not occur until the 18th century. It would seem more likely that the dial, which was originally in the cemetery of the church, was not constructed until after the 1532 publication in Paris of Oronce Finé's *Protomathesis*

which included a comprehensive treatment of dial types but no mention of the analemmatic sundial. Finé's treatment of dialling was published separately in 1560 as *De Solaribus Horologiis,* and has recently been paraphrased in English by Drinkwater 1990.

11. Delambre 1817, p. 472. The first reference is to Frederico Commandin's publication of Ptolemy's work in Rome. The second is to Sebastian Munster's *Compositio Horologiorum* 1531 and its renamed second edition *Horologiographia* 1533; the book was the first publication surveying all types of dials showing equal hours and having a gnomon parallel to the celestial axis.
12. The Oxford English Dictionary (first edition) gives the following etymology: L. *analemma,* the pedestal of a sun dial, hence the sun-dial itself Gr. αναλημμα, a prop or support, from αναλαμβ–αν–ειν, to take up, resume, repair. Thus the word itself, as borrowed from the Greek, is intended to suggest the idea of a support. The reported etymology takes this suggestion very literally (*ie.* a pedestal); while the sense to which we have alluded is more figurative, with the analemma providing graphic support to shorten an otherwise more difficult construction. Going beyond the etymology, the OED gives four definitions of *analemma.* One of them corresponds to the figure 8 graph to which we will turn presently; a second is simply "a sort of sundial". The remaining two correspond to the other senses we have explored here: "orthographic projection . . . as used in dialling"; and "a gnomon or astrolabe [*ie.* an instrument] . . . used in solving certain astronomical problems".
13. Janin 1974, p.3.
14. Vaulezard 1644. For a historical review of the different proofs for the analemmatic dial, see Janin 1974.
15. See Note 10 above.
16. Lalande 1757, p. 483.
17. He did not find either Vaulezard or Foster.
18. Lalande 1757, p. 483.
19. Lalande 1757, pp. 484, 488.
20. The figure is virtually identical to the one given in Vaulezard 1644, which is reproduced in Janin 1974, p. 7. The construction was cited by many authors, even after simpler constructions were found.
21. Gibbs 1976, p. 105.
22. See the Oxford English Dictionary (1st ed.) entry for *Analemma,* which cites this passage to support its listing of "a sort of sundial" as the first meaning of the word.
23. Attributions appear in Delambre 1819, p.637; Apel 1990, p. 66; and Boursier 1936, p. 175. A more detailed discussion of the context of and the evidence for this invention are given in Gotteland 1990.
24. What is still missing at this point is the first historical connection of the word *analemma* with Grandjean de Fouchy's mean time meridian. The author would be pleased to have such a citation. In French, the curve is still the meridienne de temps moyen; the German and Italian word are *Zeitgleichungskurve* and *Lemniscata,* respectively. English seems to be the only language linking the curve to etymological roots in the ancient analemma.
25. For an illustration of this dial, see Boursier 1936, p. 174. Pictures of this dial, based on the Boursier illustration, have appeared in a number of dialling books.
26. Examples of firms specializing in producing sundials of this variety are Ameco Sundials of Poulsbo, Washington USA and Celestial Arts & Sciences of Santa Fe, New Mexico USA. The latter firm refers to its offerings as analemmatic sundials, when they are in fact classical dials with analemma curves replacing the hour-lines in a manner similar to the Ildéphonse dial mentioned in the text of this article. The usage of the *analemmatic sundial* terminology in virtually every modern text on dialling would suggest that its application to a classical dial, based on a gnomonic rather than orthographic projection, is either incorrect or it heralds a significant shift in dialling terminology.
27. Cited in Apel 1990, p. 67.
28. U.S. Patent #35,225 issued 13 May 1862 to Paul Fléchet; Apel 1990, p. 67.
29. U.S. Patent #64,982 issued 21 May 1867 to Lloyd Mifflin.
30. The contest was conducted by Hermann Egger in the pages of *Sky & Telescope* magazine. See Egger 1966.
31. Egger 1970.
32. The omitted portions on some of the analemma curves in these illustrations correspond to dates and hours at which the sun is below the horizon.
33. Note that, as given, these formulas do not uniquely determine the value of Z. However, since Z represents the solar azimuth, its value must range between -180° and +180°, and it must have the same sign as the apparent time $T - \varepsilon_\delta$. With these additional conditions stipulated, Z is uniquely determined.
34. The placement is approximate because we have simplified the formulas of S and W by using T instead of $T - \varepsilon_\delta$.
35. For a discussion of this situation and the indignation it created among diallists, see Janin 1970.
36. The author is indebted to Colvin L. Randall of the Longwood Gardens staff for his help in providing information on the history of the Longwood Sundial.
37. Thompson 1976, p. 93, quoting recollections of engineer Knowles R. Bowen.
38. Thompson 1976, p. 94.
39. It is not clear when the double analemmas became part of the sundial. The published recollections of Knowles Bowen, the engineer, and comments by George Thompson, who was duPont's personal secretary (Thompson 1976), seem to suggest a single analemma on the original dial; this view is supported by the reports of noon-time readings being taken. However, no one seems to be able to recall a time when the dial did not have a double analemma arrangement, and there is a photo in the Thompson book (p.94) of Bowen with two gnomons astride two analemmas; the photo is undated.
40. Seidelmann 1970 and 1975. Developing on this idea, a large sundial foundation with weighted-average double analemmas was designed by Albert M. Thorne for a mall area at the University of North Carolina at Charlotte. Unfortunately, funding was not obtained for the sundial fountain, and the Longwood Gardens dial remains as perhaps the only large standard time analemmatic sundial.

(To be continued)

CELESTIAL DIALS: AN UNUSUAL "NOCTURNAL"

GIROLAMO FANTONI (ITALY)

Sundials have obvious limitations in their use because they require the presence of the Sun and thus cannot operate by night. As a logical consequence early diallists, with the aim of measuring time also after sunset, turned to the Moon and Stars, devised instruments to be used with these celestial bodies.

In the golden centuries of dialling, particularly after the fifteenth century, a number of night instruments were developed; and although they never reached the popularity and diffusion of the daytime counterparts, still enter into dialling history and deserve their due interest today.

Sometimes a day dial and night dial were combined into one and the same instrument to produce a "continuous dial", usable during all the twenty-four hours of the day. When this permanent dial was manufactured in a portable form, it took the functions in a futuristic way, of the present-day wrist watch.

Now let us see, very briefly, how a combined solar-stellar dial could be structured.

THE PORTABLE DIURNAL CLINOMETER

Among the solar dials, the one that is most suitable to be inserted in a combined portable "day and night dial" is certainly the "altitude dial", namely the one that from the daily variable solar data uses the altitude of the Sun to give its indications.

In the diurnal section of a combined dial, our ancestors often used the altitude sundial called a "clinometer" (Fig 1). The type of dial is a small plate on which the appropriate time and date diagrams are engraved or drawn; the instrument is completed by a sight to aim at the Sun, and by a plumb bob which indicates the inclination of the plate and the altitude of the Sun when this is sighted.

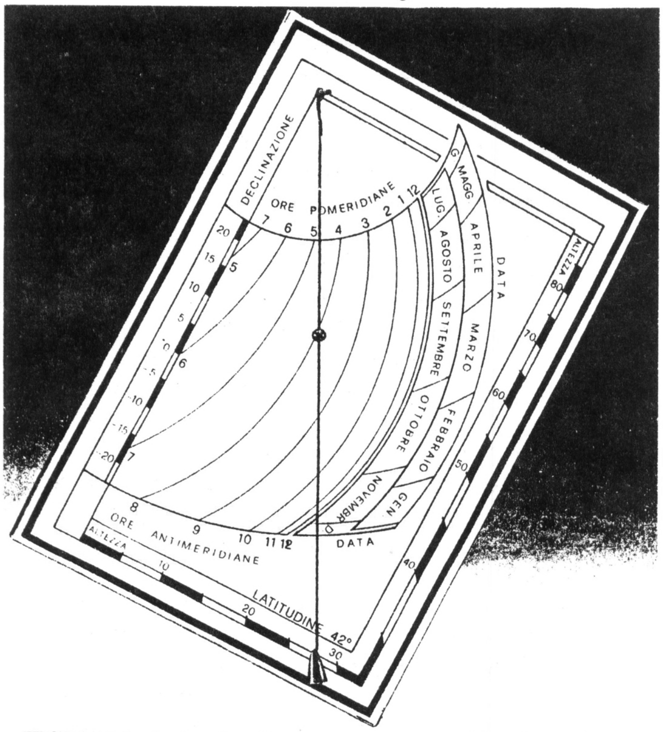

FIGURE 1: A simple clinometer constructed by the author. The bead on the plumb bob indicates the hours 8 am and 4 pm.

Along the plumb bob thread a bead can be shifted up and down, and adjusted in position in accordance with the date (Fig 2). When the Sun is seen through the sight, the position of the bead indicates the time on the dial hour scale. Since the Sun reaches the same altitude twice each day, the operator must select the correct hour between the

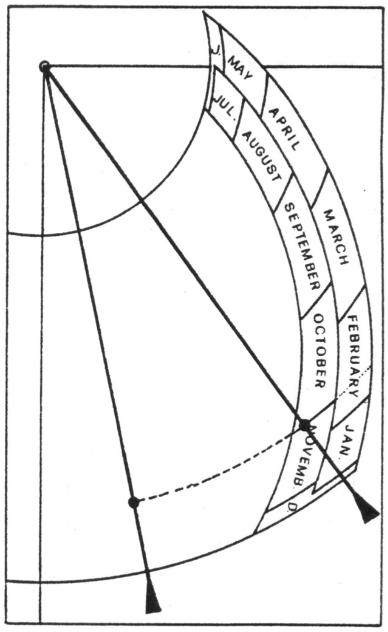

FIGURE 2: In a clinometer the moving bead should be set in accordance with the date. Here the date is 1 November or 9 February.

AM and PM hours. For example in Figure 1 the choice should be made between the symmetrical hours 8am and 4pm.

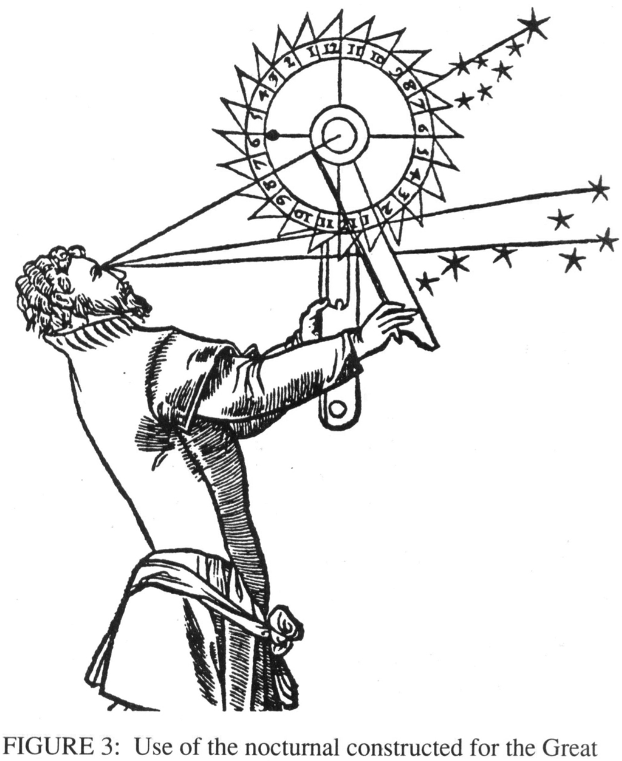

FIGURE 3: Use of the nocturnal constructed for the Great Bear - Ursa Major (from a sixteenth century print by Petrus Apianus).

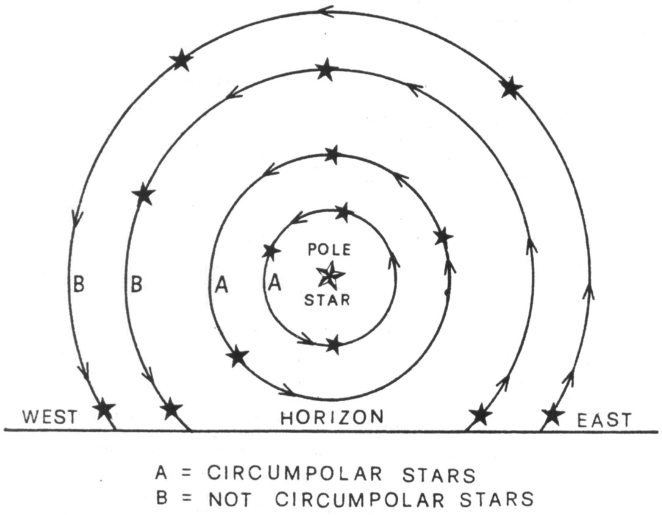

FIGURE 4: During the daily rotation of the firmament, the circumpolar stars do not set, and are over the horizon for the full twenty-four hours of the day.

THE CLASSICAL PORTABLE STELLAR DIAL

The stellar dial (Fig 3) is also generally a flat dial; therefore it is well suited for its application to a combined "day and night instrument", because the two dials can be combined and located on the two separate sides of the same plate.

The simplest version of a stellar dial is the so-called "nocturnal", which uses the rotation of the firmament around the Pole Star. If we take the sky as the dial of a watch, and the line joining the Pole Star and another star as the hour hand, it would be easy to establish a relationship between the position of the stellar-hand and the hours (the date should also taken into account because the speed of the stars are slightly different and their relative positions change day by day.

In the past, the stellar-hand generally was made with the star Dubhe of the Great Bear, or the star Kochab of the Little Bear (sometimes also Schedar of Cassiopeia was used). This choice was dictated, since in order to organize a permanent celestial watch, it is necessary to use stars that remain over the horizon throughout all the nights of the year. Astronomers call such stars "circumpolar" (Fig 4). At our latitudes, the main circumpolar stars are those of the Great Bear, the Little Bear, and Cassiopeia.

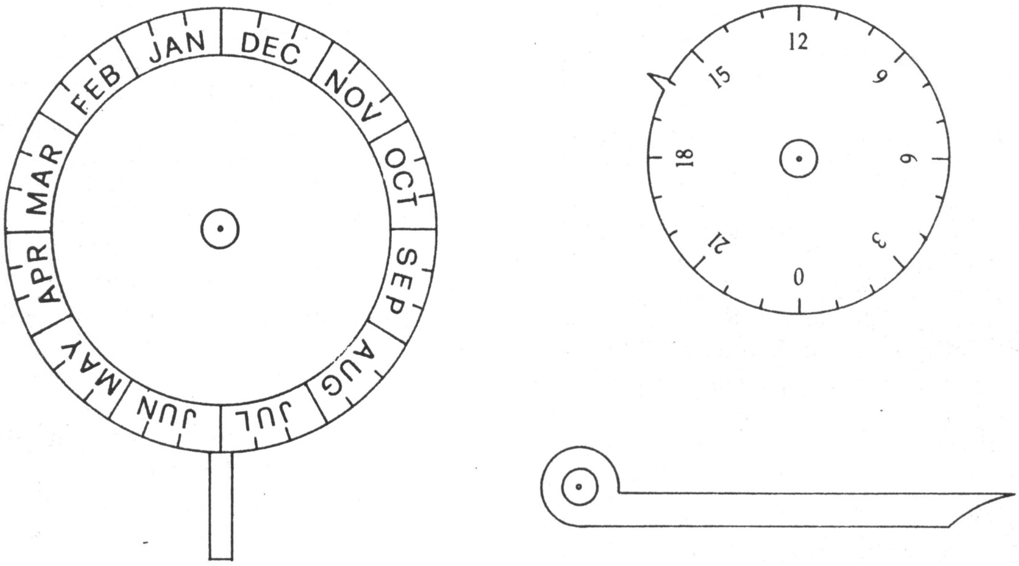

FIGURE 5: The three elements of a nocturnal.

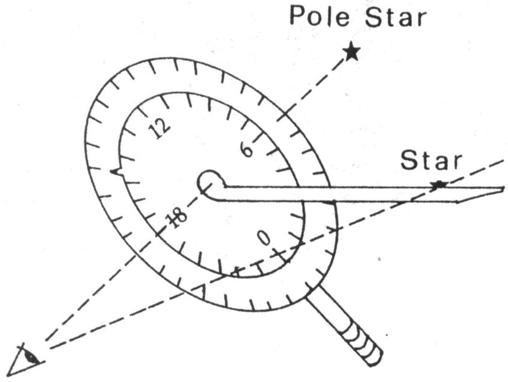

FIGURE 6: Use of a nocturnal with the star for which it is constructed.

The simplest nocturnal consists of three elements (Fig 5):

1 A supporting disc with an handle, and on its edge a numeration of twelve months (365 days) marks the complete yearly cycle counterclockwise.

2 A concentric smaller dial with a twenty-four numeration on its edge; this indication runs anticlockwise, a tooth on the edge is in such a portion that the zero hour stays at the inferior point when it indicates the date on which the Sun and the selected star have the same right ascension,(ie they are both on the same meridian).

3 A pivoted cursor centred on the disc centre.

In the centre of the nocturnal a little hole serves to point the instrument at the Polar Star. Since this instrument is a night device, the diurnal hours from 6 am to 6 pm may be omitted in the smaller ring.

To use this dial it is necessary first to place the tooth of the smaller disc on the date; then (see Fig 6) holding the plate almost parallel to the Equator and in such a position that the Pole Star can be seen through the central hole, move the cursor until it touches the selected star, in this position the cursor shows the hour on the smaller disc.

The clinometer and the nocturnal that has been described may be installed on the two sides of a small plate to obtain a portable day-and-night usage dial. Nothing further needs to be said on this subject; it has been presented only as an introduction to the following instrument; it is a nocturnal worthy of special comments and a detailed description.

AN UNUSUAL NOCTURNAL

Recently a combined "day-and-night dial" was submitted to me by its owner (Mr. Licini from Pescara) for a technical evaluation. At a first glance the object seemed to be a combined portable dial, similar to the one I have just described; but the structure of the night section gave rise to some perplexities, since it presented a number of discrepancies. The instrument is rather small, engraved over an almost square copper plate, with each side about 6.5 cm long, it can be held easily in the hand.

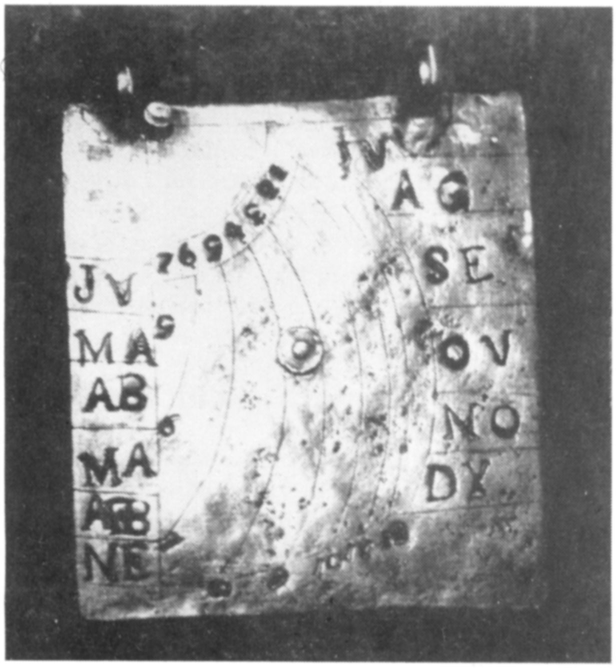

FIGURE 7: The "day" side of the combined "day and night" dial made by Cecyl Yode in 1762. The dial is a clinometer, identical to the one shown in Fig 1.

On one side of the plate there is a clinometer (Fig 7), almost identical to the one previously described (Fig 1). This diurnal dial does not require further comment, its sight is readily apparent on the upper side; the plumb bob is not present but its point of attachment is clearly visible near the fore element of the sight [right-hand side]; the engraving and the overall craftsmanship appear rather rudimentary.

On the other side of the plate (Fig 8) there is a rotatable disc pivoted at its centre, with a double hours numeration 0-12 on its edge; on the periphery of the disc there is also the expected protruding tooth. Close to the centre two inscriptions - "GRANADA MR'R CECYL YODE" and "ANO - DE 1762" clearly indicate where the instrument was made, its author, and the year of its construction. On the fixed part of the plate, the peripheral annulus is divided into the twelve parts of the year, indicated by the first two letters of their Spanish names.

The revolving hour disc with the projecting tooth and the outer sequence of months clearly indicate that this instrument is a nocturnal, inserted on the back of the plate to give it an additional "night" capability. But immediately a strange puzzle arises because both the hours and the months rotate clockwise, whilst in all other known nocturnals (the ones which use the Pole Star as centre of the dial, necessarily rotate anticlockwise. It is apparent that this instrument is not a classical nocturnal.

A reversed rotation of hours and months can be justified only if we look at the firmament towards the South, but in the Southern region of the sky there is no fixed Pole Star, hence there cannot be a celestial hand made by visible circumpolar stars.

After an intensive study, I believe I have reached a fair conclusion: this strange night instrument must be a

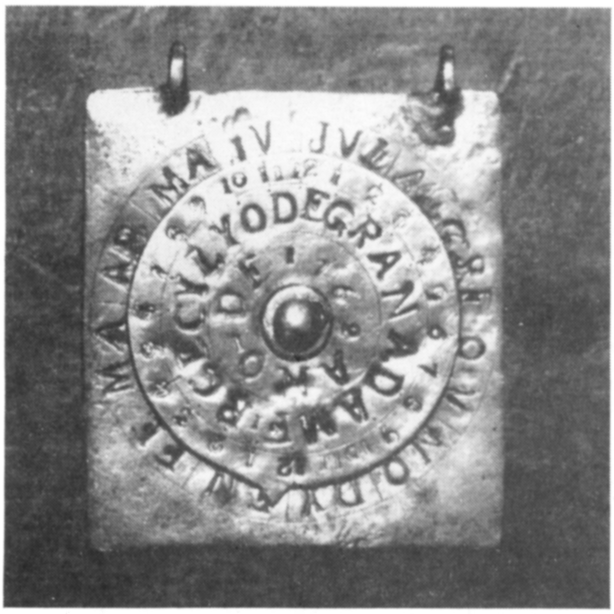

FIGURE 8: The "night" side of the Yode portable "day and night" dial. The reversed rotation of the days and of the hours is apparent; here they rotate clockwise.

FIGURE 9: The two inscriptions in the centre of the rotatable disc ("GRANADA MF'R CECYL YODE" and "ANO - DE 1762") show the place, maker and year of making.

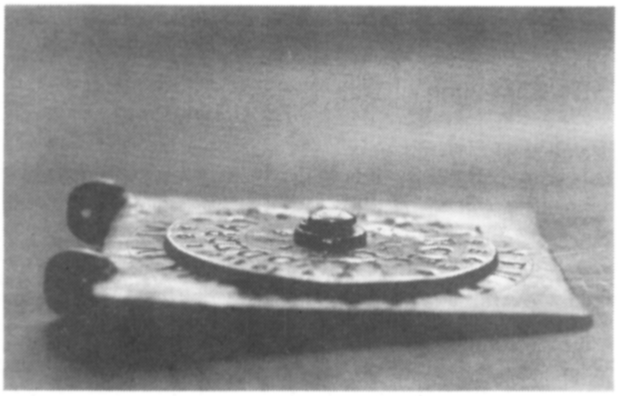

FIGURE 10: A perspective view of the Yode combined dial. The details of the diurnal sight and the point of attachment of the thread acting as the night cursor are clearly visible.

"Southern nocturnal" built, not to be used with the Pole Star and a Bear Star, but with a couple of stars opposed in right ascension; a search in the stars catalogue, together with a comparison with the construction of the instrument, showed that the two stars must be Sirius (Alpha Canis Maioris. magnitude -1.6) and Vega (Alpha Lirae, magnitude 0.11), by chance two of the brightest stars in the sky (1).

Sirius and Vega, in the very favourable situation of being almost perfectly opposed right ascension (their difference in right ascension stays around 178 degrees, show up in alternation in the visible sky. In all the nights of the year one of the two stars is always over the horizon, although they are not circumpolar (2).

The cursor for alignment of the star and the hour reading was here replaced by a thread; it is now missing but its point of attachment is clearly visible in the photographs (Figs 8 and 10), near the centre of the dial. The duplication of the numeration of the hours can be justified here because whatever the position of the disc may be, a complete set of 12 hours must stay in the upper part of the instrument, where the two stars always appear when they are visible.

A solid confirmation of this interpretation is obtained with a few elementary calculations. Sirius and Vega reach opposition to the Sun respectively on the 1st of January and 30th June; on these two dates the setting of the hour disc places the twelfth hour exactly on top of the vertical superior radius; when at midnight the Sun is on the inferior meridian (hour 12) Sirius or Vega (whichever is in opposition to the Sun) shows that the time is midnight.

The study to decipher this strange dialling problem was rather taxing, especially because, in spite of the extensive bibliographies I consulted, I found no mention of other dials working in such a way.

I must say that Cecyl Yode (if he actually was the author of the "Southern Nocturnal" had a very brilliant idea when he realized that the two beautiful stars Sirius and Vega were almost on exactly opposite meridians of the celestial sphere. Finally I need to comment that Mr. Licini, to whom this instrument was sold as a "perpetual calendar!", should consider himself rather lucky for the acquisition of this unique nocturnal for his collection.

REFERENCES

1 The three most brilliant stars of the sky are, in the order, Sirius, Campus, Vega.

2 For those readers who wish for more details, I will add that the two stars, situated almost on opposite meridians (the right ascension for Sirius is 101.2 degrees and for Vega 279.2 degrees) have declinations respectively of 16.7 degrees South and 38.5 degrees North. Consequently throughout the year Sirius rises a short time before Vega sets, and sets a little after Vega rises, there are periods and hours when both stars are visible in the Eastern and Western sections of the horizon. In any case one of the two stars is always visible in all the nights of the year, from a dialling point of view, this star couple performs the task of a single polar star.

ERRATA

It is regretted that errors creep into the articles within the Bulletin in spite of much time and effort expended in trying to prevent these.

Bulletin 93.3 - Professor J.G. Freeman's article "Determination of Local Solar Time . . .", page 23:

1. OBSERVATIONS, line four should read *Lengths of OP, OB_1, OB_2 are measured, as are the angles between OB_1 and OB_3, and between OB_2 and OB_3 . . .*

2. CALCULATIONS . . . Penultimate line of (5) should read $A_1 = A_3 + \alpha$

   Formula (9) should read *Tan* $A_3 = \dots$

3. NUMERICAL EXAMPLE . . Line 3 should read $a_2 = 47{\cdot}4°$

Bulletin 94.1 - Mr. Michael Hickman's article on "Sun Compasses":

Page 17, left-hand column, third paragraph, for 'Blanford' read - *Blandford.*

At the end of this paragraph for '. . . there as significant differences.' read - . . . *there are significant differences.*

Page 21, left-hand column, penultimate paragraph, for 'These ellipses are hyperbolae . . .' read - *These ellipses and hyperbolae . . .*

The Editor himself does not consider that these slight printing errors will have deceived or confused any BSS Member. See also pages 46 and 47.

RING DIALS

JOHN MOORE

There are three different types of ring dial that are normally encountered.

a) THE POKE DIAL.
b) THE EQUINOCTIAL RING DIAL.
c) THE ASTRONOMICAL RING DIAL.

All are basically Altitude Dials and work on the principle of measuring the sun's altitude. They are self aligning, not requiring the aid of a compass to determine the direction of North or South. The gnomon is generally a pin hole through which a small spot of light passes onto the hour scale on the inside of the ring.

THE POKE DIAL

This dial is so called because it was carried in the poke or pocket. It is the simplest form of ring dial and was relatively cheap to make. It was probably the only type of dial that could be afforded by the average man, although from the small numbers extant, it perhaps did not gain the great popularity that might have been expected.

FIGURE 1: Poke Dial by T.W. c1700

In its commonest form (Fig 1), it consists of a plain flat ring of metal having a diameter of about 2 inches. The hour scales are inscribed on its inner surface. The gnomon, which in this case is a pin hole, is cut into a moving band that fits into a groove in its outside diameter. The band slides around the circumference enabling it to be set against a calendar scale to correct for the sun's seasonal change in altitude. On most dials there are two pin hole gnomons, each on opposite sides of the ring, one for Summer and the other for Winter. Correspondingly there are two internal hour scales.

In use, the dial is held by the hand, suspended by a cord or ribbon which is attached to a lug on one edge. Gravity holds it vertical while the dial is rotated for the sun's rays to pass through the appropriate season's gnomon and fall on the correct scale on the ring's inner surface. As it is simply an altitude dial there are no means for the user to know from its reading whether the time is before noon or after noon. A knowledge of the position of North would be of help, but the user would probably rely on his body clock, or stomach, for this information. At the time of the manufacture of these dials, (around 1700), the exact hour was of little importance to the average gentleman. Time keeping was imprecise, probably being no closer than an hour or more from the correct figure.

This type of dial was not intended for travel and was only correct for one particular latitude. Each of the hour scales is divided into three marked A, B, and C. The hour calibrations are not straight across the inside of the ring but are at an angle (Fig. 2). On the outside of the dial next to the joint in the sliding gnomon ring, the same three letters are to be found (Fig. 3). It is therefore necessary to use that part of the scale indicated by the appropriate letter. The reason for this variation across the scale is due to the fact that as the gnomon is slid around the outside of the ring its distance from the internal hour scale will vary, necessitating the correction.

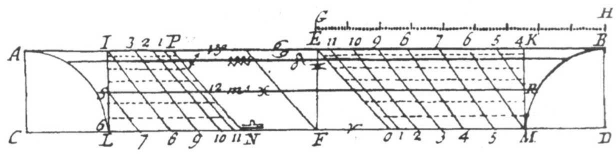

FIGURE 2: Internal Hour Scale Markings of a Poke Dial as illustrated by Bion.

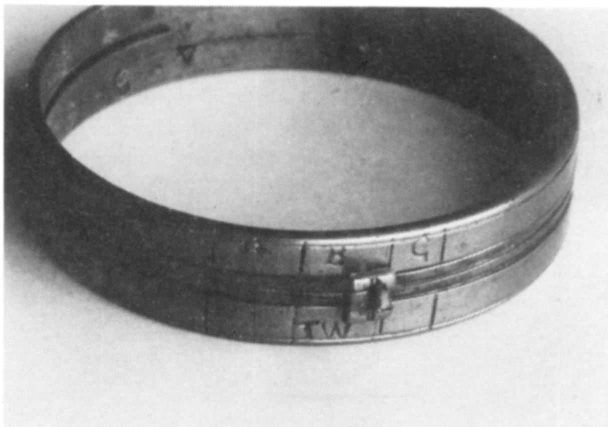

FIGURE 3: Poke Dial by T.W., showing the three bands A, B & C. It clearly shows the irregularities of the Punch Markings.

The Poke Dial illustrated is signed simply 'TW'. Several virtually identical dials are known by this, as yet, unidentified marker and a comparison between them reveals some interesting facts. The calibration marks are applied quite crudely with punches and details such as misalignment of particular letters or numbers, such as A, B and C seen in Fig. 3 are identical on all TW dials so far examined. This leads to the conclusion that the markings were applied in groups and not individually as may first be expected. It is difficult to imagine how a multiple character punch could be made. It is quite possible that these dials were produced on some type of rolling machine where the brass ring was pushed against a set of fixed punches, apparently an early form of mass production. Naturally the scales and calibration marks were applied to a flat piece of metal that was later rolled. It was subsequently joined by brazing near the suspension loop. Close inspection shows that when the dials were hooped, the bending was greater at the points where the metal had been weakened by its calibration lines.

Many forms of Poke Dial are known of sizes varying from less than one inch to three inches or more in diameter. Those from the better makers are usually engraved rather than punched. Some only have one pin hole gnomon with a subsequently more complicated hour scale. Others even have an 'S' shaped internal scale that helps to correct for the errors caused by their outer curvature.

An interesting variation on the poke dial is the signet ring dial which was worn on the finger. When removed it would be stood on its flat face and was aligned so that the sun's rays would pass through a hole in its edge onto the hour scale engraved on its inside. Owing to their small size, the accuracy of these dials would have been particularly poor.

Most poke dials were made of brass or bronze, but dials to be worn on the finger, often of gold.

THE EQUINOCTIAL RING DIAL

This is the traditional ring dial that most of us associate with the name. It was originally developed from the Armilliary Sphere by Gemma Frisius in 1557, but its final form was only arrived at when the Reverend William Oughtred published a description of it in 1652. Many instrument makers turned their hands to this design, at first in London and later on the Continent. One of the better known exponents of the style was Henry Wynne who published 'The Description and Uses of the General Horological-Ring Dial' in which he describes the dial in detail and explains how it would be used. The dial in silver by Henry Wynne shown in Fig. 4, conforms almost exactly to the details given in his booklet.

FIGURE 4: Silver Ring Dial by Henry Wynne, c1680.

This type is also 'Universal'. This means that it can be used at any latitude. Many were also made that could be adjusted for use in the Southern Hemisphere. A Universal Equinoctial Ring Dial by 'John Naish 1707' is shown in Fig. 5. The scale on the left is for setting its latitude and covers both hemispheres from pole to pole. In use the suspension ring is set for the latitude so that the dial would then hang in the correct position for it use. The inner of the two rings is folded out so that it is at 90° to the outer ring. It carries the hour scale which is divided into 24 equal parts numbered **I - XII** twice. This 24 hour calibration makes the ring dial truly 'Universal', but most dials made solely for use in the Northern Hemisphere usually have a small gap around midnight. Their makers obviously did not expect them to be used north of the Arctic Circle.

FIGURE 5: Ring Dial by John Naish, dated 1707.

Across the centre of the inner ring is a bridge supporting the sliding pin hole gnomon. This bridge may be said to represent the Earth's axis with the two poles at either end. It is necessary to set the pin hole in the correct position that corresponds to the sun's current altitude. To facilitate this, a calendar scale is provided. On the reverse side is usually an alternative Zodiac scale and often a scale for the sun's declination calibrated $\pm 23\frac{1}{2}^\circ$. Wynne also describes a further scale across the bridge, this time not universal, but for London only, showing the times of sunrises and sunset throughout the year. This is seldom seen on ring dials.

When suspended in the open position, the sun's rays would pass through the small pin hole gnomon. The dial would be carefully rotated until the small spot of light fell on the line inscribed around the inside edge of the chapter ring. In theory this is quite easy, but in practice, it requires a steady hand. If the dial is being used outside it will obviously sway in the wind, so a sheltered spot is desirable. These dials were made with thin rings to reduce the effects of wind. If it were used on the deck of a sailing vessel, as many were, the ship's movement would have added to the problems. The spot of light is very small and quite difficult to see on the inside ring.

A useful guide to the dating of British made dials is from the date of the first point of Aries, (the Vernal Equinox), when the sun's declination is 0°. If the gnomon is set at this point, the reverse side of the bridge will indicate a date on the calendar scale. On the Naish dial this shows as the 10th March. The modern Gregorian Calendar gives the Equinox as 21st March confirming its 1707 date which was when the older Julian Calendar was in use. The new calendar was adopted in Britain as late as 1752, but considerably earlier in some parts of the Continent. This method of dating dials must be used with care and does not apply to Continental made instruments. On the reverse side of the outer ring there is usually a simple Nautical Quadrant calibrated from 0° to 90° (Fig. 6). This is utilised by inserting a pin in the hole at the top right between the towns of Cracouy and Bordeaux. The suspension ring should be set at 0° and the shadow of the pin will then fall on the quadrant scale giving a measure of the sun's altitude. This reading would enable the user to determine the latitude of his location by reference to the tables of the sun's altitude. It is also possible that the quadrant could be used for finding the altitude of other celestial bodies. With a bit of ingenuity it could also be used for checking the heights of mountains or buildings with the aid of simple trigonometry. When used horizontally an angle could be found between two features on land or sea. However, other instruments dedicated to these more complex functions would generally be used at this time.

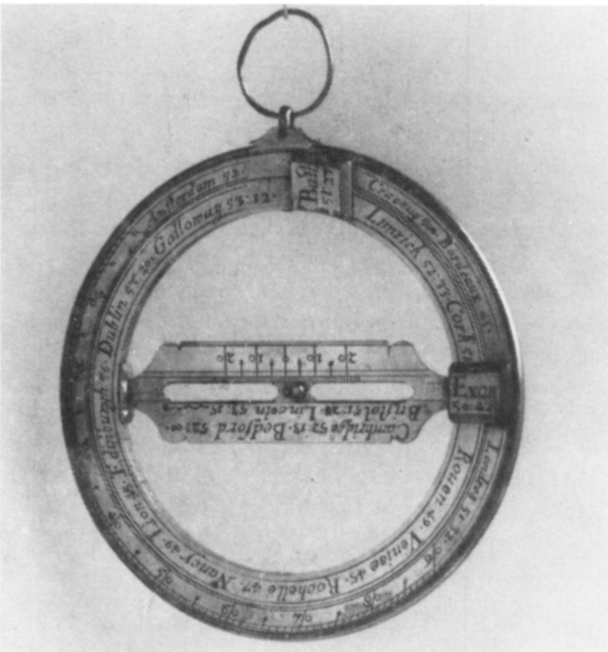

FIGURE 6: Nautical Quadrant on the Reverse of an Unsigned English Dial. c1690.

Like the poke dial, this is also an altitude dial with no means of indicating am or pm. At noon the outer vertical ring obscures the shadow for about 15 minutes either side of the hour. Furthermore, at the two equinoxes the horizontal ring obscures the sun completely. This ring is, of course, representing the Equator and is in exactly the same place as the sun at this time. This makes this type of dial unusable for about one week either side of each equinox. The only real solution is to change the gnomon's date setting, or the latitude setting by a few degrees, ignoring the small error that would result.

These dials were universal and therefore intended for use by travellers. Most are engraved with the names of various towns and cities throughout Europe, (sometimes further afield), and their latitudes (Fig 6). There is relatively little space on their slender rings to provide comprehensive lists, but their makers were inventive and used any available space. With some of the longer town names they would frequently resort to abbreviations. The dial by Henry Wynne actually uses the outside edge of the chapter ring to squeeze in seven more towns.

Studies of ring dials show little variation in style. They were eventually made over most of Europe, mainly between the years of 1680 and 1800. Those that are unsigned can sometimes be attributed to particular countries from their list of towns. The design almost certainly started in England following William Oughtred's description and it was soon followed by makers on the Continent. Examples are found from many countries but in particular Germany, France and Poland.

The dials were predominantly made of brass and bronze but some very beautiful ones are made of solid silver. Occasionally the brass may have been silvered or gilt. Sometimes one of the rings would be silvered and the other gilt. They would all have had individual carrying cases, (Fig. 7), except for those that were included as part of a set of mathematical instruments made for the scientific minded gentleman.

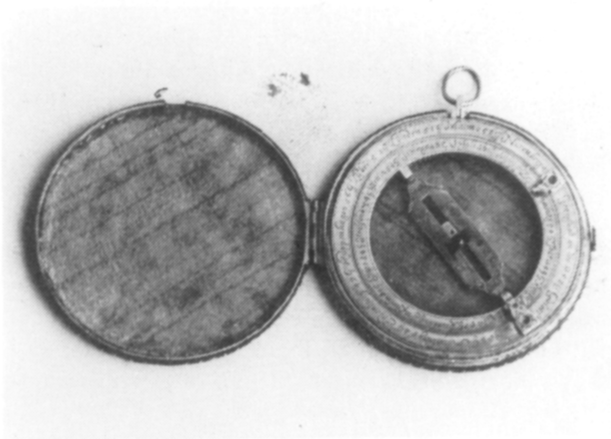

FIGURE 7: Silver Ring Dial in its Case, c1690. Possibly German.

Most ring dials are around 4 inches in diameter, but examples are known from less than two inches to twelve inches or more, their accuracy increasing with their size.

Their suspension systems are worthy of study in their own right. The author has noted at least ten different methods of attaching the sliding suspension loop to the outer ring. The Universal Equinoctial Ring Dial is potentially very accurate and some large ones were made complete with a stand (Fig. 8). These would sit on a solid surface, possibly just inside a window, and could be accurately levelled with three screw feet and the aid of the built in bubble levels. Some stands also included a magnetic compass so that the dial could be correctly and semi-permanently set. Alternatively it could be used to check the local magnetic variation. The dial itself could often be lifted off its stand so that it was still portable, offering the added flexibility of inside or outside use.

FIGURE 8: Standing Ring Dial by Thomas Heath, London, C1750.

THE ASTRONOMICAL RING DIAL

It is similar in general appearance to the Universal Equinoctial Ring Dial but with its addition of one further ring plus an alidade. These dials were not very common but their method of construction overcame the disadvantage of the loss of time readings at noon and at the equinox (Fig. 9). The Hour ring on these dials is set in the polar axis and the time is read at the point where the inner ring crosses it. The inner ring has a rotating alidade. This is essentially two pin hole sights, one at each end of an arm, which could be lined up so that sunlight passing through the upper one would fall exactly through the lower one. This was a very accurate method of taking observations and was used on many astronomical instruments. It also saved the observer's eyesight making it unnecessary to directly look towards the sun. The alidade was built on the side of the inner ring and this offset helped to prevent the eclipse of the shadow of noon.

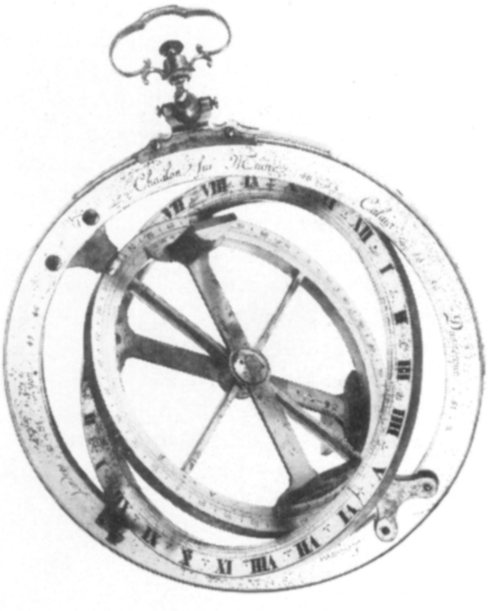

FIGURE 9: French Astronomical Ring Dial

This dial too was frequently set up on a stand it accurate measurements warranting the extra stability thereby provided.

For further information on the Ring Dial, its construction and use, the reader is directed to the well known book by the Frenchman, M. Bion,'The Construction and Principle Uses of Mathematical Instruments'. The English translation by Edmund Stone, published in 1758 was republished in facsimile in 1972. It has several pages devoted to sundials which are described in detail.

ACKNOWLEDGEMENTS

The author would like to thank Harriet Wynter for providing the photograph used in Fig. 8 and The National Maritime Museum for the photograph in Fig. 9.

WINSLOW HALL CALENDER FOOTPATH

(Continued from page 44)

immediately, although it was some time before I was able to progress my thoughts to the design that I now show here.

I initially measured the house sufficiently to allow me to proceed with my project and found a coincidence that lovers of such matters enjoy, the angle from the threshold of the house to the pediment casting the shadow was identical to the latitude of the position of the house. Another coincidence is that Christopher Wren was a competent astronomer.

Having found this relationship I proceeded to project the shadow of the house throughout the complete solar year, and this showed me that the shadow of the pediment was always visible although barely so at the winter solstice. At the summer solstice the shadow of the chimneys had receded completely within the shadow of the pediment.

From this study I proposed a calendar footpath as indicated in Figures 1 and 3. The footpath is a celebration of the shadows of the house and the tip of the pediment is utilised as a gnomon. As the house is built of brick with stone dressings, this is reflected in the path which is of brick and triangular stones which are the shape of the shadow cast by the top of the pediment. The stones represent the entries of the sun into the zodiacal signs and thus provide a solar calendar.

A NOT SO MODERN MYTH

MARTIN BARNES

In the *New Civil Engineer* (Institution of Civil Engineers magazine) of 4th April 1985, there appeared an interesting article about the Box Tunnel on the original London to Bristol Great Western Line, and the presiding genius Isambard Kingdom Brunel who masterminded the project. The 3.2 kilometre long tunnel was the longest ever built at the time of its completion in 1841, and it also employed the steepest gradient used up to then although the line is almost level for ten miles on either side. By 1869 a legend had arisen which was described in the contemporary press, which has had its supporters and detractors ever since. The essence of this legend is that the sun shines right through the tunnel on one day only each year, and that is on Brunel's birthday on 9th April. In 1927 even the official historian of the GWR endorsed this view although he got the date wrong and stated the phenomenon took place on 21st June, possibly mixing up this event with that of Stonehenge and Druid ceremonies.

There are various arguments for and against this legend.

FOR

The tunnel was not really necessary. A longer tunnel free route along the Avon valley was possible, indeed all later lines follow this easier route.

The steep gradient was deliberately concentrated within the tunnel.

The alignment is a deliberate kink in the line.

The line east of the tunnel continues straight for some distance on a short level stretch and then drops at a gradient of 1 in 660. If the line had been curved or steeper, the necessary cutting would have blocked the sun's rays.

AGAINST

Any other alignment would have made the tunnel longer or necessitated a longer tunnel at Middlehill, west of Box.

A different approach to the east could not have run through the valley with its minimum excavation requirements to reach the Box Hill barrier at its minimum barrier width.

Steep grade tunnels are a typical Brunel device.

Brunel was not a conceited man.

Martin Barnes set out to prove or disprove the supposition that Brunel might have deliberately aligned the tunnel to allow sunlight to penetrate the length of the tunnel on his birthday. He did this by calculation of the altitude and bearing of the tunnel axis vis-á-vis the track of the sun. He points out that the nautical almanac he used to obtain the necessary data would have been available to Brunel in similar form in his day. Since in the 1830's the sun could not have shone through the tunnel on Brunel's birthday unless it was realigned by moving the portals by 150 feet in relation to each other, or the gradient steepened to 1 in 50. Mr. Barnes decided that although the required alignment was not difficult, the gradient would have been thought impossible at the time. Since neither of these alternatives was adopted, he concluded that Brunel did not mean to commemorate his birthday in this unusual way.

He further points out that it has never been true to state that the sun shines through the tunnel on one day only, unlike the phenomenon at Stonehenge where the heelstone is touched by the sun once only in the course of a year and that is on midsummer day. The sun may shine through Box tunnel both in April and September, but it will never shine all the way through on Brunel's birthday.

CALCULATIONS

Data from Ordnance Survey map:

Grid bearing of tunnel 79° 45′

Latitude at centre point 51° 25′ 15″

Longitude at centre point 2° 25′ 27″

Correction of grid to true bearing 10′

From Beckett *Brunel's Britain*

Gradient of tunnel: 1 in 100 rising west to east.

Length 9 600 ft, Width 30 ft, Height 36 ft.

Isambard Kingdom Brunel was born at 00.55 9th April, ~~1993.~~

CALCULATION OF TUNNEL AXIS ALTITUDE

True bearing of tunnel axis = 79° 45′ - 10′ = 79° 35′

Altitude at rail level with gradient of 1 in 100 = $\sin^{-1}(0.01) = 34.378'$. The altitude of the tunnel centre line from the centre of the eastern portal to the distant western portal is about 41′, the distant opening appears almost as a point at ground level.

This is little more than half a degree from the horizontal so the sun can only shine through around sunrise. Atmospheric refraction makes the sun appear higher by about 29′ when it rises, the sun is also about 32′ in diameter.

In order to shine through the tunnel the sun must be at a bearing of 79° 35′ and at an altitude of 41′ so that it is centred on the axial height of the tunnel at the eastern end. Figure 1 shows the sun's track from 6th April to 9th April 1985 when the sun almost covered the tunnel aperture completely, and about half on the following day. The first occasion was about one minute after sunrise, the second about three minutes after sunrise.

As the tunnel is just over two degrees west of Greenwich, the time of sunrise is 9 minutes later at Box Hill. Taking also into account that Summer Time began on 31st March, the actual clock time was:

6th April 05.25 + 9 + 60 + 1 = 06.35 Greenwich Mean Time
7th April 05.23 + 9 + 60 + 3 = 06.35

This is not quite the whole story because the sun's declination reduces within the leap year cycle by about 5.5′ each year and then jumps back by about 17.1′ at each leap year. There is also a gradual increase of declination of about 0.26′ annually because of the leap years omitted at 100 years if not divisible by four. The effects of these changes of the sun's track relative to Box tunnel is shown

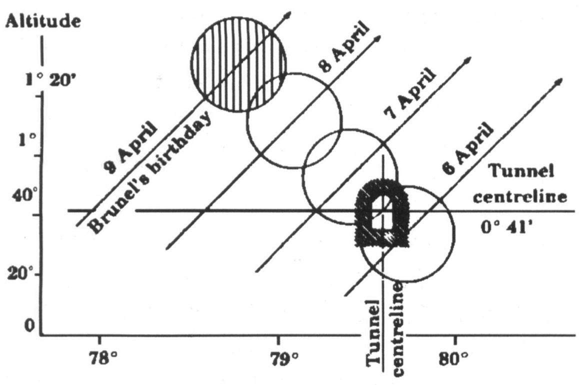

FIGURE 1: The sun's track in relation to Box tunnel in April 1985.

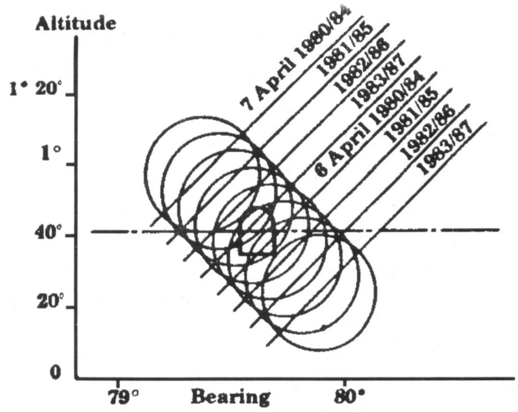

FIGURE 2: Leap year variations in the sun's track relative to Box tunnel 1980 to 1988.

in Fig 2 for the years 1980 to 1988. Because of these minor variations the sun does not always shine through on two days in April. The length of the tunnel is such that there is a difference in local solar times between eastern and western ends. Strictly speaking the line from the centre of the eastern portal to the observer's eye should be the path of the sun's rays considered in the calculations but this height is insignificant in comparison with the length of the tunnel and the magnitude of the sun.

THE SUN'S TRACK IN THE 1830's

The tunnel was commenced in 1836 which happened to be a leap year, but in the years whilst Brunel was designing the tunnel the declinations of the sun at 5.30 a.m. were approximately as follows:

1832	...	7° 35.7′
1833	...	7° 30.0′
1834	...	7° 24.3′
1835	...	7° 18.6′
1835	...	7° 35.7′

For the sun to be able to shine through the declination must be less than 6° 54′, the closest to this was in 1835 when it was within 24′. A mere 75 feet displacement of either portal only would have been sufficient to allow the sun to shine through on Brunel's birthday. However it was not until 1841 that the tunnel was open, and the first

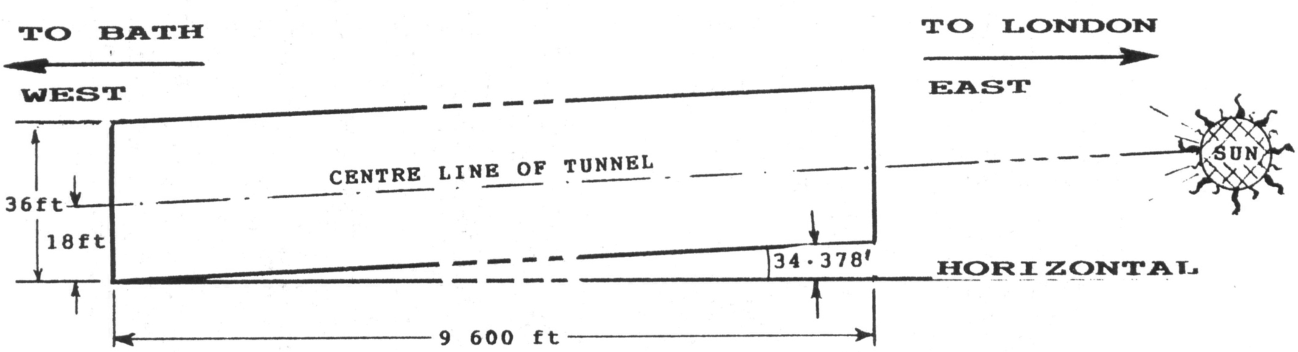

FIGURE 3: Conditions when the Sun's rays pass through the Box ~~Hill~~ tunnel at dawn in early April. Note the angle of the gradient is greatly exaggerated, it is only slightly over half a degree and cannot be shown correctly. This slight gradient is sufficient to prevent sunlight passing through from the West.

opportunity for the sun to shine through not until 1843.

On the basis of the previous discussions, it is clear that if Brunel had wished to commemorate his natal day, he could have done so without incurring a great deal of expense if he had a free hand with the route to be taken. The legend is not without plausible foundation and is now part of railway lore. Few people will have the chance to check the correctness or otherwise because the days to view it only occur on one or two days in April and permission to view is necessary from British Rail to be able to stand at the correct vantage point. It only needs a trail of diesel smoke or a slight morning mist to prevent sunlight traversing the length of the tunnel and necessitate a wait of another year for a further chance to view the phenomen which lasts only for a minute or so even under good conditions.

One has to remember also that when looking at Brunel's masterpiece, the proportions were correct when Brunel's broad gauge of 6 ft $0^1/_2$ in was first laid down. The present gauge of 4ft $8^1/_2$ in looks out of place against the huge opening of the tunnel. Had the tunnel been of the normal proportions of other railway systems, it would be even more difficult to witness the phenomena.

ACKNOWLEDGEMENTS

The Editor would like to thank our Treasurer Mr. R.A. Nicholls for bringing this unusual aspect of sun indication to his notice, and also to Mr. Martin Barnes for permission to utilise the material in his article of April 19th, 1985 in order to produce this shortened version. It is not a direct reprint of Mr. Barnes's article and any errors or shortcomings are the responsibility of the BSS Bulletin Editor.

FINAL COMMENT

The necessary change in alignment to bring the tunnel into the position to allow sunlight through the tunnel on the 9th April is very small in relation to the length of the tunnel, it is equal to only four times the height of the entry portal applied to either end, or two times applied to both ends. It would have entailed very little extra work or cost initially, so this is the strongest evidence that Brunel did not plan to arrange the coincidence. It is more likely that it never even crossed his mind in the first place.

Of course such situations where there is a straight tunnel at the correct gradient and an unobstructed site such that the sun rays can gain access at first light are fairly rare. The Editor would be pleased to hear of any similar example in Britain.

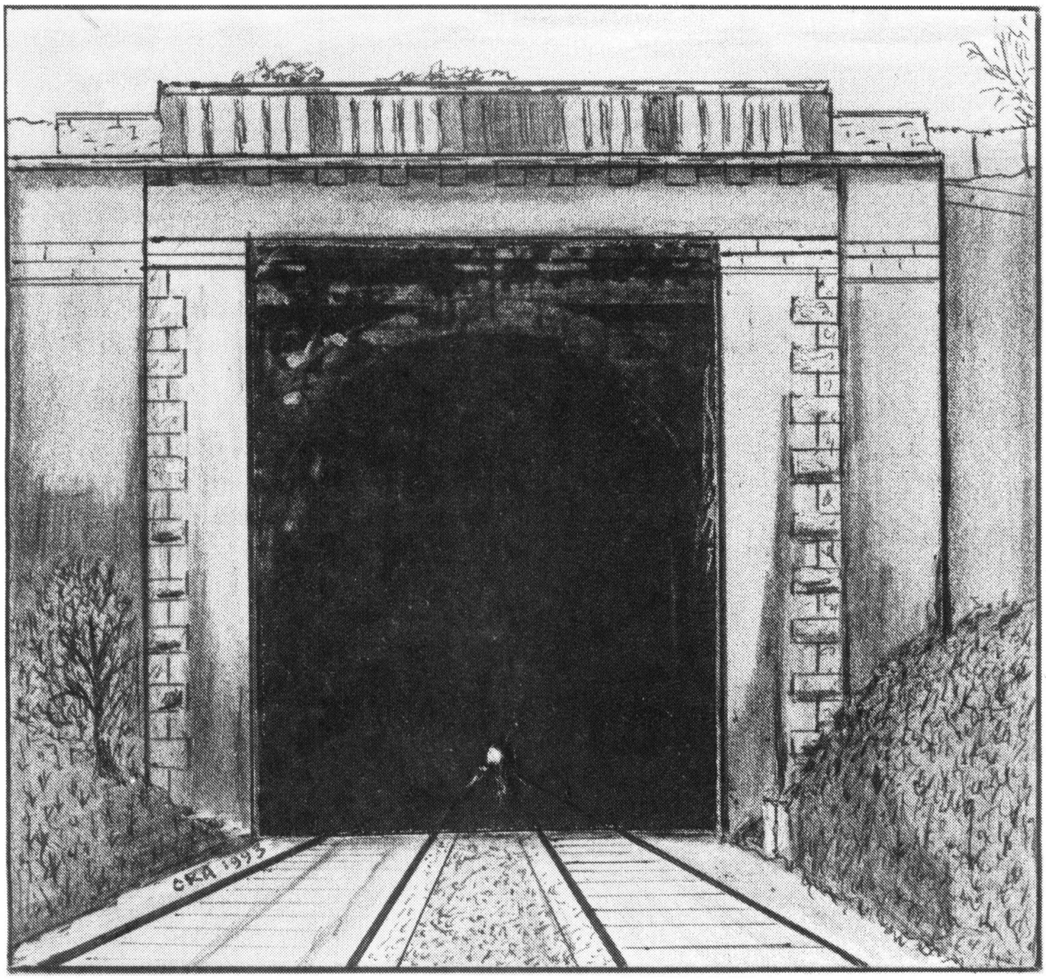

FIGURE 4: The view at the West end of the Box Hill tunnel at dawn on Good Friday 9th April 1982 - the anniversary of Brunel's birthday. It is sunlight at the far end but no there is no direct view of the sun.

THE BARLEY CORN CIRCLE MEASURE

BY HUGH H. FRANKLIN

One of the oldest linear measures known is the Northern Foot of 13.2″ and its cubit of 26.4″. This can be traced from 3000 BC, and was the foot (albeit decimally divided), of the very ancient pre-Aryan race of the Indus valley civilisation. BC 2500-1500 at Mohenjodaro. It is also found marked on Egyptian cubit rods of BC 1900. Teutonic peoples held on to it tenaciously wherever they migrated, and was so firmly established amongst them as a land measure that the Romans under their general Drusus adopted it in BC 12 for their northern border settlements. It was the basic measure used in this country until the new and present 'foot' was established by Edward I in 1305, although Rods, Furlongs and miles still maintain their same value, they are no longer measured by the Northern foot. The system was as follows:-

Unit -the Northern Foot = 13.2″ (NF).
Land Rod or Pole = 15 NF = 198″ = 16.5′
Furrow length or Furlong = 40 land rods = 600 NF = 660′
Sub-divisions of the NF: 4 'Palms' of 3.3″
12 'Thumbs' of 1.1″
36 'Barley Corns' of .3666"

Thus 1 NF = 1.1 EF (English Feet).

(This brief history is extracted from a Science Museum Survey, 'Weights and Measures' by F.G. Skinner, H.M.S.O. 1967; and from which other standards of measure have also been used.)

One other measure I would like to introduce, (not in Skinner), is the contentious 'Metalithic Yard' proposed by the late Professor Alexander Thom. He found this measure (2.72′±.003′), when surveying stone circles and allied megalithic monuments all over N.W. Europe, and maintained that it had kept its exact value not only from Scotland to Brittany, but also over a period of time covering a thousand years or more and by succeeding races of people. This has not found favour with the majority of archaeologists and statisticians. (Wood J.E.) The Indus Inch (1.32″) is mentioned by Heggie, 25 of which are very close to Thom's Megalithic Yard.

Whilst playing with Sundials, I came across a measure which is smaller than Thom's by .0588″, which I shall designate as "M", (2.715095129 EF). I hesitate to say it has anything to do with his "MY", by as "M" has an intimate relationship with circular measure it must be worth pursuing. From my sundial exercises the following maxims emerged which I hope will amuse, interest and entertain all those who can work a pocket calculator. If what follows is already known, then I apologise, but state that I have not come across it in anything I have read. Please use the full register of your calculator in working them out. On a sphere rotating once in 24 hours. (86400 secs):-

1. *The speed of rotation measured in Barley Corn (BC) per sec. at any latitude, is always equal to twice the number of miles (m) in the circumference (c) at that latitude.*

e.g. c = 15000 m = 11000″ per/sec, ÷ .36666″ = 30000 BC.

2. *At 60° latitude the speed of rotation in Northern Feet (NF) per sec, is 10 times the number of miles in one degree at the equator.*

e.g. c = 24902m,÷360 = 69.1722 m/°
c at 60° = 12451m = 760.8944 ft/sec = 691.722 NF/sec.

3. *The speed of rotation at any latitude measured in 'M' per sec, is always 1/10th of the number of miles in the side of an inscribed square (sq) of the circumference at that latitude.*

eg. sq = 3600m, thus c = 3600 x $\sqrt{2}$ x Pi,
= 15994.37858 m
speed of rotation = 15994.37858 x 5280 ÷ 86400 fps
= 977.43425 fps = 360 M
Thus my 'M' = 977.434 ÷ 360, = 2.715095129 ft
= 2.468268299 NF

4.(a). *The number of $\sqrt{2}$M per degree of arc at any latitude, is always equal to 12 times the diameter (d) in miles.*

eg. d = 500, c = 5000π = 15707.96327m, ÷ 360
= 43.633m/°
= 230383.4613ft/°
230383.4613 ÷ $\sqrt{2}$M (3.839724354ft) = 6000 (12 x 5000)

(b). Thus Diameter in miles, ÷ 20 = $\sqrt{2}$M per/sec time.

The relationship between Barley Corns and M, is shown by taking an inscribed square with sides of 20 BC. The diameter is 20$\sqrt{2}$, and the circumference is 20 $\sqrt{2}\pi$ BC = 88.85765876BC. This is equivalent to 32.5811415″ or 2.715095129ft = M.

In fact M can be shown to exist following a similar method of working. Taking an inscribed square of 10 miles in a circle rotating once in 86400 secs, the diameter is 10 $\sqrt{2}$, and the circumference 10 $\sqrt{2}\pi$ = 44.4288m, ÷ 86400 = 2.71509 ft/sec.

Could it be that there are more ancient measures which could be related to a circle or its inscribed square? If one reads Skinner it seems that nearly all measures were derived from either the Egyptian Royal Cubit (RC) and Double Remen (DR), or the Sumerian Cubit, (itself from the Northern Cubit (NC)). He gives the RC as 20.63″, and its $\sqrt{2}$ DR as 29.16″, Now if there are 1296000 secs of arc in a circle, there would be 291702.4864 secs of arc in its inscribed square, giving 206264.8063 for its radius. These numbers look remarkably like 10,000 times the stated measurements for DR and RC., and I am going to measure that this is so, for using them does indeed produce some interesting results allied to our Mile, M, the Barleycorns and other linear and square measures.

To return to maxim 3. for a moment. This is an interesting circumference of latitude, (50.036°), for each degree of arc is 10$\sqrt{2}\pi$ miles (44.4288 = 86400M), and 977.434ft = 888.57658 NF, the same sequence of numbers for the BC in the circle with a 20 BC square. A circle of 977.434 ft will have an inscribed square of 220 ft (200 NF), 9 squares of which would equal 10 Acres.

If you are playing with your calculator you will find that sequences of numbers turn up time and time again in odd spots, get to know and recognise them. For instance, if a circle rotates in 86400 secs, a length the size of the inscribed square will rotate in 19446.832 secs, and there are 1944.6832 M in one mile. Another one, .19446832 miles = 1026.793ft = 933.4479 NF., this is the number of poles in 2.917024864 miles, and is also 1/10th the number of M Rods (MR) in 12 miles. (MR = 2.5M).

If your mind is not yet going round in circles it soon will! My assumption that a DR is 29.17024864″ will show that 800DR = 1944.68324 ft, which, times M, = 5280 ft = 1 mile. Just one more for you while on this odd looking number, DR ÷ EF (English Feet = 12″), = 2.43085405., if this were taken as a number of miles, it would equal 19.4468324 furlongs, there being 8 furlongs to a mile.

Using M as a number and not feet, if it is multiplied by DR, we get:-

29.1072″ x 2.71509 = 79.2″ = 6 NF = 6.6 EF. x 2.5 = 1 Pole.

Using the figures from Maxim 4, a circle of 5000π rotates at 959.9310886 ft/sec = 250 √2M/sec = 10000π.BC /sec = Maxim 1.

With these last few examples we have connected up linear and square measure with circular measure using a variety of ancient and imperial units and the 'mystery measure M'. Indeed I feel the Acre may have had its origin in circular measure. A circular Acre (4840 sq.yds.), has a circumference of 739.8588ft, the square root of which is 27.20035, so it could be 272 x 2.72. (M rounded up.).

Alternatively, the side of a square Acre in inches x DR, 2504.524″ x 29.17024864″ = 1.1531 miles, pretty close to the number of miles in 1 min of arc at the Equator. (1.15287m). 1 Acre is also a rectangle of 10 M.DR x 100 M.DR (22yds x 220yds).

I have looked at measures derived from the DR and NF, namely the Greek Olympic foot (GF), Roman foot (RF), Natural or Pythic foot (NatF), the Jewish and Assyrian cubits (JC & AS), and with no more than fractionally extending their quoted sources (Skinner), the following list of mile equivalents is obtained:-

1 mile = 63360″ = 5280 EF   4800 NF
= 2400 NC   6400 NatF
= 3600 JC   172800 BC
= 800 DR.M   100 AS.DR
= 1944.68M   32000 M.digits. (40 to DR)
= 2000 RF.M   (16 to RF)

These round whole numbers I find impressive, and I will leave you to work out those we have not already met.

Now the question which puzzles me is this, if the NF, DR, BC's, "M" and the NatF (or Pythic), were around and being used prior to 2500 BC, when writing was just being invented, and a thousand years before the advent of maths and counting with a place value system, before the invention of the Zero allowing complicated maths to be done, before the use of the sexagesimal system of circular measure, and presumably many years before our current division of time, (Ifrah & Barrow), why and how do these measures have a geodetic relationship with our idea of the figure of the Earth? By whom, how and when did the mile originate?

A mile circle will rotate at 2 BC/sec = .733″ = .0611′., so any circle of latitude in miles multiplied by .0611 or divided by its reciprocal 16.3626 will give its speed of rotation in ft/sec. Does latitude have anything to do with the siting of Megalithic monuments? Silbury Hill is (by grid reference) 16.36 miles North of Stonehenge. Avebury is 51.428° (360°/7). The rows at Carnac are at a latitude which has .01296 miles/second of arc, and the foresight of Er Grah is at a latitude which rotates at .19446832 miles/sec. Sphericity may enter the equation here but I am not competent to deal with it. Carnac does seem to show the existence of a Meg Yard more so than most sites (Heggie). G.S. Hawkins' photogrammetric survey of Stonehenge cites the diameter of the Sarsen circle as 99′1″ to the centre of the stones = 15 DR.M = 6 poles.

The International Nautical Mile is given as 1852 metres = 6076.11568 EF. (Anderton & Brigg).

1 pole ÷ M = 6.077135 ft, x 1000 = 6077.135 ft = 72925.6216″ = 100,000 digits, = 2500 DR.

I guess when you play with your calculator many numerical 'coincidences' (?) will be found - I have only scratched the surface here and given you a few pointers. Another one for instance : on an Ordnance Survey map with a Representative Factor of 1:2500, the number of inches to the mile is 63360 ÷ 2500 = 2.5344. Using this scale a Pole would be represented on the map by 2.5344″ ÷ 320 = .00792″ = DR.M ÷ 10000.

My personal opinion is that there was once a universal system of measure which has since become distorted divided and obscured, little bits of it surfacing now and again, such as the Hazel rod of late 2000 BC from a Danish burial mound, marked with a division only slightly smaller than Thom's MY (Heggie). At least this exercise has shown that there could have been a Megalithic yard expressed as the circumference of a circle surrounding a square with a side of 20 Barleycorns; it may be this measure which is emerging from Stone Circles.

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ANCIENT SUNDIAL RE-CREATED AND REFINED

ALLAN MILLS

A matching pair of sundials with an evolutionary theme have recently been placed above the entrance to the Geology Department at Leicester University.

The dial on the left is unique in that it accurately indicates 'antique hours' - the earliest timekeeping system (used in Egypt, Greece and Rome) where the sunlit portion of the day is always divided into twelve equal parts.

The absolute duration of this 'hour' therefore depends on the season, being longer in summer and shorter in winter. The gnomon is simply a horizontal south-facing peg, with the shadow of its pointed tip indicating the time of day within areas bounded by very shallow curves.[1,2] Midday occurs at the end of the sixth hour.

The right hand dial at a conventional vertical declining dial, employing the familiar (but comparatively modern) 'equal hour' system, where the hour is always 1/24 of the entire day. Its gnomon slopes up towards the pole star, and the shadow cast by the entire edge indicates the time by its position relative to the straight hour lines. Midday is now called 12 noon.

Geological time and evolution are symbolized by the Jurassic ammonite on the first dial, and Man on the modern dial. The latter design is based on a drawing by Leonardo da Vinci, and is encompassed by one of mankind's major inventions - the wheel.

The quotation is from one of the earliest textbooks of geology: James Hutton's *System of the Earth,* 1785.

The dials were designed by Allan Mills and carved from Welsh slate by Michael Fisher.

1. A.A. Mills 'Seasonal-hour sundials for the British Isles (50-60°)' *Bulletin of the British Sundial Society* 1990 No.3 15-21.
2. A.A. Mills 'Seasonal-hour sundials on vertical and horizontal planes, with an explanation of the scratch dial' *Annals of Science 50* 83-93 (1993).

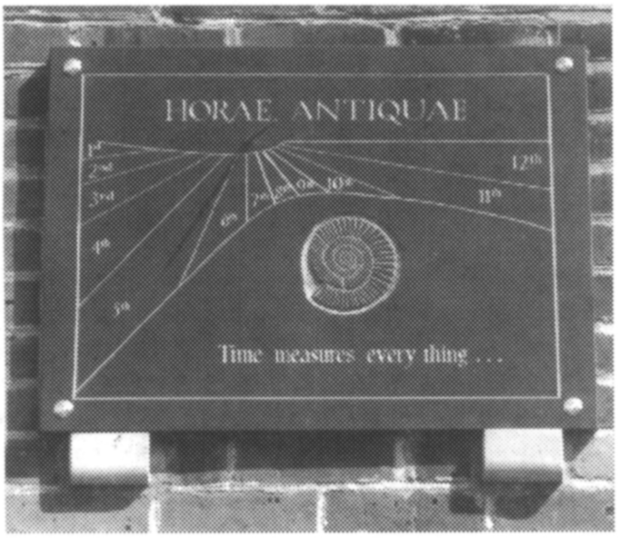


FIGURE 1: The "antique hours" dial divides the daylight period into twelve equal parts.

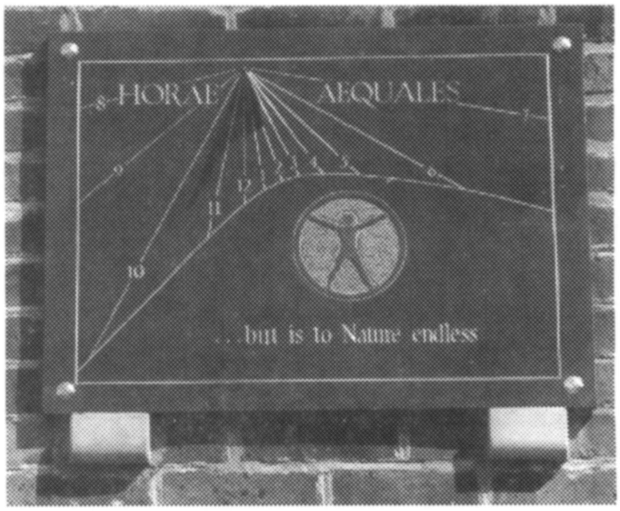


FIGURE 2: The "equal hours" dial divides the entire day period into 24 equal parts.

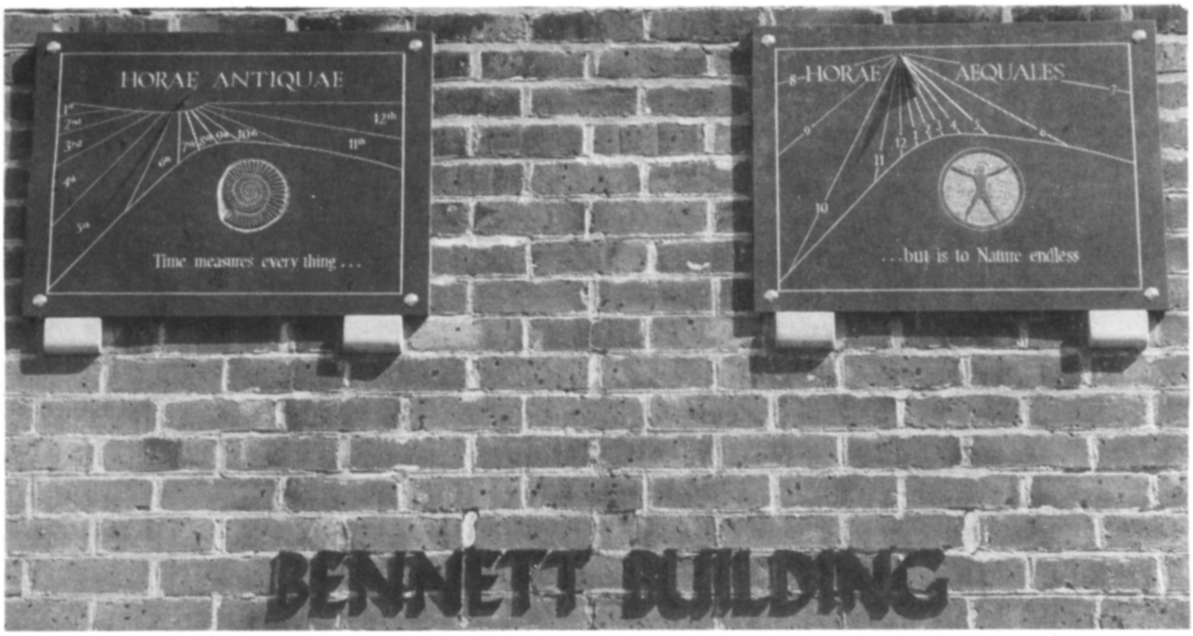


FIGURE 3: The two dials placed above the main entrance to Bennett Building

BOOK REVIEW

PRACTICAL ASTRONOMY - A User-friendly Handbook for Sky Watchers, H. Robert Mills, pp. 235, 46 b & w photographs, 93 line diagrams, 24 x 17.5 cm, ISBN 1-896563-02-0 hard cover, £16.50. ISBN 1-896563-00-4 paperback, £9.95. Albion Publishing Limited, Chichester, 1993.

This is of interest for several reason. It is the first book under the new imprint of Albion, it is intended as a user-friendly guide, and it is the work of our well-known member Mr. Robert Mills who is usually seen at meetings surrounded by a host of instruments of his own devising.

The main work is divided into six main sections, of which section 2 "The Sun and Sundials" is the main area of interest to diallists. But nothing can be looked at in isolation and this book is a very clear guide to the mechanics of the earth/universe system. If we wish to set a dial accurately by means of the Pole Star, it is necessary to know something of the celestial sphere. Everything to set the diallist on the correct route to astronomical knowledge is set out in the first section - The Celestial Sphere.

Pages 63 to 110 deal mainly with sundials, linking theoretical considerations with practical realisations. The quotation at the start of the Preface sums up the approach succinctly - "I listen and forget, I see and learn, *I do and understand*". There is little in this section which cannot be found in any dialling treatise but no one has set out the concepts and realisation more clearly than the author. How many other authors tell you how to use empty drinks cans and old bicycle wheels to create accurate sun time indicators?

The remaining sections comprise - 3 Star Positions, Star Maps . . . 4 Light and Basic Optics, 5 Miscellaneous Calculations, 6 Appendices and Useful Information. Much of the information is of interest and of help in understanding the functioning of sundials.

The foreword to the book is by the well-known Heather Couper, Professor of Astronomy at Gresham College, London.

On the debit side, the index is meagre but it is amplified by the subheadings in the Table of Contents, the photograph illustrations lack sparkle and contrast through underexposure, the list of reference books does not contain one example of a dialling work, and a British Sundial Society mention just about creeps in with its Bulletin ending the list of suggested reading.

The back cover gives a fascinating glimpse into both the publisher and the author's life, the front cover shows, in colour, Robert's nocturnal for obtaining sidereal time and a nomogram for conversion from sidereal time to mean time. The several quotations from Kipling reveal Robert's long asociation with India, and the following example exemplifies the modus operandi of the book:

I keep six honest serving men
(The taught me all I knew)
Their names are what and why and when
And how and where and who.

The reviewer has no hesitation in fully recommending this book to students, schools, and dialling enthusiasts. It is a remarkable compilation of the greatest clarity and is unique in its emphasis on practical realisation. If you are someone who uses books for what they are intended, buy the hard cover version. The book may be user-friendly, but the soft cover version will not find the constant user friendly. This is a book you will refer to again and again.

* * * * * *

THE COURSE OF TIME

It was not so in Heaven. The elders round
The Throne conversed about the state of man;
Conjecturing, for none of certain knew,
That Time was at an end. They gazed intense
Upon the Dial's face, which yonder stands
In gold before the Sun of Righteous,
Jehovah, and computes times, seasons, years,
And destinies, and slowly number o'er
The nightly cycles of eternity;
By God alone completely understood,
But read by all, revealing much to all.
And now, to saints of eldest skill, the ray
Which on the gnomon fell of Time, seemed sent
From level west, and hasting quickly down.
The holy Virtues watching, saw, besides,
Great preparation going on in heaven,
Betokening great event, greater than aught.

Oh Earth! thy hour was come: the last elect
Was born, complete the number of the good,
And the last sand fell from the glass of Time.

An extract from *Course of Time* by Robert Pollok, 24th March 1827, Book VI, page 164.

THE URANICAL ASTROLABE OF JOHN BLAGRAVE

CHARLES K. AKED

After reading the article "Errors and Misconceptions" by our Chairman in BSS Bulletin 93.2 of June 1993, commendable for its honesty, the present writer was prompted to look up John Blagrave entries in normal biographical sources. Chambers Biographical Dictionary does not list him, nor the *Encyclopædia Britannica*, 11th Edition. Similar sources are equally blank so we must assume that John Blagrave is considered of little significance by the ordinary biographer. Anthony Wood in his *Athenae Oxienses* is the main source for the details of John Blagrave's life and career. A short account of him and also of two other members of his family is given in the *Dictionary of National Biography*. The detailed Blagrave family tree may be found in Berry's *County Genealogies of Berkshire*, mention of the Blagraves is made in Pepy's "Diary".

Turning to Professor E. G. R. Taylor's work - *The Mathematical Practitioners of Tudor and Stuart England 1485-1714* we do indeed have a short biography. Since many members will not have a copy of this indispensable work, it is given here in shortened version to save the effort of acquiring the book.

BLAGRAVE, John was of gentle birth and lived at Southcote Lodge, Swallow-field, Reading. As a youth he was given access to the mathematical books in the library of Sir Thomas Parry and became a self-taught professional mathematician. He accepted engagements as a land-surveyor and for the design, erection and repair of sundials. He also published an almanack, devised many fine astronomical and surveying instruments, some of which he made and engraved himself, and wrote a number of important books on practical mathematics. He produced his first instrument and book [The Mathematical Jewell] in 1585, which won him the patronage of Sir Francis Knollys. Treasurer of the Royal Household, with whose family he seems to have resided for a period.

... ... On his death-bed he sent for Edward Pond and put his papers and instruments into his charge. These would have included his unpublished *Anatomy of the Sphere* and his *Travellers' Tablet*. the latter a little pamphlet written "long sithence" [since] (he said) to show the use of a pocket equinoctial dial. [John Blagrave was only 54 years of age when he died].

It will be noted that this extract omits reference to the major achievements of Blagrave and exposes one of the shortcomings of this extensive collation of biographical references, namely the incompleteness of the entry. The entry is however further expanded by the separate inclusions in later pages of the details of his published works. Before proceeding further, therefore, it will be of interest to give a very brief outline of John Blagrave's life.

He was the second son of John Blagrave who lived at Bullmarsh near Sonning, his mother being a daughter of Sir Anthony Hungerford of Down-Ampney in the county of Gloucestershire. The Blagraves were a prominent Berkshire family who produced several men of note in the sixteenth and seventeenth centuries. The mother had been married previously to a Mr. Graye and bore three sons to Blagrave, namely, Anthony, John and Alexander. One of the unusual facts with respect to Anthony is that his son Sir John Blagrave decided to have all his teeth extracted. He then had a set of ivory teeth made and set in again. Alexander, the youngest was reputed to be one of the best chess players in England at the time.

The actual date of birth of John Blagrave is unaccountably unknown, he is generally considered to have been born in 1558. He attended school at Reading, from which school he is supposed to have gone to St. John's College at Oxford. There is no record in this college's registers of him ever having attended there but this is not unusual at this period. He did not take a degree, again this was not uncommon at the time. After this he lived at Southcote Lodge, Swallowfield, Reading. He was married to a widow but left no issue, for the lease of land settled on him by his father in 1591 for ninety-nine years was bequeathed by John to his nephews and children. According to Anthony Wood there were about eighty such beneficiaries on Blagrave's death on 9th August 1611. There was a daughter of his wife from her former marriage, she is named in his will.

John Blagrave was buried in the churchyard of St. Laurence at Reading, where to this day there is a bust of him against the south wall of the church. He chose to be buried in the same grave as his mother so he evidently had a great love of her, (see the Epilogue at the end of this article).

Fortunately Blagrave's leanings towards science is recorded:

He studied these works [mathematical books] in the library of Sir Thomas Parry to such good merit that he gained appreciation as the flower of the mathematicians of his age. In spite of his predilection for Astronomy, like many mathematicians of his period he devoted much time to the methods of journeying by sea over uncharted tracts. [Those who used the sea were generally too untutored to develop better methods, those with mathematical abilities generally did not travel the globe; hence these were unaccustomed to the conditions under which ordinary seamen had to work with observational instruments when attempting to find their position at sea].

Blagrave's first book was entitled *The Mathematicall Jewell*. ... ... published in 1585, the title page of which is shown in the Chairman's article. Because Blagrave had recently suffered a serious financial loss, possibly as much as three thousand pounds, from 1577 to 1583, he cut all the wood-blocks for the book himself and also engraved the plates of the Astrolabe which he called "The Mathematicall Jewell". In dedicating his first work to Lord Burleigh, Blagrave took the opportunity of acquainting his Lordship with the travails of publishing the work because of opposition from other practitioners.

Blagrave's first book not only describes his instrument and its uses, it is also leavened with anecdotes of both personal events and local incidents such as the setting up of a dial on the wall of Sonning Church on 26th July 1581 to set the church clock by. Another account tells of his setting out of a large dial on a sloping bank of earth. It was three yards square and set out for his near kinsman Humphrey Forster.

The instrument described in this first book was an Astrolabe with four movable parts whose special merit lay in the disposing of the separate plates for each latitude, thus greatly reducing the cost. Blagrave's single plate would serve its purpose from Pole to Pole. The plates could be drawn upon paper but the Rete had to be stiffened by a thin cut out sheet of brass if paper was used, see Fig 1. The Mater could be mounted on a substantial sheet see Fig 2. The Label and Alidade were affixed to the Mater and Rete by a central rivet which allowed the requisite motions in use. At this period it was common to print sheets which allowed someone desiring an instrument to make this out of thin card instead of the much more expensive normal brass. For instructional or educational purposes the use of paper scales was quite adequate.

In the fourth part of his book Blagrave proposes that his readers might use small portable "Jewells" but also very large ones which could be set out on a wooden board with the scales and other parts delineated on fine paste board, using several different coloured inks to differentiate the various lines. In order to facilitate the drawing of the great number of arcs required with accuracy, Blagrave devised a triangularly arranged set of rules which allowed either the engraving of brass or the marking of paper or board. His method was more accurate than the use of compasses for arcs with a far distant centre. From what has been written here, John Blagrave's "Mathematicall Jewell" was an improved astrolabe which made use of a single plate instead of a multiplicity of plates for separate latitudes which added considerably to the initial cost.

THE URANICAL ASTROLABE

About 1597 John Blagrave's circumstances had improved to the extent that he was able to employ the skilful engraver Benjamin Wright to produce a new and better instrument which he called the "Uranical Astrolabe". Blagrave was by now familiar with the concepts of Copernicus and decided to employ these new ideas instead of the old Ptolemaic system where the Primum Mobile made its impossible daily circuit in twenty-four hours around the earth.

Before going further it will be as well to inform the reader that Uranical was the term then currently employed to denote heavenly in an astronomical sense. The significance of this will become apparent after reading the account of the instrument. To a modern reader the word "Uranical" is somewhat mystifying and confusing. The writer will not mention what his first thoughts were on seeing this word for the first time.

Blagrave put his new proposals succinctly thus:

"Old Stophlerus [Stoeffler] and our English Laureat Geoffrey Chaucer, according to the ancient astronomers (ie in line with their systems) appointed the Starry Heavens to move rightwards from East towards West, upon the Earth or fixed Horizon of the place. And I according to Copernicus cause the Earth or Horizon to move leftwards from West towards East, upon the starry Firmament fixed.

In so much that if in this my Astrolabe you hold still that particular mover with one hand and with your under hand turn about [rotate] the Celestial, then it is jumpe Stophler again. In which motion (a pretty thing to note) one that standeth by [ie an onlooker] shall hardly perceive any other but that the Rete moveth, although indeed you turn about the mater, strongly confirming Copernicus's argument, who sayeth that the weakness of our senses do imagine the Heavens to move about every 24 hours from East to West by a Primum Mobile, whereas indeed they have always been fixed, and it is the earth that whirleth about every 24 hours from West to East, of his own proper nature allotted unto him".

In essence the parts normally engraved on the Rete have been transferred to the Mater and vice-versa, placing the starry heavens on the Mater which of course is stationary. Blagrave was able to employ such a construction since Queen Elizabeth was on the English Throne and Protestant like her father Henry VIII. Copernicus's conception was anathema to the Catholic Church to the extent that even the great Galileo was forced to recant his views and accept that the firmament moved. Present day knowledge, of course, makes the idea of the whole universe moving round a central earth ludicrous but to challenge this was a very dangerous action if you were subject to the rule of the Catholic Church in those days. It is curious that diallists today, whilst aware of the earth's motion around its axis and the sun, find it much more convenient to regard the earth as fixed, with the sun travelling diurnally around it.

Our modern appreciation of the Uranical Astrolabe is a result of the work done by that indefatigable researcher Dr. R. T. Gunther who was then in charge of the Museum for the History of Science at Oxford. He published the results of his research into Blagrave in *Archaelogia* Second Series, Volume XXIX, pages 55-72. His paper was read to The Society of Antiquaries, London, 21st March 1929. By this time the instrument was known only by name because not a single example of it was known to be extant in complete form, the components were separated in those museums which had examples and no one knew how these were assembled to perform the instrumental function envisaged by John Blagrave.

Gunther actually unravelled the secret of Blagrave's Uranical Astrolabe because of the extensive dialling library in the History of Science Museum and the nearby Bodliean and Ashmolean libraries. At the time there were only three copies known of John Blagrave's third book on the Astrolobium Uranicanum Generale and the listing of the libraries concerned gave no hint whatsoever that the book was about an instrument. This is because the book itself is incomprehensible without having an actual instrument before one.

In 1928 the British Museum published A Map of the World designed by John Blagrave and engraved by Benjamin Wright in 1596. This map has a curious diagonal scale engraved on the side of the plate. In actual fact this scale has nothing to do with the map of the world but is a second essential part of the Uranical Astrolabe. Blagrave called this the "Zenitfer" and its purpose was unknown to cartographers.

The examination of this map led Gunther to examine a print of this scale bound in the Ashmolean manuscript No. 417, which led to his fortunate discovery of the third part of the Uranical Astrolabe, namely the "Celestial" which was printed from the engraved plate made by Benjamin Wright in 1596. This is a most remarkable tour de force as may be seen from Fig 3. The proof is in the left lower corner where the title is displayed:

ASTROLABIVM VRANICVM Generale Celum habens stellatu fixu terram que sive horizontem in 24 horarum spacio continuo circumvolventem cum omnibus supplementis as artem judicandi necessariis. PER JOANNEM BLAGRAVVM generosum Readingensem mathesibus benevolentum.

Benjamini Wright Anglus Londinensis coelator.

ANNO DOMINI 1596.

Surprisingly enough the Blagrave map of the world in

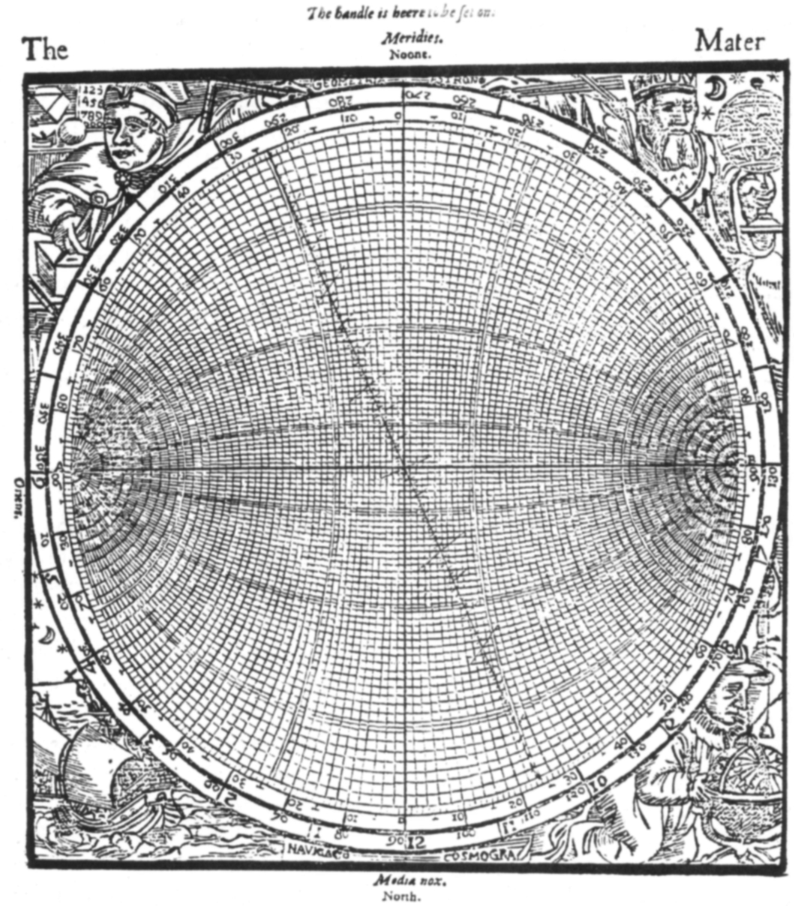


FIGURE 1: The MATER of the "Mathematical Jewell" engraved in 1584 by John Blagrave.

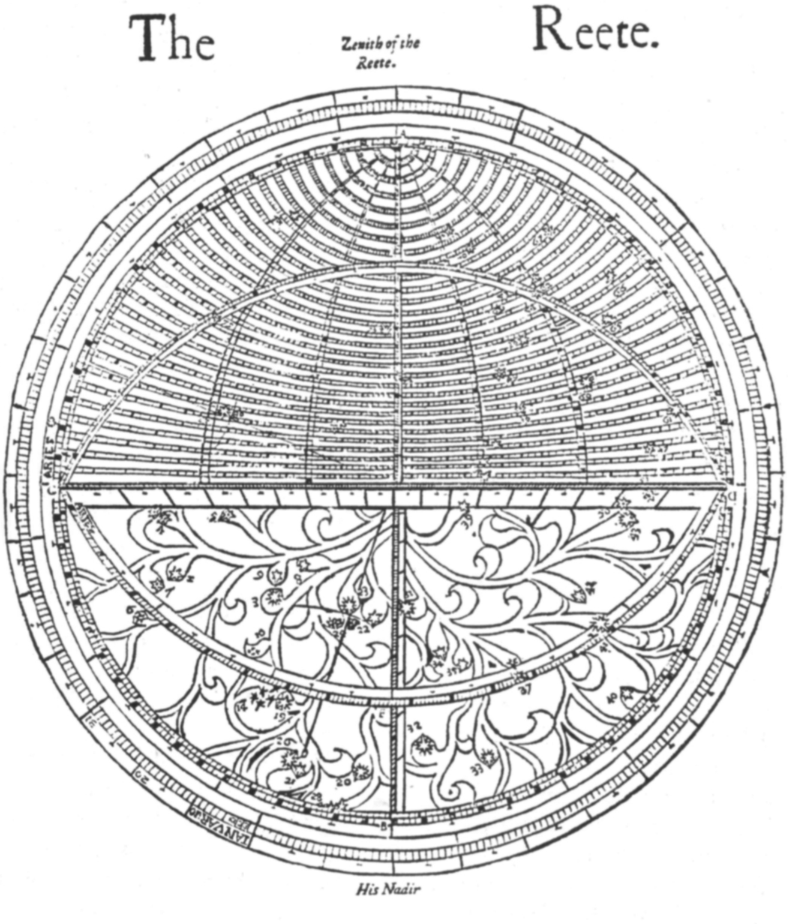


FIGURE 2: The RETE of the "Mathematical Jewell" engraved in 1584 by John Blagrave.

the British Museum was printed some fifty or so years after this date as is indicated by the water-mark in the paper used, whereas the Ashmolean print is on paper made in the last decades of the sixteenth century.

Gunther was now in a position to be able to reconstruct the Uranical Astrolabe for the first time in over two centuries. But first let us examine the plate in Fig 3 more closely.

The upper left corner is a Perpetual Table and is supplemented by the lower right hand corner to give the Precession of the Fixed Stars which amounts to about one degree in 67 years. The upper part gives this for 1 day, 1, 4, 20, 100 and 1000 years. The lower right table gives the corrections to be applied because the precession is not a uniform motion, and this is computed to the year AD 3440! Alas no BSS member of today will be able to check Blagrave's value by direct observation.

At this period great significance was placed upon astrology and so in the lower left corner, with the inscription, is a "Domineering" table to give the planets which dominate each planetary hour of the day and night. It might be humbug to us today but was a very serious matter in those days. These scales also required pointers to make the reading easier.

The upper right corner contains the arms and motto "Virtus Invicta" of Charles Lord Howard of Effingham, to whom the work is dedicated. On the left of this is a triangular scale of hours - an "horarium planetarium" devised by John Blagrave which requires a small label [or pointer] graduated with the planetary hours and pivoted on its centre. The separate map of the world shows a sketch of this pointer near the "Zenitfer" and the use of this little instrument is given in chapter 29 of Blagrave's work. Incidentally the winged heads shown are intended to be those of the main winds.

The centre of the plate is of course the most important and it is a little confusing at first sight because of the over-emphasis of the mythological figures outlining the main star groupings. At the centre of the firmament is the celestial North Pole, the Pole star being set a little distance away as it should be. An equatorial circle is divided into 360 degrees commencing at the first point of Aries as is conventional. The only line relating to the earth is that at 45 degrees to the lower vertical which covers altitude from 30 degrees south of the equator to 90 degrees at the North Pole. The part which enables the terrestrial observations to be made is described later. Thus the map shows a stereographic projection of the stars visible to an observer in the Northern Hemisphere. The magnitudes of the stars are represented by seven symbols but are not easily distinguishable on the actual chart.

The topicality of this engraving is best illustrated by looking at the rear legs of the star constellation Ursa Major where an object like a brush may be seen. This actually is the comet Berenices of 11th July 1596 discovered by Tycho Brahe and Moestlin and observed also by John Blagrave at Reading. It was visible for only five weeks and must have been added at quite a late stage of the engraving.

Up to Gunther's research this print was regarded as no more than a map of the heavens which had been delineated for use as an astrological chart. The most essential part to make it meaningful was not printed with the celestial chart but was printed by the side of the terrestrial map where it had no obvious significance whatsoever. Hence the continued confusion.

To complete the Uranical Astrolabe Blagrave designed a moving rule of about one inch in width, pivoted at the centre to fit diametrically across the planisphere. This he termed a "Zenitfer", a word not recorded in the Oxford Dictionary. This Zenitfer also carried a cursor to which a further component could be added, the Almicantifer with a pointer. All these parts are to be seen delineated at the side of the terrestrial map but are shown here above the Celestial where they should really have been placed. In addition, Blagrave displayed a pattern of this arrangement which could be viewed at the house of the bookseller Mr. Matts which was against St. Dunstan's church in Fleet Street under the sign of the Plough. Those interested could give instructions to Mr. Matts who would send a letter or notice weekly to John Blagrave.

Blagrave noted that in the absence of an Almicantifer, a thread of silk carrying a pearl would serve, the pearl substituting for the steed of the pointer, and in place of the ledge of brass, a piece of lantern horn could be used. Gunther comments that in the absence of the engraving of the Zenitfer on the terrestial map, the scales are so elaborate and the description of these in the book are so complicated, he doubts if anyone could have reconstructed them.

At this point the writer began to launch into a full description of the many indications of the instrument and then found after a short while that he was suffering from mental indigestion at the complications of the explanations. Since many BSS members complain that some of the articles in the BSS Bulletin are too complex, these explanations would be entirely wasted on them and therefore those really interested in the complex features of John Blagrave's Uranical Astrolabe are recommended to turn to the sources which are listed at the end of this short article. To do justice to this instrument would require a complete issue of the BSS Bulletin being devoted to it.

THE STEREOGRAPHIC PROJECTION

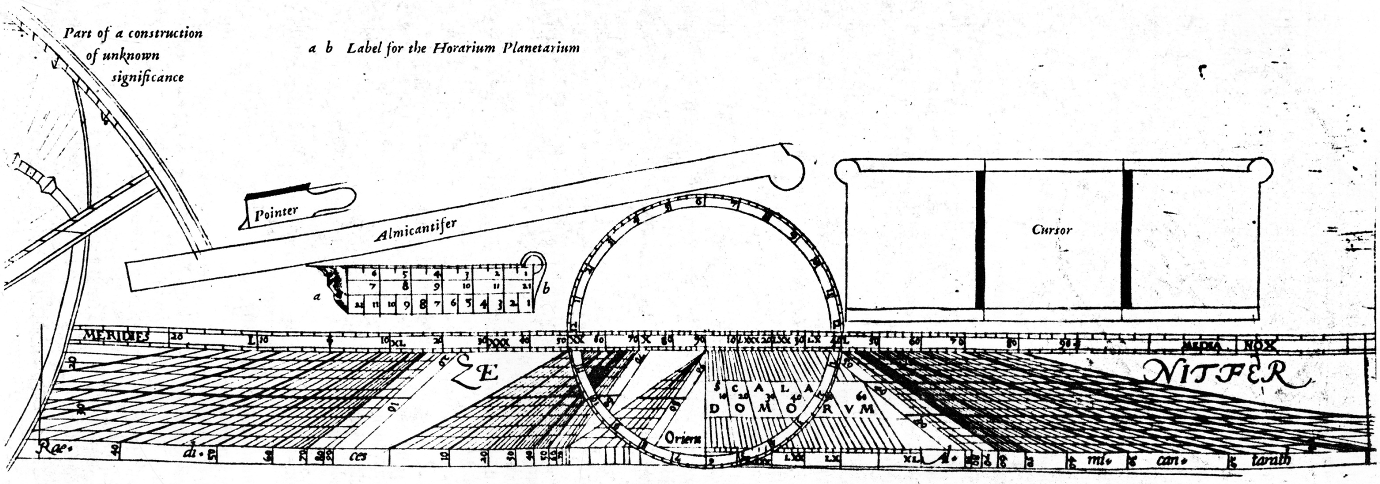
Evidently John Blagrave experienced difficulty in explaining the method of stereographic projection of a sphere to his clients. His explanation is thus [rendered into modern idiom]:

Even as a loaf of dough or paste, after it is newly moulded round and copped [given a rounded top], if you then put it in a press it will become a flat-cake. Even such a cake made of the round sphere or globe so pressed is the Celestial of our new Astrolabe, which I would have you now for this purpose imagine to be a round Globe again and every one of the circles had their proportionate convexity so that a pretty little fellow like Tom Thumbe might easily sit himself under these as under a Canopy in the very centre of the concavity. [ie as one sits under an umbrella].

Of course this projection means that the centre portions of the projection are cramped in comparison with the outer parts but after all the observer is more concerned with the parts of the heavens which have greater motion.

FURTHER COMPLICATIONS

This Zenitfer was fitted with a cursor whose edge was maintained at right angles to the zenitfer's fiducial edge. On this was fixed the Almicantifer carrying no markings but on which slid a small index termed the "pointer". The Almicantifer could be engraved with the particular degrees of altitude for a specific latitude and then the pointer was



THE ZENITFER AND CELESTIAL OF BLAGRAVE'S URANICAL ASTROLABE, 1596

Published by the Society of Antiquaries of London, 1929

The Celestial and Zenitfer (above) of John Blagrave's "Uranical Astrolabe" engraved by Thomas Wright in 1596

FIGURE 4: TITLE PAGE of John Palmer's 1658 edition of John Blagrave's work on the "Mathematical Jewell".

Dyalling which he published in 1609. Should there be any demand for the minutiae of the Uranical Astrolabe, the account of these will also be undertaken. For the present this article is quite long enough.

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Archaeologia, Vol 29 New Series, Pages 55-72, 1929, The Society of Antiquaries, London. Contains a two-page plate of the "Celestial".

Astrolabes of the World, Robert T. Gunther, Pages 492-501, 513-517, First Edition 1932, reprinted 1976 by Holland Press 1976 as two volumes in one. Between pages 500-1 is a plate showing an astrolabe of the Blagrave type in the Mensing Collection, it is 475 millimetres in diameter and is neither dated nor signed. Its suspension bracket is in the form of a crown. The astrolabe is both well made and engraved. The account of the Uranical Astrolabe is that taken from *Archaeologia*, including a two page illustration of the Celestial.

The Mathematical Practitioners of Tudor and Stuart England 1485-1714, E. G. R. Taylor, First Edition 1954, reprinted 1967 and 1968. See entry no. 52 on page 181, and entries no's. 65, 72, 92, and 114 for Blagrave's works, see below.

The Mathematical Jewell. Showing the making and most excellent use of a singular Instrument so called: in that it performeth with wonderful 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, John Blagrave, 1585.

Baculum familaire ... A Booke of the making and use of a Staffe, newly invented by the Author, John Blagrave, 1590. This device was invented by Blagrave for his patron Sir Francis Knollys. Primarily intended for use by military personnel, it could be used also for ordinary surveying.

Astrolobium Uranicum Generale ... A necessarie and pleasant Solace and Recreation for Navigation in their long journeying. John Blagrave, 1596. This book was accompanied by the map (Nova orbis terrarum descriptio) engraved by Thomas Wright, which carried the engraving of the Zenitfer essential for the working of the Uranical Astrolabe. The map was invariably and inevitably separated from the book in the course of time.

The Art of Dyalling, John Blagrave, 1609. This book is dedicated to Sir Thomas Parry, Chancellor of the Duchy of Lancaster. It is a clear and practical work in which Blagrave deprecated the practice of elaborate dials showing the planetary hours. His animosity towards Roman Catholicism emerges in this book when in suggesting multiple dials to show the time in the great cities of the world - "if some dissenting Puritan in Reading wished to bid the Devil choke the Pope in the midst of his meat, he would know when he dined, or equally it would serve some silly Papist who wished to ask a blessing on him". There is no evidence of any Pope suffering evil or good as a result.

His Exercises, Thomas Blundeville. Editions in 1594, 1597, 1605, 1613, 1622, 1636. Blagrave's Astrolabe is described on pages 599-643 of the first edition.

The Catholique Planisphere which M. Blagrave calleth the Mathematical Jewell, [by which instrument you may take latitudes, find longitudes, observe altitudes, measure distances, survey capacities, draw dyalls, and resolve triangles, whether plain or spherical], John Palmer, 1658. John Twysden first taught Palmer the use of Blagrave's Mathematical Jewell. This book was intended to be sold with the instruments made by J. Moxon who commissioned Palmer to write the book which was dedicated to Twysden. It was a common practice for the London instrument makers to commission a mathematician to write the books which were sold to instruct the purchaser in the use of the instrument he selected. The actual instrument makers were often unable to express themselves in a succinct and accurate form.

BSS Bulletin, No. 93.2, June 1993, pages 30-2, "From the Chairman's Pen - Errors and Misconceptions", Christopher St J. H. Daniel. Includes an excellent illustration of the title page of The Mathematical Jewell on page 31, to which refer to complement the article here. Blagrave was competent in drawing and painting, thus the engraving of the armillary sphere shown on the title page is signed I. BLAG SCVLP., as are the other engravings in the work.

There are other writings of Blagrave's in existence but the preceding are the main ones of interest to diallists.

AN ANCIENT CHINESE SUNDIAL WITH 100 DIVISIONS TO THE DAY

ALLAN MILLS

INTRODUCTION

The division of the solar day (the period between successive noons) into 24 parts has been established in Western culture for a very long time, appearing to derive initially from a division of the sunlit period into 12 equal intervals. Apart from the 12 'moonths' in the year that nature gives us, the number 12 was important in Mesopotamian and ancient Egyptian counting systems, and is again reflected in the long-established 12 divisions of the zodiac. Subsequently, the night too was broken up into the same number of parts, giving a total of 24 divisions for the entire day.

These intervals - unlike our hours - were not of constant duration, $^1/_{12}$ of the time from dawn-to-dusk in Summer obviously being a longer period than the same fraction of the shorter Winter illumination. (Only at sites on the equator are all the periods equal.) For this reason it is usual to refer to these units as SEASONAL HOURS, and all early sundials were designed (or at least intended) to delineate the passage of time in terms of these variable units.[1] This system was highly convenient for agrarian peoples with no good source of artificial light.

The invention of the mechanical clock at the close of the 13th century resulted in the spread of a new timekeeping instrument that attempted to measure-out time in constant, invariable units, all equal to $^1/_{24}$ of the mean solar day. This is the definition of the EQUINOCTIAL HOUR, and all modern clocks employ this unit. The sundial was forced to adapt, and did so by modifying the old shadow-casting spike or vertical pillar into an inclined gnomon sloping upwards towards the celestial pole.[2] It is known that astronomers in Greek times used the equinoctial hour to calculate future celestial events (it is hard to calculate in variable units) but no Greek or Roman dial specifically graduated in these specialist units appears to have survived.

ALTERNATIVE SCHEMES

There is no fundamental reason to have 24 hours in the mean solar day, and the end of the French Revolution saw a move to decimalise the day into 10 'new hours', each with decimal sub-divisions. The experiment failed: the old system is far too ingrained into our Western way of life.

It is therefore of interest that Chinese culture, for so long isolated from any influence from the West, may for a while have employed a unique timekeeping system based on the division of the day into 100 equal parts.

THE CHINESE SUNDIAL

The archeological evidence is a limestone slab about 11" square and 1" thick (Fig. 1) found in 1932 in an excavation near old Lo-yang, Honan Province, latitude 34°40'N (Refs. 3 and 4). It was acquired by Bishop W.C. White, and eventually passed to the Royal Ontario Museum in Toronto, Canada.*Fig. 2 shows the face of the dial inscribed upon it more clearly: a 10" diameter circle described about a central hole bears 69 small holes at equal intervals of 3.6°, thereby marking hundredths of its circumference. Inscribed radii join each point to the centre. The 68 short arcs so delineated occupy 244.8°, the remaining 115.2° being undivided. Beginning at the top right, each small hole is numbered 1 - 69 in a clockwise direction with symbols which, it will be observed, repeat after 'ten' - ie. a decimal notation. From the style of these characters (particularly the 'seven') scholars date the artefact to the Western or Former Han dynasty - perhaps 2nd century BC. Records exist of two further dials of this nature, but their present whereabouts appear to be unknown.

So, the object illustrated in Fig. 1 is really all we have. It was identified as a sundial by the Chinese scholar Dr. Liu Fu, although such an attribution has not gone entirely unchallenged by those who, citing the apparently superfluous lines making L's, T's, V's and a square, prefer a divinatory function.[4] A major problem is the lack of an original gnomon, but of course this is quite normal for ancient sundials,[5] metal being so valuable. In view of the

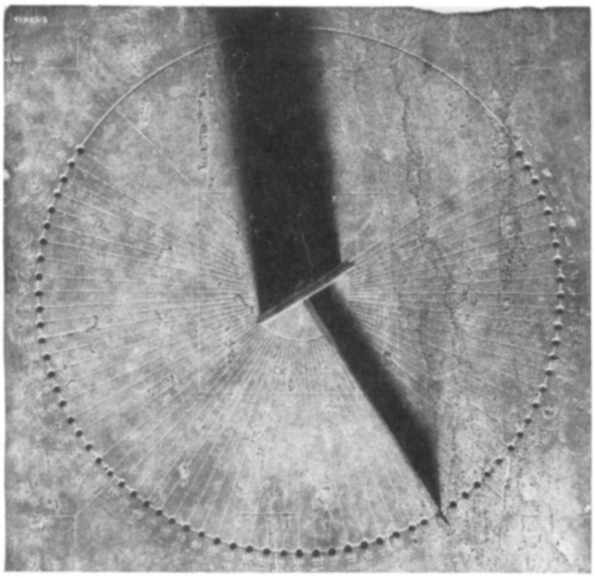

FIGURE 1: The artefact believed to be a sundial found in Honan, China. The gnomon is a modern conjectural addition. Photograph courtesy of the Royal Ontario Museum, Toronto.

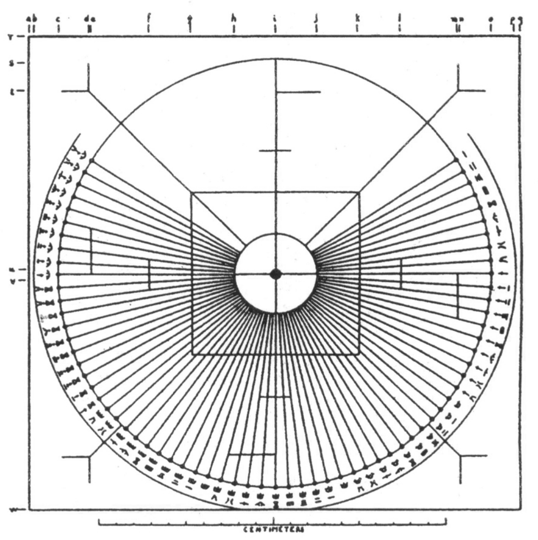

FIGURE 2: Details of the dial, as shown diagrammatically in Reference 6.

* Now on extended loan to the McLaughlin Planetarium

basically polar and equatorial character of Chinese astronomy, Liu Fu proposed that the graduated surface would originally have been inclined in the equatorial plane (ie. at about 55° to the horizontal) so that a perpendicular stylus in the central hole pointed at the celestial pole. This arrangement is, of course, a conventional equatorial dial in our current Western terminology (Fig. 3). Each 3.6° unit (the k'â) becomes equal to $^1/_{100}$ of the day, or 14.4 of our minutes. On this basis the ungraduated arc represents the shortest night, whilst the 'noon mark' is number 35.

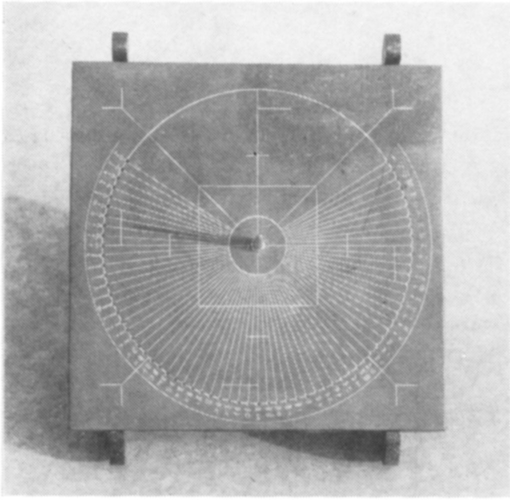

FIGURE 3: A recent reconstruction of the Chinese dial. A wooden stand and central stylus give a conventional 'equatorial dial', but it is operative only during the Summer months.

Such a sundial receives the sun's rays on its upper face for only the Summer half of the year, when the sun is north of the celestial equator. To deal with this limitation, in the numerous examples of late (Ming and Chhing) sundials still to be found in China[3] the pin-stylus extends right through the dial and both the upper and lower faces are graduated,[4] (Fig.4).

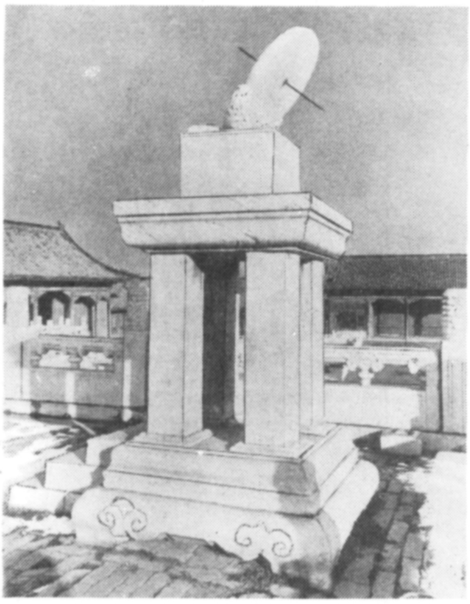

FIGURE 4: A pierced equatorial dial in white marble within the palace complex in Peking. This photograph dates from the 1930s (Ref. 4) and the present condition of the dial is not known. Date uncertain: possibly 17th century AD.

There are no markings on the underside of the stone shown in Fig. 1, so the Canadian astronomer Peter Millman suggested[6] that a more complicated gnomon might have been used. This is shown more clearly in the reconstruction illustrated in Fig. 5. The idea is that the dial was fixed in the equatorial plane as before, but with a rotation of 180° from the standard orientation shown in Fig. 3 so that no. 35 is at the apex.

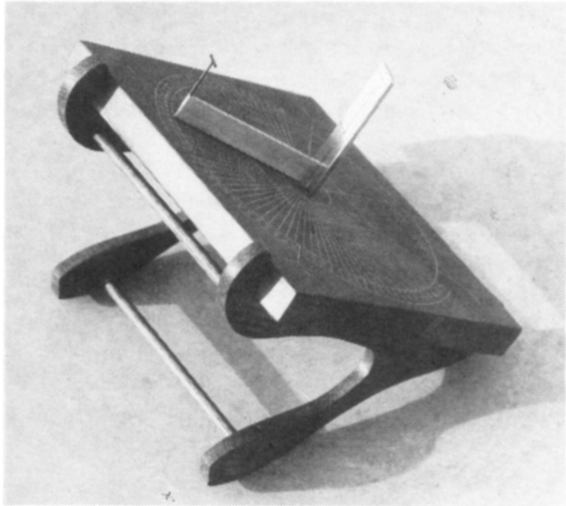

FIGURE 5: Reconstruction of the dial with a gnomon and orientation that permits its use as an equatorial dial throughout the year.

A special gnomon was then moved around the ring of holes until the shadow of its T-bar fell centrally upon a receiving surface moving with it at the centre of the dial. This vertical plane is long enough to accommodate the entire ± 23.5° annual range of the solar declination, and the height of the shadow could also indicate the solstices and equinoxes.

This arrangement certainly works satisfactorily to our eyes, but this does not prove that it is the true solution to the function of this enigmatic dial. A 100-fold division of the day might have delighted the Revolutionary décimaliste, but equal units throughout the year would be even more remarkable if in general use in such a basically agricultural country as ancient China. Perhaps the rarity of the dials is telling us that the system was confined to a special group within one part of the Empire, and found favour for only a comparatively limited period.

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THE MERIDIAN OF THE BASILICA OF SAN PETRONIO IN BOLOGNA - PART I

GIOVANNI PALTRINIERI (ITALY)

The basilica of San Petronio in Bologna has a meridian line of exceptional length which was traced out on the floor of the left nave in 1655 by Gian Domenico Cassini, the celebrated Italian astronomer (see Figs 1 and 2, also photos 1 and 2). [The photographs will be in Part II.]

Almost eighty years previously, in 1575, the Dominican Egnazio Danti had constructed a similar meridian in the same basilica, however it was of smaller dimensions and lesser accuracy. Following the extension of the church towards the south with the addition of a bay in 1653, the wall containing the aperture for Danti's meridian was demolished, thus rendering the meridian useless.

At this time the Chair of Astronomy in the University of Bologna was occupied by Gian Domenico Cassini, who conceived the reconstruction of the meridian line with greater dimensions, the object being to obtain solar observations of a greater precision than with any other instrument constructed until then.

Rather than utilising a hole in a wall as Danti had done, Cassini thought of constructing an aperture in the apex of one of the vaulted arches of the nave to obtain a greater stability of the hole admitting the sunlight. It was first necessary to check that the supporting columns in the church would not obstruct such an enterprise. With respect to the meridian line of Danti, it showed a considerable error in the north-south alignment. Taking accurate observations Cassini carefully determined the instant when the sunlight grazed the facade of the church, from this he calculated the azimuth angle from the south, and transferred this to an accurate ground plan of the basilica. This resulted (after careful measurements) in proving that it was possible to trace a meridian line which skirted the bases of the columns and was just able to pass through the row of columns without hindrance to allow extension to the distant point required by the winter solstice, see Figs 1 and 2.

THE CAMERA OBSCURA

Many different ways have been devised of constructing solar dials which measure a wide range of hours: with a meridian line the indication is the instant of noon or midday when the sun is "in the meridian", or exactly on the meridian of the locality. The function of an internal sun clock or "Camera Obscura" is comparable with that of a horizontal dial fitted with a vertical gnomon, provided with a line for the twelfth hour, or in other words, midday. The virtual "shaft" (of light), emerging from the aperture to strike the ground has a height commencing at the floor to the centre of the aperture in the wall or ceiling, and projects a luminous ellipse on to the pavement. The optical phenomena is demonstrated in the camera obscura, the rays of light are channelled through a hole of modest dimensions and reproduce the precise contours of the sun but as a reversed (and inverted) image.

With a meridian line it is in fact possible to observe the solar image clearly with the aid of a sheet of paper placed on the ground, or even more spectacularly, to project the image of an eclipse of the sun or moon on to the floor.

A little before midday, when the sun succeeds in entering the aperture, we see its luminous image on the floor: slowly this image advances to the meridian line, and the exact instant when it is central on the line is the hour of 12 noon local time. At this moment the sun is at its maximum height above the horizon for that day, it will divide the the interval between dawn and sunset into two equal parts, and the sun is situated exactly due south. The height of the sun varies from one day to another: the limits of its excursions are contained between the dates of the two solstices and, in consequence, the same occurs on the meridian line.

This instrument has two precise functions. The first is to indicate midday on each day of the year, the second is concerned with the calendar. By means of a simple calculation it is possible to indicate the point projected on the line for a certain date, or its inverse. In consideration of the characteristics of such an instrument, research was begun with a meridian in Florence towards the year 1000 in order to determine the exact date of the solstices and the equinoxes; and with a view to the revision of the Julian Calendar which was only put in hand much later by Pope Gregory XIII in 1582.

But first we will look further into the details of the instrument.

THE MERIDIAN LINE

The meridian line can be considered as part of a large right-angled triangle, the larger this triangle is, the greater the resulting accuracy of indication (assuming that each triangle has been constructed to the same standard). The vertical line (of the triangle), or gnomon height (h), finds its origin in the centre of the gnomon hole, and ends on the ground vertically below. Whatever the height h may be, it is assumed to be exactly 100 units for simplicity of calculation, in other words the length h contains 100 units (or modules). In practice one measure the gnomon height in metres or centimetres, this value is divided into 100 parts, thus giving the length of one module.

Whatever trigonometrical result is obtained with the instrument it will be in terms of modules, which multiplied by the length of a module in millimetres, will give the corresponding length in millimetres.

Figure 3 shows the functioning of a meridian line in a diagrammatic form. The zenith angle of the axis of the sun's rays in indicated by z, that is the amplitude (width) - vertex in the hole, - that such an axis forms with the vertical. To z will correspond L on the horizontal line which has its origin at the vertical point. The dimension L is the distance on the meridian line which is engraved with the modular units. This line is also used to measure the tangent, from this the zenith angle may be obtained as follows:

$$\tan z = L/h \quad \text{or more simply} \quad \tan z = L/100$$

From the semidiameter of the solar image on the meridian line one has the angles Z_1 and Z_2 which correspond to L_1 and L_2 of the major axis of the ellipse, with the minor axis transverse to the line.

From these fundamental functions, Cassini succeeded in calculating the exact refraction of the sun's rays for the first time, and the exact apparent diameter of the sun, obtaining confirmation by experiment of the eccentricity of the earth's orbit, for the measured dimensions are not constant during the course of the year but vary proportionately as the distance changes between the earth

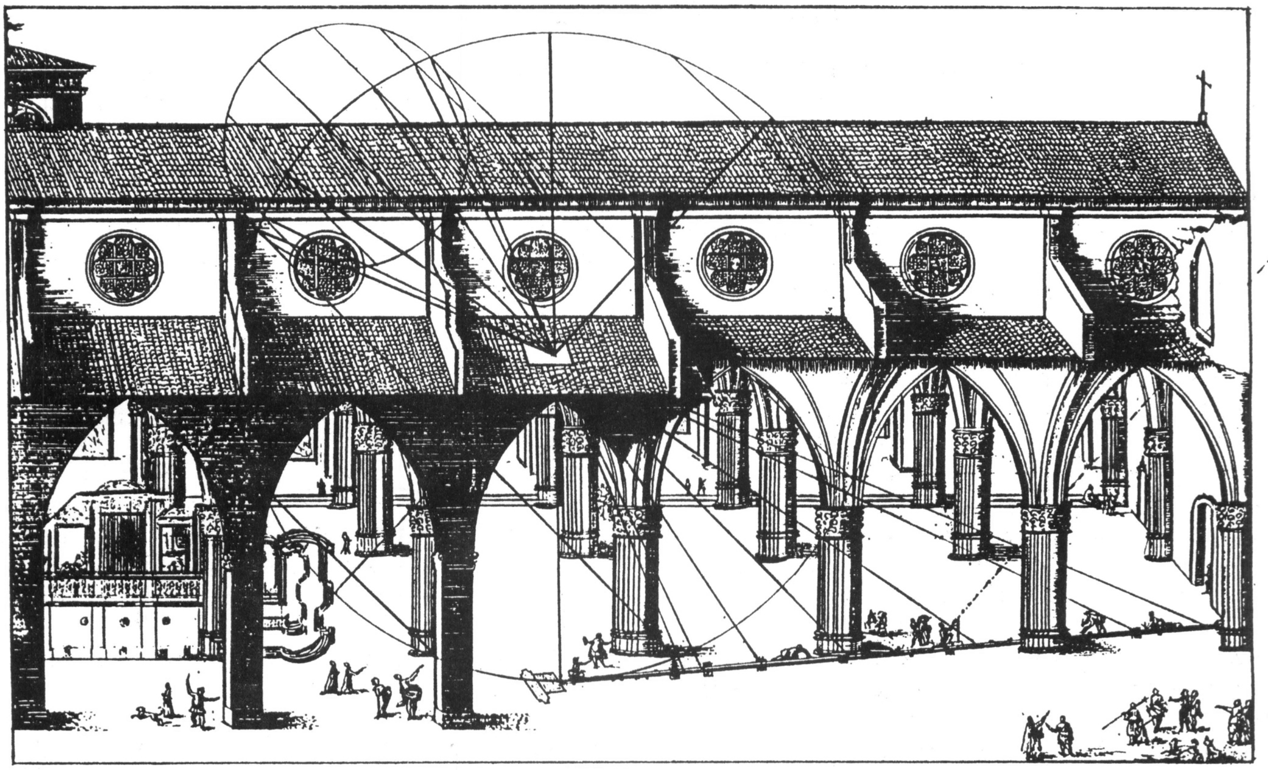

FIGURE 1: Sectional view of the Basilica of San Petronio, engraving of 1695 included in the treatise of Cassini

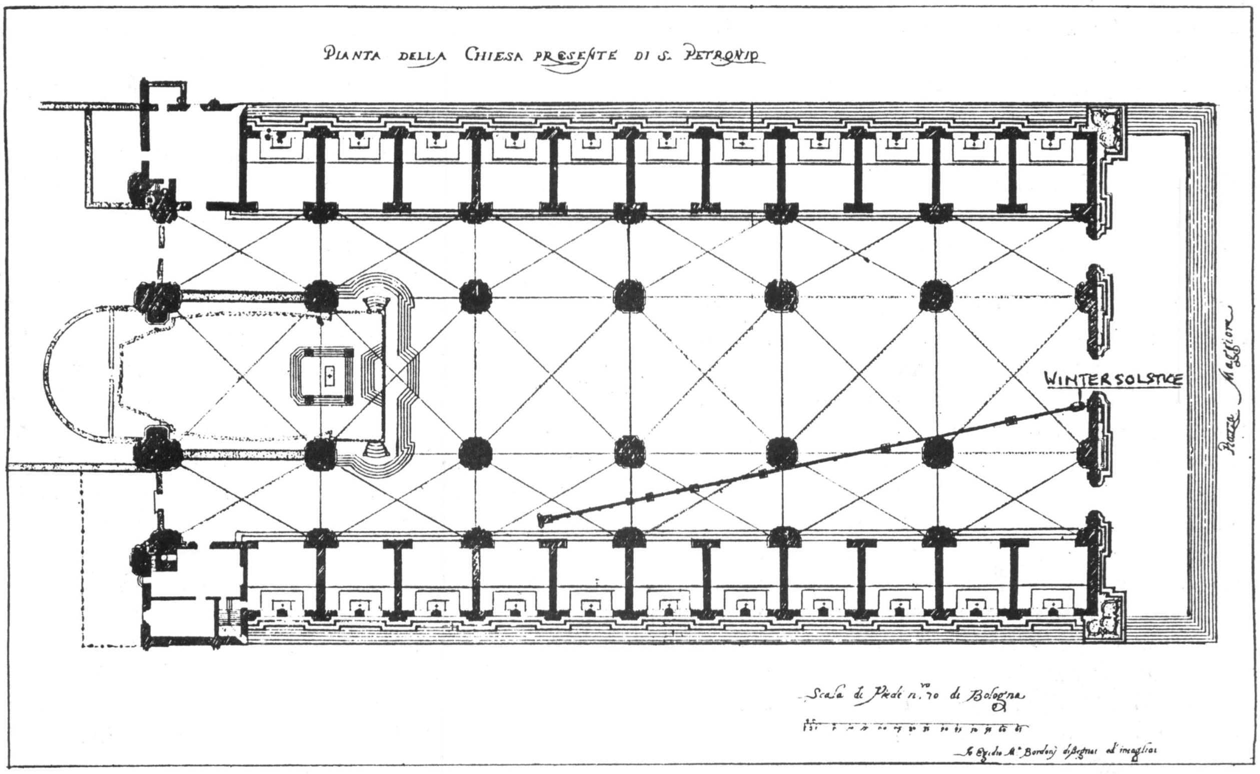

FIGURE 2: Plan of the Basilica of San Petronio, the Meridian Line passing between the nave columns

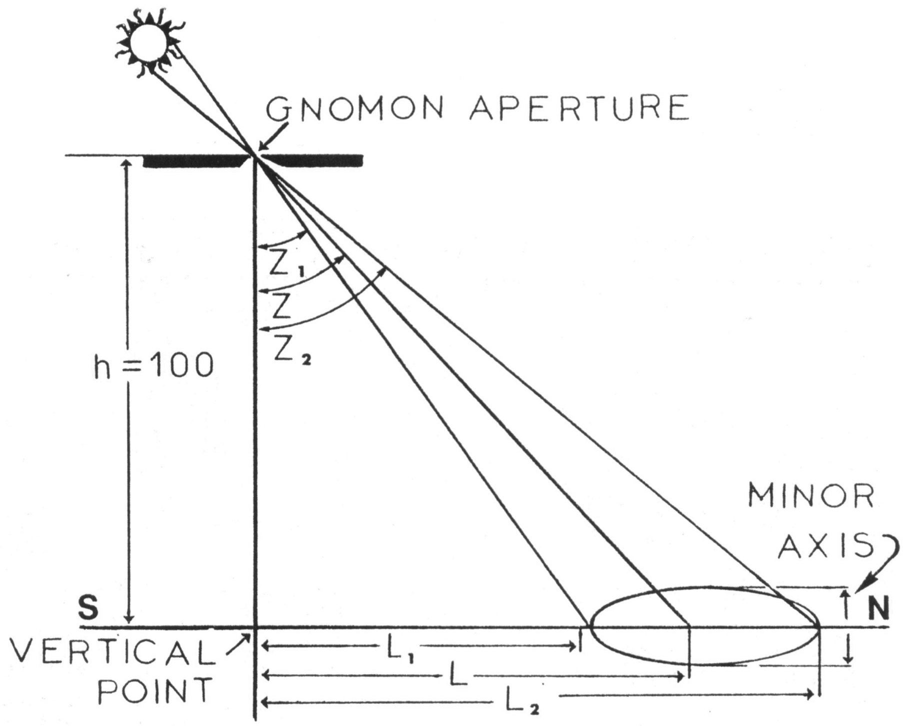

FIGURE 3: Functional diagram of the Bologna Meridian Line

and the sun.

The strict relationship between the solar declination δ, zenith angle z and the calendrical date, allows the tracing of a series of precise references on the meridian line; moreover one can note the identity of the days in which the sun passes from one sign in the zodiac to another. Similarly there is the strict recording of the amplitude of the diurnal arc, that is the interval between sunrise and sunset: this has contributed greatly to the creation of meridian lines in Italy, and also more than in any other country in the world, the reason and duration of a particular system of timekeeping which originated in this country.

ITALIAN HOURS

Up to about the end of 1500 a system of timekeeping was used (in Italy) which was based on the setting of the sun and a twenty-four hour day commencing at this instant - *the Ora Italiana Comune*, which in 1700 was subjected to a change of half an hour to become the *Ora Italiana da Campanile* (Italian hours from the bell tower); this later system was based on sunset at 23.30, followed by half an hour for twilight and finally with the ringing of the Angelus, all clocks struck 24 hours. This instant was deemed the end of the previous day and with night, the commencement of the next day.

Although such a system now seems peculiar, it had the great advantage being able to know (if one knew the clock time), how much time remained before the sky grew dark by subtracting clock time from 24. (This was of great value to those travellers who made long journeys).

There was one minor disadvantage, in order to follow the setting of the sun, a daily adjustment of about a minute (more or less according to the season) to mechanical clocks was necessary since these kept regular time. Also the time of midday moves in the course of the year; the recording of the relationship between the date, zenith angle and the consequent sunset was an important role of the meridian line in giving the indication of the time of midday according to the system of Italian hours.

CONSTRUCTION OF THE MERIDIAN LINE, CASSINI, 1655

Turning now to Gian Domenico Cassini and his achievement.

The astronomer, after the careful study of the possible solutions for a new meridian line, concluded that the optimum position for the gnomon aperture was in the centre of the fourth vault of the north nave. The meridian line would thus occupy much of this area but without interfering in any way with the religious functions, and would just graze the first and second columns to terminate near the western wall of the church at the winter solstice. (It is rare for a church to be of sufficient length to be able to accommodate a full meridian line, as at Bologna, which allows the winter solstice sun to cast an image on the church pavement, see Fig 2 and photo 6.)

After his deliberations Cassini informed the Senate of Bologna, who looked favourably upon the proposals and urged him to commence the work. The line of the meridian was provisionally traced, defining the exact position of the gnomon aperture by cementing a marble tile upon the roof of the vault. On the horizontal plane of this was fixed a thin brass plate containing the gnomon aperture. The diameter of this aperture corresponded to one thousandth part of the height of the hole above the pavement. The diameter of the opening in the tile was enlarged underneath to allow the sun's rays to pass through without hindrance to the pavement below. All the objects on the roof which might possibly interfere with the operation of the meridian were removed.

A fine copper wire with a weight on the lower end was lowered from the centre of the gnomon aperture, and placed in a container of water to damp out any oscillations caused by currents of air. This made it possible to define accurately the vertical point of the aperture on the meridian line below, this being the origin of the meridian scale. In order to determine the gnomon height, a chain made of links of wood was used with two registering bosses screwed at the extremities. The measurement was carried

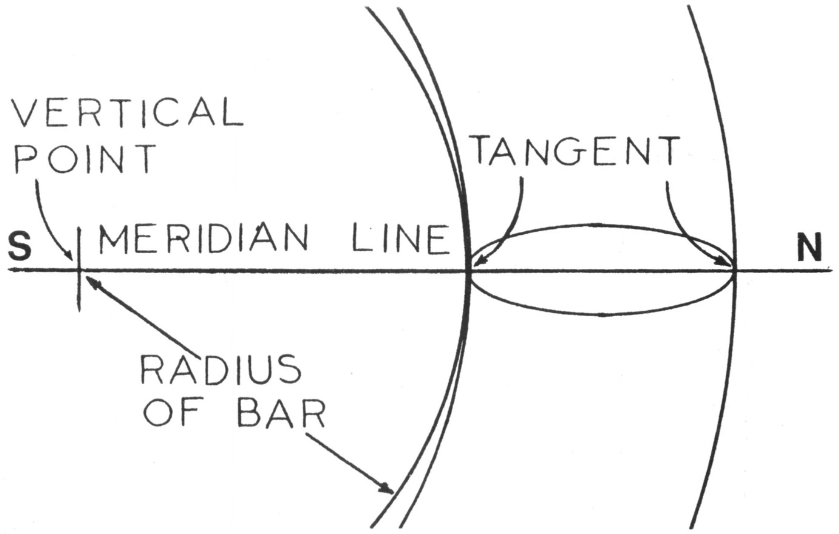

FIGURE 4: The sun's traces at the Summer Solstice 22nd June 1655

out with the chain under tension to eliminate any possible stretching later.

The gnomon height, or the distance between the upper plane of the horizontal brass plate of the gnomon and the marble slab on the floor below was found to be 1000 inches of the Paris foot, that is 71 ft 5 inches in Bologna feet (27·0699 metres).

As the time of the summer solstice of 1655 approached, a wide level pavement was arranged from the projection point to the vertical point, whose horizontal plane was guaranteed by a series of water channels connected to each other to function as a level reference. The date of 22nd June (date of the summer solstice) was fixed as the time to lay out the meridian line. As soon as the image of the sun stood out from the column and on to the pavement, one could mark the outer and inner limb of the ellipse and continue the meridian line up to the steps of the chapel, see Fig 4.

Using a bar of wood with metallic points at each end, one was positioned on the vertical point and the other used to describe the two arcs on the limits of the ellipse previously traced. (The sun always projects an elliptical or hyperbolic image on the floor, never a circle, the arc traced by the compass bar will be a tangent to the outer limits of the image and indicate a single point contact: the said point corresponds to the position at midday (local time) when the sun reaches the maximum height above the horizon for that day). Extending a line fixed at one end at the vertical point, to cross exactly over the two tangent points traced, and continued up to the internal wall at the far end of the church, allows the true meridian line to be defined.

In order to obtain perfect horizontal alignment of the meridian line (Fig 5), a long channel was arranged to run under the extended line: the edges of the channel being constructed as to follow the level of the water which it contained. To secure greater accuracy Cassini calculated how much the water (which followed the spherical contour of the earth) deviated from a true straight line. Although the resulting value was very small, Cassini did not lose the opportunity to include any correction to the horizontal displacement.

Draining out the water, two indicating scales of marble were inserted into the channel, one on each side of the line under tension. The first scale comprised marble slabs in lengths of two hundredths part of the gnomon height to show the progressive relative scale markings, whilst the second scale was made from marble slabs whose dimensions were equal to the tangent of each degree of the zenith from 1° to 68°, on each of which was engraved the respective angular value.

After concluding this delicate operation, the tensioned line was removed and a flat strip of iron laid in the floor to constitute the defined meridian line. The meridian line was then embellished by a series of slabs of marble on which the signs of the zodiac were engraved, these were inserted into the pavement adjacent to the meridian line. Further slabs placed at regular intervals indicate all the times of the rising of the sun, the second and third parts of the earth's circumference with the distance from the vertical point. Cassini calculated that the distance from the vertical point to the centre of the image projected by the winter solstice sun corresponded exactly to the six hundred thousandth part of the circumference of the earth. (The determination of the relationship between a given length and the circumference of the earth by Cassini anticipated the later metric system adopted in France.

The final definitive establishment of the meridian line

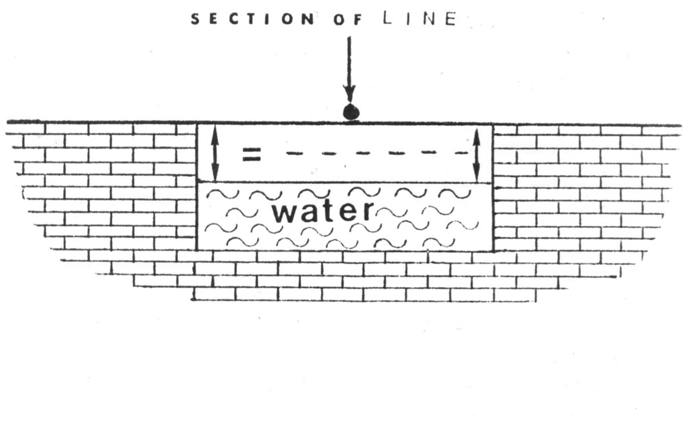

FIGURE 5: Section of meridian line during construction

FIGURE 6: Portrait of Gian Domenico Cassini (1625-1712)

FIGURE 7: Reproduction of Medallion commemorating the completion of the Meridian Line in the Basilica of San Petronio, Bologna, by Gian Domenico Cassini

was obtained only at the winter solstice in the same year when the relative luminous ellipse was engraved on the floor. Observations with the instrument had been initiated some time before, which allowed an estimate of where the image would fall and which was thus arrived at with especial accuracy.

Cassini records in his memoirs the meeting at the end of November 1655 with Queen Christine of Sweden, who stayed some days in Bologna and was given a drawing and description of the meridian line printed on a large silk sheet by the astronomer.

Because of the exceptional dimensions of the instrument, which allowed angular observations of high precision, Cassini named it the "Eliometro" (to measure the Sun), and was able to obtain the apparent diameter of the sun which in the course of a year varies as a consequence of the eccentricity of the earth's orbit. In addition the daily determination of the sun enabled the compilation of accurate reference tables which were a great improvement on those previously in use. The San Petronio meridian line was thus finally complete.

In 1669 G. D. Cassini journeyed to France for a visit which was intended to be short but which became a permanent one with an astronomical appointment in Paris. He returned to Bologna briefly forty years after he had constructed his great meridian line in order to restore his beloved instrument which had played so important a part in the progress of science.

THE RESTORATION BY GUGLIELMINI AND CASSINI, 1695

In 1695 Cassini was directed to Rome but stayed briefly in Bologna to put in hand the restoration of the meridian line made necessary by a lowering of the gnomon plate and the subsidence of many of the marble slabs adjoining the line. First securing the permission of the Senate of Bologna, he was assisted by his sons Giocomo and Domenico Guglielmini (the latter had succeeded to the Chair of Astronomy in Bologna), and with Egidio Bordoni acting as technician, he carried out the work of restoration in the following way.

One hundred modules were measured out on the line, constructing a pole of wood of that length. The module was compared with the unit of measurement used in France so that the module was exactly 10 inches of the Paris foot. The gnomon height was adjusted to correspond.

Not wishing to have any sensible deviation along the meridian line, a long channel was arranged along the length to allow the levelling of a side; an instrument furnished with a plumb line was allowed to just touch the surface of the water, providing a perfect horizontal reference for the resetting of the marble slabs forming the scales.

Not being able to remain further in Bologna, Cassini charged Guglielmini with constructing a special sextant to use in San Petronio with the help of the meridian line, with the eventual intention of determining the latitude of the basilica with precision. This instrument is now preserved in the Museum of San Petronio, and was used to align the meridian in the direction of North; some of the panes were removed from the large window in the facade, and with the help of a particular sight positioned on the wall it was possible to make observations of the pole star. (Note the Pole Star being observed in Fig 1).

As a reminder of the construction of the meridian and its later modifications a large commemorative slab was built into the wall between two chapels. Below this was fixed a brass plate with a length corresponding to a module, that is one hundredth part of the gnomon height. Additionally a book was printed which records the details of the meridian construction and its subsequent restoration. A beautiful bronze medal was minted, see Fig 7 and photos 1 and 2 [in part II].

(To be continued)

A LARGE TRANSLUCENT UNIVERSAL EQUATORIAL SUNDIAL

BY MAURICE J. KENN

Having demonstrated previously, on a small scale, the merits of a simple, translucent equatorial sundial[Ref. 1 & 2], I have more recently been inspired to build a somewhat larger universal version of this novel sundial.

Conveniently an empty, 1m high x 0.5m diameter, translucent, "Orange-juice bottle" came to hand, as shown in Plate 1.

This container has been suitably halved, inscribed, mounted and provided with a 1m long x 1.25mm diameter gnomon, as shown in Plates 2 and 3.

In these photographs, and in Plate 4, the sundial is arranged to show the sun time, from the front and from the rear, for Latitude 51° 30′ North (for example in London, England, and with the gnomon pointing up to the North Pole Star).

However, in Plates 5 and 6, the sundial has been re-arranged to show the sun time, again from the front and rear, for Latitude 33° 55′ South (for example in Sydney, Australia, and with the gnomon pointing down to the same Pole Star, now "Downunder"). The time in the Southern Hemisphere is indicated by the small numerals on the dial. These small numerals are necessarily arranged in reverse order to the larger numerals which are designed for use in the Northern Hemisphere.

The hourly divisions on this sundial are evenly spaced, at 15-degree intervals, and the sundial can, if necessary, be made to read "Clock" (or "Mean") time (even including "Summertime") by adjusting the dial (with a small rotational movement about the inclined axis) in accordance with calendar and the "Equation of Time.[Ref. 1 & 2]

The principal feature of this sundial, however, is that it can be read easily, at a distance, from both the front and rear.

Additionally, in the words of A.P. Herbert, the sundial provides "Fun with the Sun".[Ref. 3]

* * * * * *

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2. Kenn, Maurice J. "Sundials can be Simple and Legible'. *The British Sundial Society,* Bulletin 91/3, p.33, October, 1991.

3. Herbert, A.P. 'Sundials Old and New' *Methuen & Co. Ltd.,* 1967.

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Author's Address:
Maurice J. Kenn, 38 Corkscrew Hill, West Wickham, Kent, England, BR4 9BB.

Plate 1

Plate 2

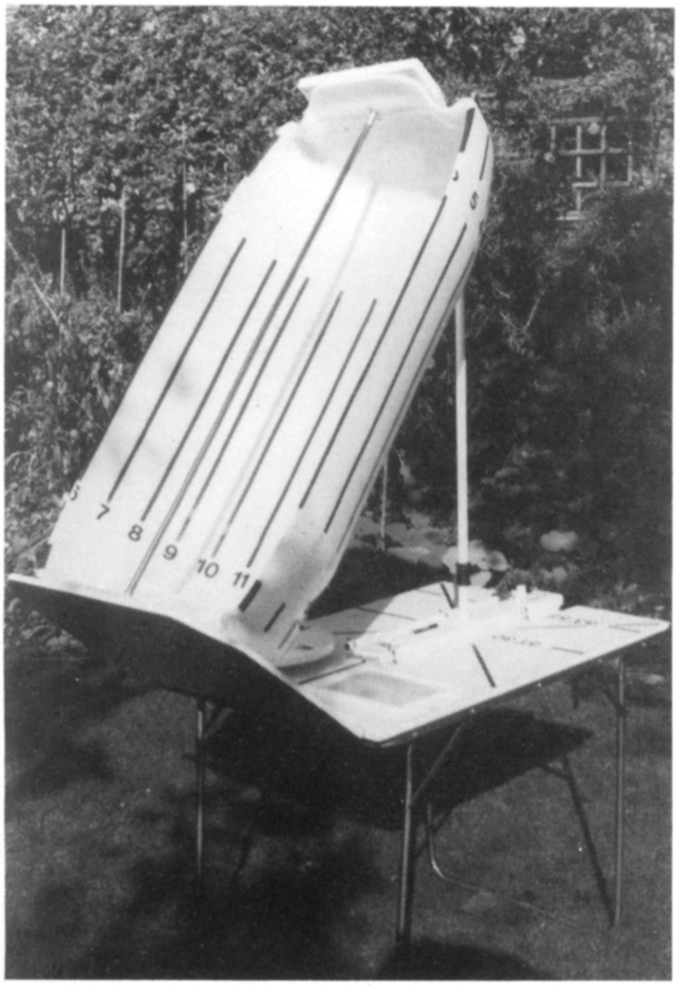

Plate 3

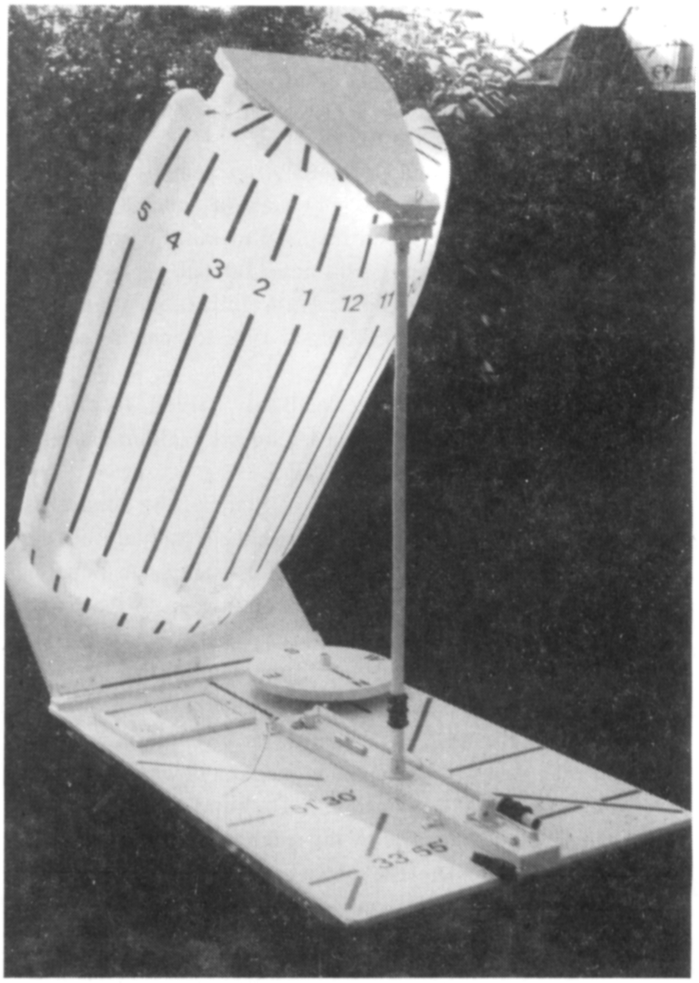

Plate 4

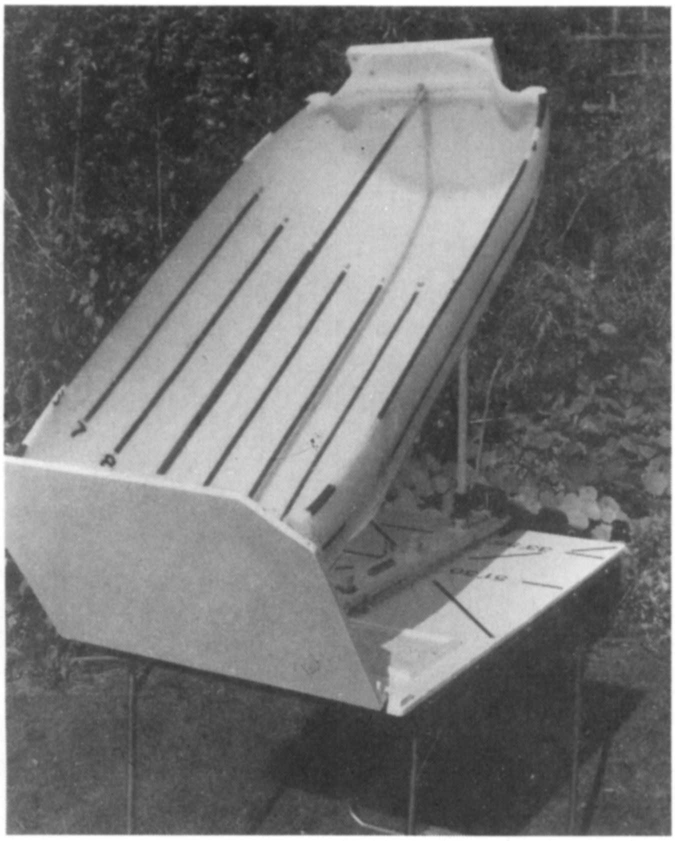

Plate 5

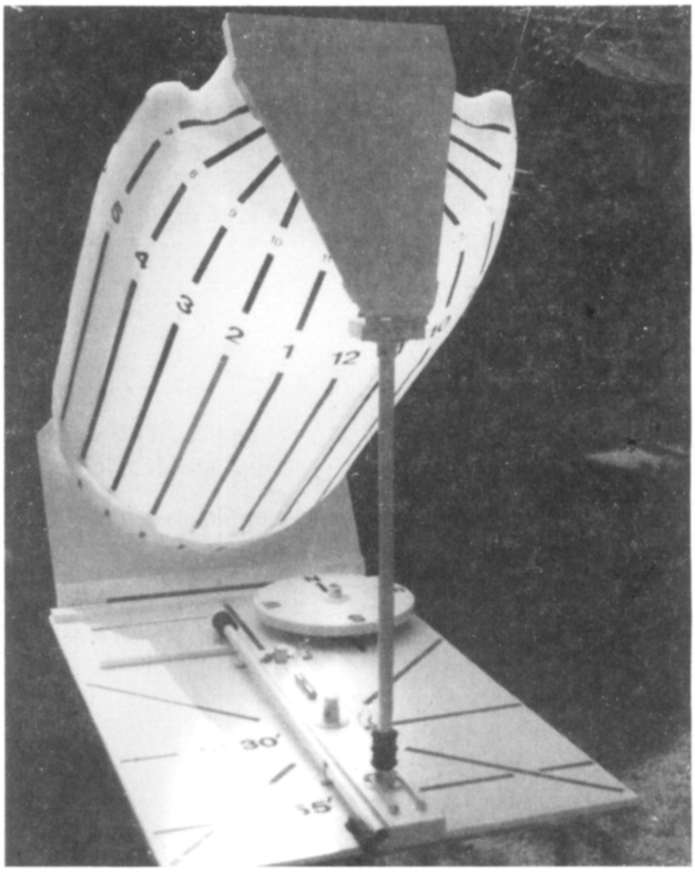

Plate 6

THE TRANSYLVANIAN ANALEMMATIC SUNDIAL

BY ROBERT McVEAN

1. INTRODUCTION

a) Aim

The Transylvanian sundial was installed with the aim of providing improved science education for Romanian orphans. In addition the construction and installation provided an exercise in management training for Groundwork Management trainees in 1993.

b) Location

Bradet is a small village near Sacele in the Transylvanian mountains. There is a school here and few supplies reach the school especially those for educational facilities.
See map 1.

c) The Sundial

We decided to install a Sundial as part of an educational garden incorporating an earth, wind, and sun theme. We wanted to build a sundial which could involve the children in the construction and the telling of the time. Therefore we built an analemmatic sundial, where the shadow from the person using the dial falls on the hour. The sundial was to consist of a plinth made of concrete with a mosaic of the months made of posts carrying surface and hour marks.

2. METHOD

a) The Team

We divided ourselves into teams of Design, Construction, and Fundraising prior to travelling to Romania. On arrival in Romania we re-organised ourselves again to ensure that the tasks we had set out to complete were achieved. We had nine days to install the sundial, build an outdoor classroom, prepare a site for a greenhouse, construct a path and build a fence to keep out horses. To build the sundial the team consisted of a core of three people with help occasionally given from other members of the party.

The following people were involved in some way or another in constructing the Sundial:

Liz Peel	John Cotgreave
Helena King	John Kilner
Alison Foote	Jon Biggadike
Roland Hughes	David Orchard
Trudy	Chris Bestwick
Robert McVean	Andrew Muddiman

b) Planning and Preparation

Considerable planning was made prior to our arrival in Bradet. This involved drawing a plan and securing materials unavailable in Romania.

The Base plan was drawn by C.H. McVean of the British Sundial Society. This plan was then scaled up for use in the installation phase. See diagram 1.

Floor tiles, outdoor paint, spades, saws, woodstain, coloured pencils, tile cutters, glass cutters and measuring tapes were obtained in Britain and shipped out by lorry before the team's arrival.

c) Installation

The main stages of the construction were as follows:

Stage 1: Setting out the dial

Stakes cut from poles of wood with several lengths of string were used for setting out the hour marks. Brilliantly clear skies allowed us to align the 'zero' - noon line to the Pole Star. This was done by three people, one holding a torch on the noon stake, another holding a torch on the 'zero' stake and the other standing south and asking 'noon' to move left or right.

Once the 'zero' to noon line had been established and marked with stakes and string the hour marks could be placed. We constructed a 5 x 3 x 4m 'clever' triangle with stakes and string to make a right angle and then placed the 0600 and 1800 hour marks with stakes and string back to the 'zero' stake. The 0600 to 1800 line formed the basis for setting out the hours using our 'clever' triangle. A thirty metre measuring tape was very useful for this job.

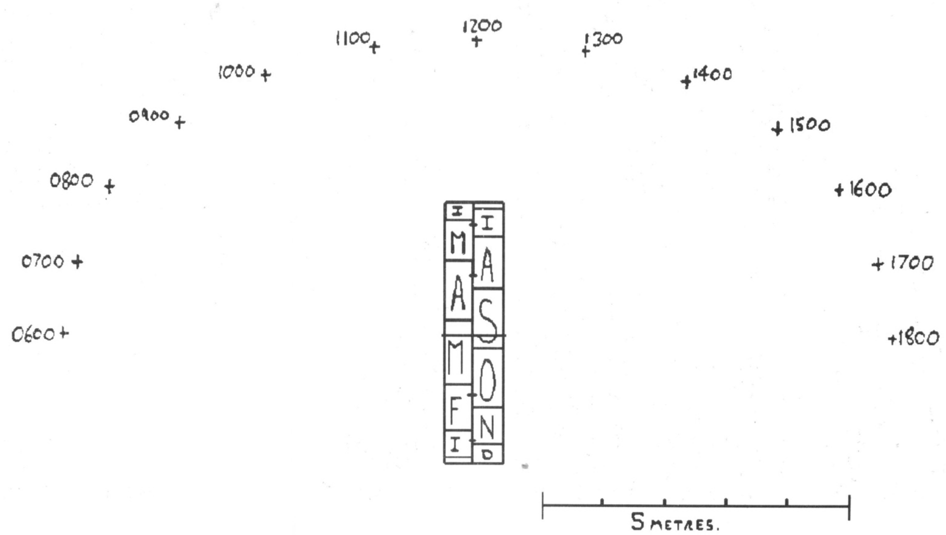

DIAGRAM 1: Plan of Analemmatic Sundial. From plan drawn by C.H. McVean, 1993.

Stage 2: Preparation

Holes were dug where the hour marks were to be placed. Hour marks were made by sawing a telegraph pole into lengths to be placed vertically in the holes. These lengths were painted with preservative woodstain. Two planks (4.26m x 0.3m) and two planks (1.0m x 0.3m) were cut for lining the plinth area. The plinth area was dug square and level and the planks fixed in position using steel rods. Hard core was placed in the base of the plinth area and the floor tiles were broken in preparation for the mosaic.

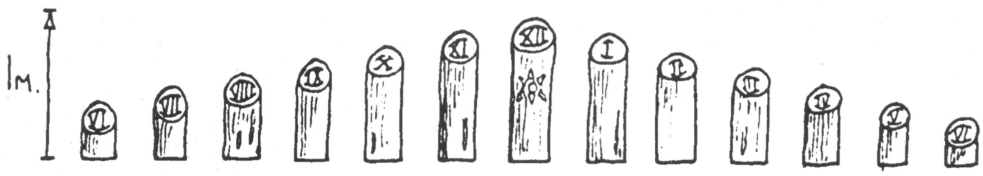

DIAGRAM 2: Hour Marks (to scale)

Stage 3: Installation

The logs were placed vertically in their appropriate holes and made firm by tampering down hard core around them. One layer of concrete (4 parts gravel: 1 part cement) was placed in the plinth area to a height 2″ short of the top of the planks. Once set a final layer of cement (3 parts sand: 2 parts cement) was used to install the mosaic.

The mosaic was made of broken floor tiles arranged in the letters of the months. Each individual piece of mosaic was blu-tacked to paper on plywood and pressed into position on the 2″ layer of fine concrete. Mirror tiles were used to line the meridian and equinoxes.

Stage 4: Final Touches

The hour numbers were painted on the faces of the hour marks. These numbers are in Roman Numerals and a sun appears on the twelve noon mark. The mosaic pieces were cleaned of cement.

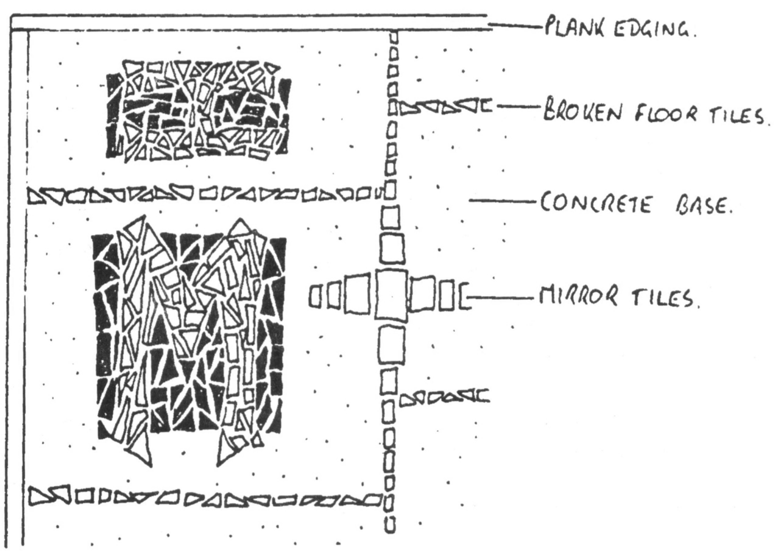

DIAGRAM 3: Details of Plinth

3. RESULT

An analemmatic sundial now stands in the grounds of the orphanage school at Bradet. One hour has to be added for summer time and the user must stand on the correct month. Future maintenance will be carried out by British Students and it is hoped that an 'explanation' panel may be produced for installation in the future.

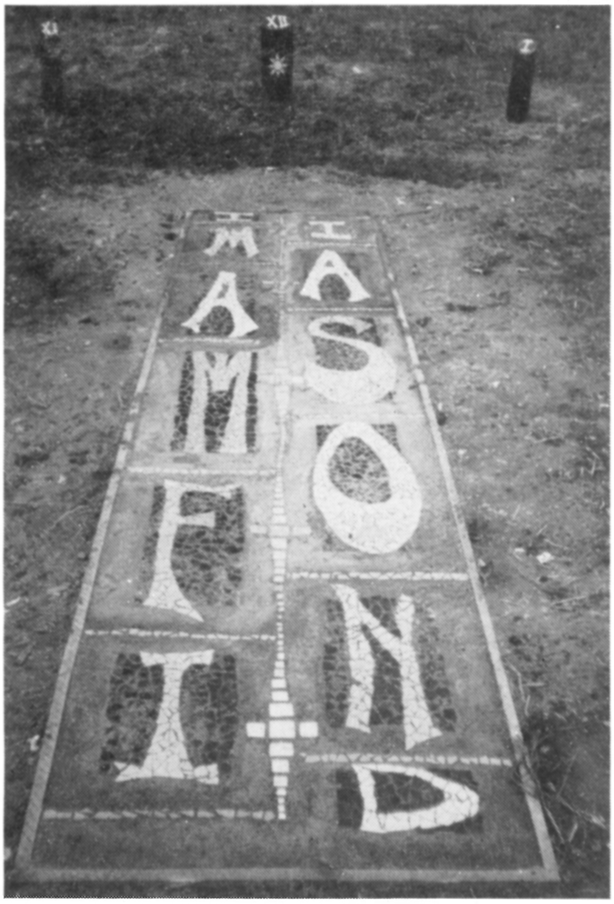

PHOTO 1: The Analemmatic Sundial

PHOTO 2: Hour Mark for XII (Noon)

CEEFAX

Reversal of Sun-time achieved in Sussex!

Page 172 on CEEFAX on Friday 11th March 1994 had the following announcement:

SUNDIAL FINALLY RUNS OUT OF TIME

An historic sundial on a Suffolk village church is causing a few headaches - because it reads the time backwards.

The problem started when the face of the dial, made famous in Charles Dicken's novel *David Copperfield*, fell off.

But when the replacement turned up at St. Mary's Church in Blundeston, the numerals were the wrong way round.

Now, yet another face is set to solve the time-telling trouble!

Note: At the risk of teaching one's grandmother how to suck eggs, it may be pointed out that the figures were not the wrong way round, it was that the figures were placed in the incorrect sequence. It was only noticed when the evening service was held in the early morning on the first Sunday after the replacement dial was fixed in place.

Quote from *Sundial of the Season* by Hal Borland (1964):

Here comes February, a little girl with her first Valentine, a red bow in her wind-blown hair, a kiss waiting on her lips, a tantrum just back of her laughter.

SALES

The first three Bulletins are now available as a Quinquennial Celebration Reprint to mark the first five years of the British Sundial Society. It contains 68 pages and is available at the price of £7.50, which includes inland postage only, for despatch to overseas members, please ask for details, or consult latest sales list.

Later issues of the Bulletin are available at the price of £5.00 each, inland postage included. Some of the earlier issues are now out of print and will not be republished.

Badges at £3.50 and ties at £8.00 with the British Sundial Society emblem, and number of publications such as the listing of sundials, are also available. The complete list of BSS items, with prices, can be obtained from the address below. Please enclose a SAE for reply to reduce BSS costs.

Because of the extra costs of despatch to overseas members, some of this has to be passed on; see the latest sales list for details.

Orders to: Mrs. Anne Somerville, Mendota, Middlewood Road, HIGHER POYNTON, Cheshire SK12 1X. Tel: 0625 872943.

CHEQUES PAYABLE TO: THE BRITISH SUNDIAL SOCIETY.

PORTABLE SUNDIALS IN ANCIENT ROME

RENÉ R.-J. ROHR (FRANCE)

History concludes that the rise and expansion of military power in the early Roman Empire was responsible for the twilight and slow decay of the sparkling culture of classical Greece. Greek culture had been at its zenith about the time of Archimedes; his death at the hands of a Roman soldier towards the end of the second Punic War, during the final storm on besieged Syracuse, was a great tragedy for mankind. Archimedes is one of the most outstanding names in the history of mathematics, following him no further research of any real importance was recorded in this science for some fifteen centuries.

The ability of the Romans as architects, engineers, or in the military field will never be questioned. But they never seemed to take any real interest in the theoretical sciences as the Greeks had done centuries earlier. Historical records of classical antiquity relate the names of almost a hundred Greek mathematicians, even including a woman, fair Hypatia, the daughter of the mathematician Theon. Her name has resounded down the milleniums.

As to the Romans, for lack of names in this field, one has to turn to such as Vitruvius, whose fame rests upon the authorship of *De Architectura*, which according to modern authorities seems to be a compilation from Greek texts.[1] The art of the Romans in building lasting monuments cannot be criticised, but it may be noted that its solidity relies largely on estimation rather than the measured artistic harmony used by the Greeks where, in spite of the lighter execution with materials, the apparent solidity remains the same.

In book nine of Vitruvius's work, a short section covers Astronomy and Time Measurement including gnomonics. Clepsydras, and some anaphoric devices.[1] Interested readers may be deceived since the whole summary on gnomonic texts consists of a list of the names of thirteen instruments in common use, of which ten are given the names of their inventors, the remaining three being ascribed to all of them. An impression is gained that the author handled this subject reluctantly, or perhaps did not master it any more than was absolutely necessary. With the exception of Berossos, the Chaldean priest and inventor of the *hemispherium*, all the names quoted are Greek. The lack of the slightest hint as to the forms or uses of the instruments, causes modern archaeologists difficulties when trying to assign these names to the ancient instruments now preserved in museums or collections.

However there is a surprising contrast between this almost empty paragraph when compared with the immediately preceding section with the astonishing geometrical study of the Greek conception known as the *analemma*. The reader cannot help noting the immense change in conceptual level between the two paragraphs - thus the plagiarism from the older Greek texts is immediately apparent. So much so that renowned modern scholars are now extending judgement from this example to the whole of *De Architectura*.[1]

Most of the instruments in the listing by Vitruvius have not been assigned to the extant dials known today. But independently of the Vitruvius list, some have been discerned as portable dials.

One of the best known of this kind is the bronze casting in the Naples Museum in the form of a ham (Fig 1),

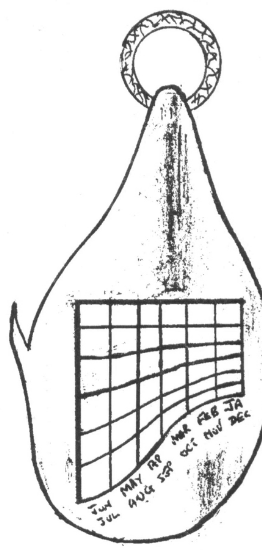

FIGURE 1: The "Ham of Portici"

consequently it is called the *Ham of Portici* from the name of the site where it was discovered in the ashes of the volcanic eruption of 1755. It is an altitude dial, ie. it derives the hour from the altitude of the sun instead of its azimuth. On the front plane, with the instrument hanging from its suspension ring, are equally spaced vertical parallel lines of which the spaces serve for successive months indicated by the abbreviations below. As the months July and August were not introduced in the Roman calendar until as late as 27 BC, one knows the time of its use. Seven more lines are drawn on this face, the uppermost being horizontal and exactly at the same height as the tip of a projection rising on the left and placed at a small distance from the dial to throw its shadow on it; the other six lines are more and more inclined towards the left. These are the hour lines for temporary hours, from 0-6 downwards in the morning, and from 6-12 upwards in the afternoon.

Temporary hours are those mentioned in the Bible, they are sometimes called Biblical hours because of this. The night too goes from 0 at sunset to 12 at sunrise, their lengths changing with the seasons and the corresponding lengths of the days and nights, the variations being in opposite sense for the north and south hemispheres.

As a curiosity, in passing, one may note that Christopher Schissler, the renowned instrument maker of Augsburg, in 1609 made a similar dial on a rectangular brass plate; of which a copy made by an amateur is shown in Fig. 2. The original is in the Rohan Museum, Strasbourg.

In another place, the Landesmuseum Treves is preserved a large mosaic taken from an ancient Roman pavement (Fig. 3) showing the picture of an old man sat down and pointing to a sundial and its gnomon.[2] The dial looks like an open book, the left and right pages are marked with the hour lines for morning and afternoon. No lines for the months are drawn, their places possibly had to be guessed by the observer, but it looks rather the result of ignorance or negligence on the part of the craftsman who made it, his employer, or even the owner of the villa. There is no age

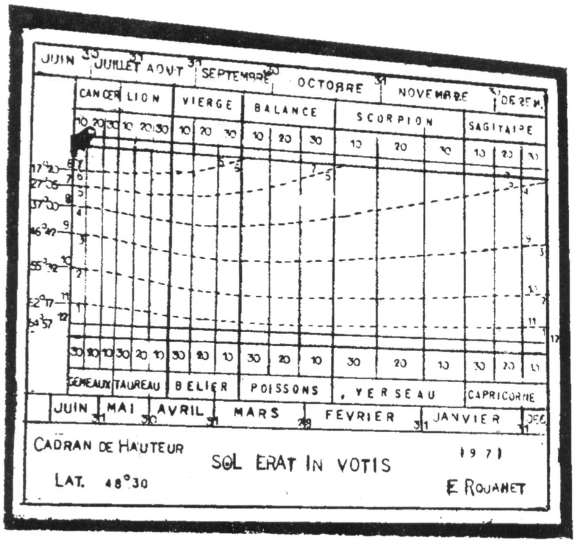

FIGURE 2: Replica of Christopher Schissler Dial made by E. Rouanet, 1971

FIGURE 3: The Treves Mosaic

without faulty dials.[3]

In a different and more frequently discovered form of this type of dial, the hour lines issue fan-shaped on discs from the centre towards one of the lower quadrants (Fig. 4). The discs were placed at the bottom of a circular box whose side was pierced with a hole at the end of the horizontal diameter. With the dial hanging vertically the sun rays in passing through the hole will mark the date on the radius, and the hour between the almost concentrically disposed hour lines. A light brass pointer aids the observer when using the dial. The sketch shown in Fig. 4 refers to a dial found on Mount Herapel, a hill near Forbach (Moselle, France). It shows only the names of the solstice months, ie. at those days in January and July.[4]

The Mayence museum possesses another variety of dial of which only one example is known. It consists of an ivory plate with a slightly raised rim. When hanging, as all these dials must be for use, the left half of its horizontal diameter (Fig. 5) is graduated into 12 parts in which are as many holes large enough to hold a short gnomon. Their line represents a series of months, each hole accounting for half a month whose names are given in abbreviations along the line. With the gnomon in the hole for a particular date, its shadow marks the hour as in the Herapel dial.

The fact that the specimen is unique and from the vary unsatisfying result of mathematical analyses[2] comes the suggestion that it possibly served in the experiments of some ancient jack-of-all-trades.

All the instruments hitherto seen were for use in one and the same latitude. In the Vitruvian list is the term *pro pan klima*, meaning "for more latitudes". A dial more fitted for travellers is a specimen found in Memphis, on the rear of which is engraved radially with the names of 35 towns or provinces and their approximate latitudes going from 9° (India) to 50° (Aquileia).

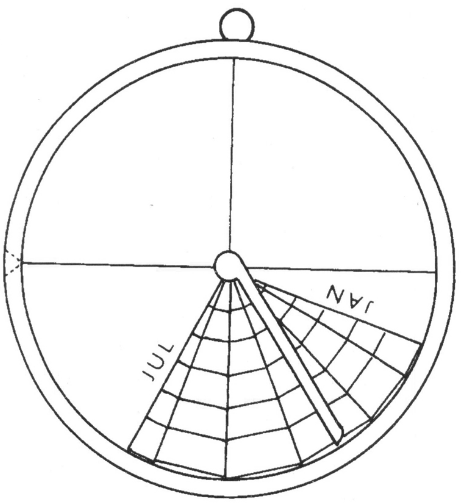

FIGURE 4: The Mount Herapel Dial

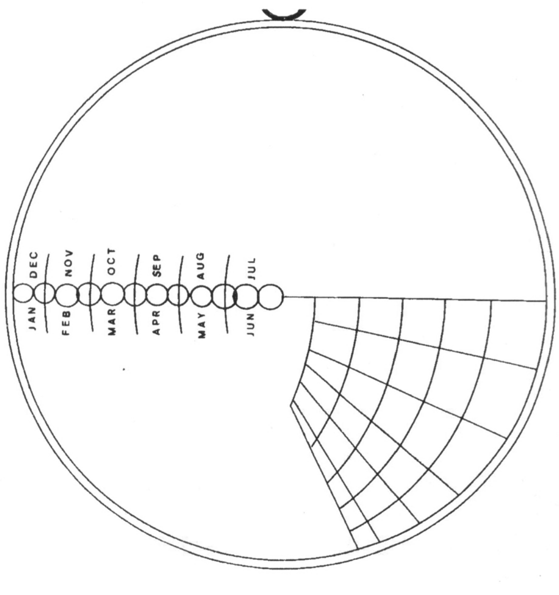

FIGURE 5: The Mayence Dial

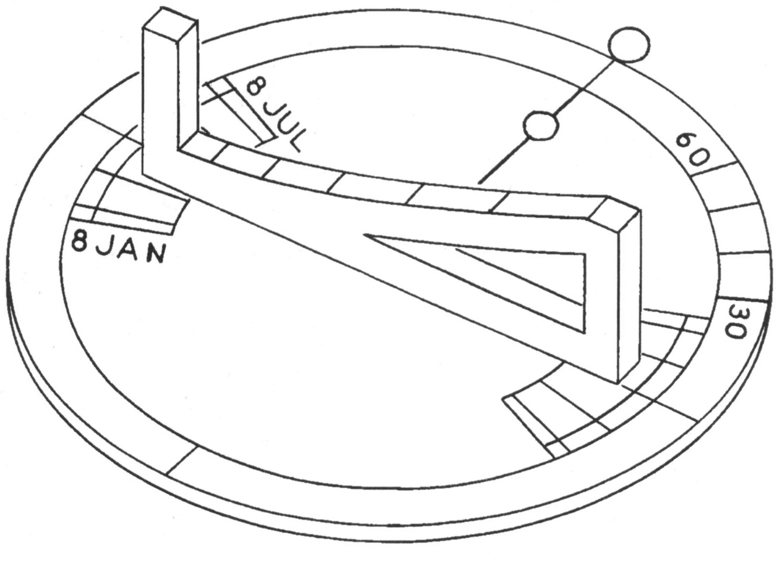

FIGURE 6: The *Pro Pan Klima* (Oxford)

Dials like the previously mentioned one have been found more often, from Crêt-Chatelard, Rome and other places, but all of them were lacking parts, mostly the gnomon which proved later on to have been of special form. A very renowned specialist[3] openly confessed that *the theory of their application could not so far be explained.* He evidently was not aware that the Museum of the History of Science of Oxford was in possession of a complete and well preserved specimen that had been found years ago near Pressburg (Bratislava) and acquired by the English collector Mr. Evans who published a satisfying study of its use.[4]

It is in the form of a brass disc some 6cm in diameter with a slightly raised edge (Fig. 6). A smaller second disc is inserted into the first and rotates around the central axis which is fixed to a third part. This part is a pierced metal plate forming a rectangular triangle BCD with its hypotenuse BD slightly concave, and a gnomon AB of exactly the same length as the side CD, see Fig. 7. Drawn from the point A as origin, six angles of 15° mark the six temporary hours of the two halves of the day on side BC. On the rotating inner disc (Fig. 8), a diameter marks the equator bearing on each of its ends the angles of declination of the sun on the days of its changing the signs in the zodiac. Again for the reason mentioned the extreme signs begin on January 8th and July 8th, a fact that dates the age of the dial at the latest in the last century BC. Perpendicular to the equator is a radius marking the north, a button on it is provided to rotate the disc as required by the user.

For use, the instrument is suspended freely on a string, the northern radius of the inner disc is suitably turned to a latitude graduation visible on the edge of the outer disc. The latitude graduation is from 30° to 60° (XXX-LX), the outermost limits of the Imperium (Roman Empire). Point B of the gnomon is placed on the date in the zodiac and the dial is then ready for observations.

To this end the dial is turned in order to place the shadow of point A exactly on the side BC of the triangle; it will then be at B at sunrise, ie. zero hour, the morning hours follow and at D the shadow will mark noon, ie. the sixth hour. During the afternoon, its movement will be back to B at sunset and the twelfth hour, and simultaneously zero hour for the night period.

As ever, Drecker[2] proves in his accurate analyses that the error committed in observations will be least in latitude 45° (North or South), but at 30° or 60° it will not exceed the ordinary errors of reading the indications. One cannot help admiring the genial inventor of this dial. He was certainly gifted with a talent for solid geometry, the more so as in the given limits the indications of the dial are nearing tangential true precision. It may be noted here that making a working model and experimenting with it would be a most interesting pastime. It would also be possible to try the dial outside the above-mentioned limits and record that it functions in all the places of the world where sunrise and sunset are daily events, but nevertheless avoiding the deceptions when crossing the polar circles 66·45°, where temporal hours are slowly losing significance as opposed to the indications at the equator where the hours indicated will be those of our present-day clocks!

As to the inventor of this dialling jewel, Vitruvius gives us two names: *Theodosius* and *Andreias.* The latter name possibly refers to Andreas who was medical adviser to King Ptolemy IV (3rd century BC) of whom nothing notable is known. Theodosius lived in Bithyny (2nd century BC) and was a mathematican and astronomer who wrote on solid geometry and time measurement, on sunrise and sunset, the change in the length of the day and night and many more matters. He must have been the inventor of this type of dial, he was a Greek from Asia Minor.

ACKNOWLEDGEMENT
The Editor wishes to express his thanks to Mr. Alan Partridge for improving the original sketches supplied by M. Rohr.

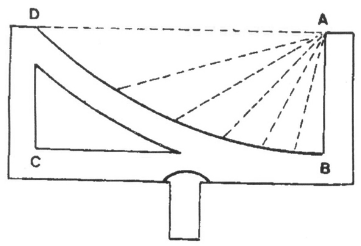

FIGURE 7: The style of the Pro Pan Klima

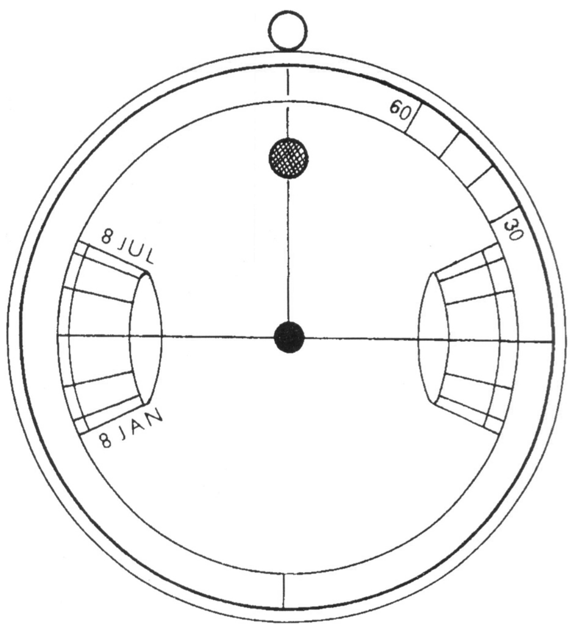

FIGURE 8: The Arvo brass plates of the Pro Pan Klima

NOTES

(1) The paragraph on gnomonics does not exceed 17 lines (copybook size).

(2) In Treves the saying is "make it the picture of Anaximander", one of the Greek philosophers. (He had a large mouth, teeth and nose.)

(3) In Roman gnomonics, faulty dials are common. The Rohan Museum in Strasbourg has a second century hemispherium found in Alsace with the circles of equator and solstices in vertical planes.

(4) These are the dates of the Solstices before the reform of the Roman calendar by Julius Caesar in 46 BC which gave us the Julian Calendar.

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[2] DRECKER, Joseph, *Theorie de Sonnenuhren,* Leipzig, 1925.

[3] SOUBIRAN, Jean, *Vitruve, De l'Architecture,* Livre IX, 1965.

[4] EVANS, Lewis, *Sundials and their Mottoes,* Hertford, 1904.

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BRITISH SUNDIAL COMPETITION
OPEN COMPETION FOR MERIT AWARDS FOR FIXED SUNDIALS
INAUGURAL SCHEME 1984-1985

The British Sundial Society is sponsoring an Open Competition to make awards in respect of the best sundials erected in the United Kingdom within the last five years. This is an inaugural scheme for a competition which the BSS intends to hold at intervals in the future.

This inaugural competition is open to the designers, makers and manufacturers of fixed sundials erected within the boundaries of the United Kingdom. Later competitions may be expanded to include categories for overseas sundials.

The objects of the competition are:

1. The encouragement of good design and manufacture of sundials.
2. The commissioning of new sundials.
3. The application of the science and art of dialling.
4. The increase in knowledge of all types of dials.

ENTRIES are called for in the following categories:

HORIZONTAL DIALS

VERTICAL DIALS

OTHER DIALS

The entry fee is £30.00.

Cheques payable to the British Sundial Society.

The full details, together with the Rules and Conditions for the British Sundial Society Open Competition area available from:

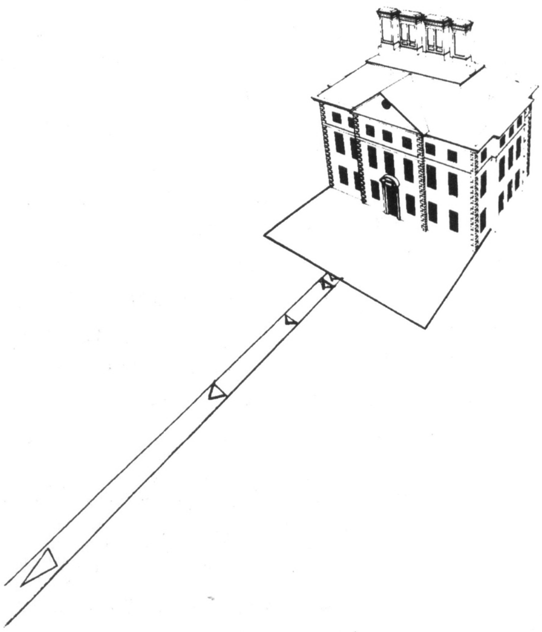
The British Sundial Society
45 Hound Street
SHERBORNE
DORSET DT9 3AB
Telephone: 0935 812544

All entries must be submitted by 21st March, 1995.

WINSLOW HALL CALENDAR FOOTPATH

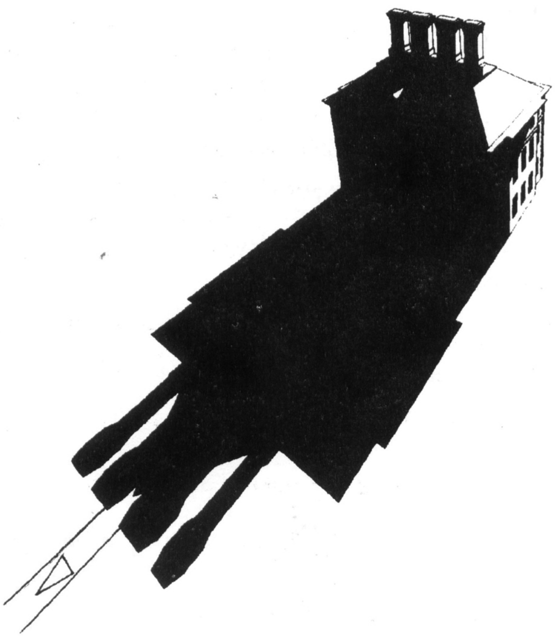
PETER AYLEY, ARCHITECT (FRANCE)

Winslow Hall is a very crisp house designed by Sir Christopher Wren and located in Buckinghamshire. It was built with the craftsmanship of the workforce which had been building London Churches following the Great Fire and also the Royal Palaces. Constructed in the first decade of the eighteenth century, its extraordinary characteristic is that of the four chimneys which appear to skewer it to the ground.

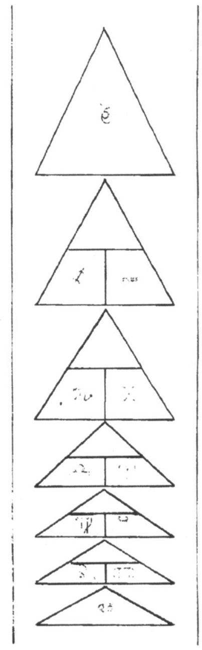


1. View of house showing the new terrace and the calendar footpath with its inlaid triangular stones.

The house is orientated very nearly due South looking across the London Road to the fields beyond. The North Elevation is almost identical to the South except for the change in level and the absence of an entrance stair.

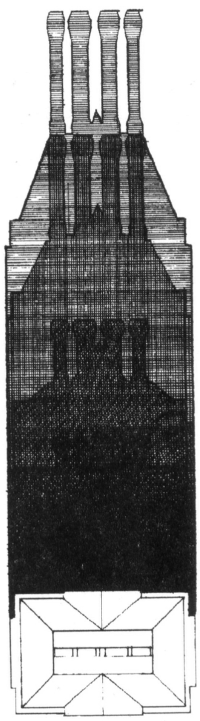


2. View of Winslow House in mid-October, showing the shadow of the pediment poking through that of the two central chimneys.



3. The triangular stones shaped as receptors of the shadow of the pediment, carved with the sign of the zodiac (grouped for display).

Visiting the house as a guest of Sir Edward Tomkins and his wife one October, I noticed that the long shadow of the house in the garden was dominated by the four chimneys which seemed to reach into infinity. As the Sun aligned itself squarely with the building, the pediment just poked through between the two central chimneys. This observation conjured up an idea in my head almost



4. Diagram showing the shadows at the entries to the zodiac signs superposed during a whole solar calendar year.

(Continued on page 14)

LETTERS TO THE EDITOR

KRATZER

It is intriguing to note points of contact, agreement, and disagreement when blocks of independantly conducted research are presented together without colation or cross-reference. The material on Kratzer translated from "German and Dutch Astronomical Instruments of the 11th to 18th Centuries" (as it should surely have been rendered!) begs several questions. Tiedemann Giese was the Roman Catholic Bishop of Kulm in Polish Prussia (now Chelmno in Poland) not of Ulm in southern German (which is virtually on the same parallel of Latitude as Vienna). He was also the friend and patron of Copernicus, who certainly did design/construct Sundials in Polish Prussia and in the adjacent Polish province of Ermland. This being so, why should Giese go to a man from southern Germany, but living in England, for a Sundial to be erected at Koenigsberg in the German Lutheran Grand Dutchy of East Prussia? Nor is even Koenigsberg quite as far north as latitude 55° (if that is how the printed 550 is to be interpreted). The quoted source for this information, and the date of that source makes it (if otherwise unverified) highly suspect as a possible piece of minor Nazi propaganda (British propaganda, with a similar "historical" base, was equally prone to distortion). Similarly, it needs to be emphasized that all British Scholars mentioning The Small Gilt Brass Sundial Made by Kratzer for Cardinal Wolsey, from its first discoverer ownwards, are quite clear that it was made for Latitude 52°, rather than the 48/49° given in the continental source.

Kratzer's Notebook is a strict copy of an "old book" kept in the Library of the Monastery of Maurbach, which was at latitude 48°, and so of course its instructions and diagrammes relate to that Latitude. Indeed all of the first generation of publishing diallists, Münster, Finé, etc. give diagrammes exclusively for that approximate Latitude; it being the Latitude of Vienna, Munich and Paris and, more significantly to a 16th century schoolman than to us, the approximate Latitude of the most northerly of the Seven Climates of Classical antiquity (see my recent article); indeed, with a little adjustment, London itself could just about scrape into this climate, and thus be considered part of Civilization! My article on "the eccentric sundial" describes the only (sic) construction in Kratzer's Notebook which is not (save in the case of other 'universal' constructions) worked through for Latitude 48°, but for Latitude 45°. If this, for the 6th climate centred or starting at Latitude 45°, was deemed suitable for Maurbach at Latitude 48°, then the construction for Climate 7, centred or starting at Latitude 49°, would certainly easily cover London at Latitude 51°. It might well be that this construction was more significant to Kratzer's method than I have allowed, and that the continental researchers have been misled by its use.

If Giese, the patron of Copernicus, really did employ Kratzer, then it might well be that Kratzer and Copernicus were in correspondence and that the former was employed on the latter's recommendation. Come to think of it, the lower part of Kratzer's Composite Instrument, with its Quadrant of altitude and shadow-casting peg, is very like the Meridian Quadrant which Copernicus is known to have constructed and used: we do not know whether Kratzer also made a version of Copernicus's curious Triquetrum, which measured celestial angles of Altitude as Chords from the Zenith! Perhaps the Dial commissioned from Kratzer was a peace offering from the Catholic Bishop to the Lutheran Duke (to whom, incidently, Copernicus once gave a course of successful medical treatment). Perhaps Krazter traveled out to Prussia to execute the commission and actually met Copernicus. Who can say? I am in no position to follow up this 'lead'!

The Translator however must be careful, and the proof reader more so. I have never thought of myself as much of a translator, but more as an interpreter of Geometry, a form of communication which is above any language. It is galling therefore to note that in the one passage in my article on "Eccentric Sundials" which is a very exact translation, an absolutely vital piece of Geometric construction has been quite lost, during the printing process, by the muddling together of two very similar adjacent sentences. In place of the 13th and 14th lines of column 2 on page 33 of the Feb 1994 Bulletin (printed as "Place one foot of your compasses on L and extend the other to the fifth part towards L beyond D. Sweep an arc from ..."), the following needs to be read (and understood!): "Place one foot of your compasses on K and extend the other to the fifth part towards L beyond D. Sweep an arc from that fifth part towards the Meridian Line until it meets the Meridian Line at M. Place one foot of your compasses on point L and extend the other to the fifth part towards K beyond D. Sweep an arc from ...". The repetitious formulaic style exactly translates the original Latin, and also conveys the necessary meaning: what was printed does neither.

PETER I. DRINKWATER

EDITOR: The above is printed verbatim et litteratim.

* * * * * *

THE EQUATION OF TIME

I read with great interest (in October's Bulletin) Mr. W. Hughes' excellent article on the equation of time.

Mr. Hughes writes "The equation of time has to be added to the apparent solar time (sundial time), plus the difference in longitude from Greenwich, to give the mean solar time (clock time)".

As this is a subject of general interest and confusion I take the liberty to elaborate on this matter:

Basically a Sundial is designed to show "Local Apparent Time" (LAT), this is "True (solar) Time".

LAT differs from "Local Mean Time" (LMT), as defined by the regular and imaginary Mean Sun, by the Equation of Time: "e".

"Local" indicates here the meridian of the place in which the sundial is to be used.

Thus by definition:

$$LAT = LMT - e \qquad (1)$$

"e" to be applied with its own sign as can be read from the graphical presentation of the equation of time, ie:

e is positive from Dec 25th to Apr 16th and from June 14th to Sept 1st

e is negative from April 16th to June 14th and from Sept 1st to Dec 25th

The difference between LMT and Greenwich Mean Time (GMT) is the longitude (g) of the place of the observer converted to time (gt).

1 degree in longitude is 4 minutes of time

1 minute of longitude is 4 seconds of time

$$LMT = GMT + gt \qquad (2)$$

gt is positive for Easterly longitudes

gt is negative for Westerly longitudes

From (1) and (2):

$$LAT = GMT + gt - e \qquad (3)$$

Your watch shows Local Time (LT), usually Standard Time or Zone Time:

$$LT = GMT + n \qquad (4)$$

n is (usually) an integer

Ex: In UK during Summer LT = GMT + 1   n = 1
In UK during Winter LT = GMT   n = 0
In New York LT = GMT - 5   n = -5

From (3) and (4):

$$LAT = LT - n + gt - e \qquad (5)$$

$$LT = LAT + n - gt + e \qquad (6)$$

To convert from Watch time to Sundial time use formula (5)

To convert from Sundial time to Watch time use formula (6)

Example:

May 3th: A place near Liverpool (longitude 3 degrees West)

Q1 : What time does your sundial show when your watch reads 1500 hours (3 PM)?

Q2 : Your sundial reads Noon, what time is it on your watch?

May 3rd : n = 1 (British Summer Time)
e = -3 Min
g = 3°W gt = -12 Minutes

LT	15 00			LAT	12 00		
-n	-1 00	H		+n	1 00	H	
+gt	-12	min		-gt	-(-12)	min	
-e	-(-3)	min		+e	-3	min	
LAT	13 51			LT	13 09		

Ans 1 : 01 H 51 min P.M.   Ans 2: 01 H 09 min P.M.

Note: LAT + n - gt = LT - e

as (n - gt) is a constant for a certain place (except when Summer Time is kept) this correction can already be applied by the computation and design of the hourlines of a sundial.

In that case you correct the sundial reading for the equation of time to get your Local or watch Time.

This is sometimes done by means of the "Analemma", the famous figure of eight.

This type of sundial is not one of my favorites.

After all, one could wonder what kind of time this sort of sundial is really showing:

It is not LAT, or LMT, nor LT, nor ST, etc . . . .

R. VINCK, Belgium

* * * * * *

FOUNDATION OF BSS

I read with pleasure David Young's version of the foundation of the British Sundial Society, and as far as I can remember that was how it happened. I would like, however, to add a comment of my own. If, as he says, Andrew Somerville was the architect of the Society, and Charles Aked was the one who gave it the final shove, it was David who made it work. Without his dedication and expertise it would not have got off the ground in the way and in the short time that it did.

I well remember the meeting that was held in Tony Simcock's office in the basement of the Museum of the History of Science in Oxford to finalize arrangements for the first AGM and conference at Exeter College, and to choose one of Chris Danel's designs for a logo. It was David who brought the "academicals" down to earth by asking, "Right, but what are we actually going to do and when?" and set about making a diary of events. It was he who made sure everything ran smoothly, and still does, with his wife Lilli's constant support. The pessimist among us doubted if more than 25 members would turn up - in the end there were more than 70! He may be a blunt Yorkshireman but there is a twinkle in his eye; and as he shuffled his papers together at the end of the afternoon he said, "Well, I've sat on a good many committees in my time, but never where there has been so much laughter". And that set the tone of the Society for all time!

At the end of that first conference when Andrew, who also had a twinkle, was giving a talk on "The Ancient Sundials of Scotland", he said that these multiple dials were usually carved in stone, but that it was possible to use other materials. He put on the screen a picture of himself beside his own replica of a Scottish obelisk sundial - crafted in snow!! The laughter was loud and spontaneous, and as it died down the voice of that other Scot, George Higgs, came from the audience, "I presume it tells the temporary hours". The British Sundial Society was on course!

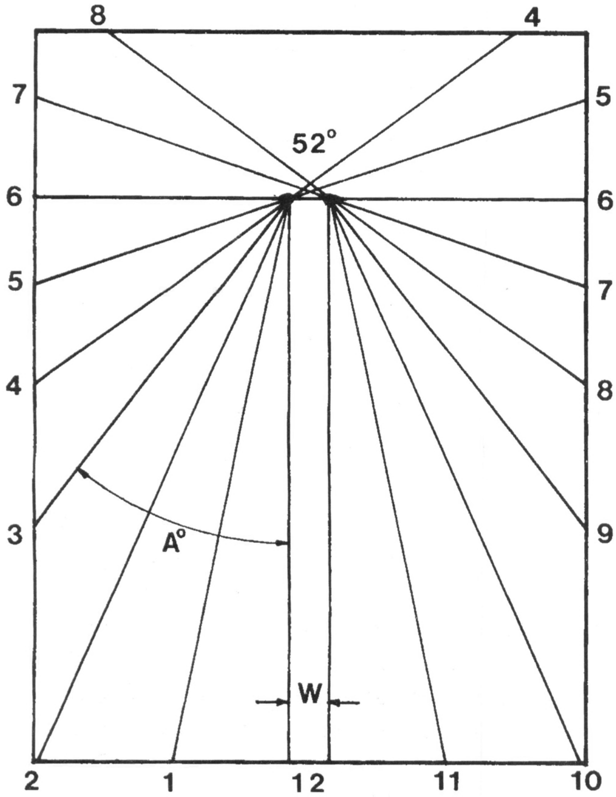
ANNE SOMERVILLE

* * * * * *

THE TEN COMMANDMENTS

I would like to thank Mr. Colin Thorne for pointing out the grave error contained in my article 'The Ten Commandments'.

The diagram supplied by me to illustrate 'wrong dials' was itself in error and I feel ashamed to admit that I had not appreciated the point that he found.



As I believe that other readers may not have picked up this point, I am supplying you with a correct diagram. The original intention was to show an extra wide gnomon to point out the gap in the scale at the noon position. The point that I missed, is that in the summer months when the sun is north of the equator, before 6 am or after 6 pm, the shadow is then produced from the opposite edge of the gnomon. This mistake, with such a wide gnomon, creates errors of around 15 minutes during these periods!

In the new diagram, this crossing of lines at the foot of the style appears untidy. To overcome the problem, in practice, dialmakers would avoid drawing the lines right to this point, terminating them at the inside of a larger ring or rectangle.

We can all make mistakes, and I must admit that I have learnt a lot from this one.

MIKE COWHAM

* * * * * *

KIRCHER'S SUNFLOWER CLOCK

In reference to W.A. Dukes' query about the illustration well reproduced in John Briggs' article (BSS Bulletins 94.1, p.16 and 93.2 p.42), I should like to suggest that the word printed clearly

ΕΑΙΟΤΡΟΠΙΚΟΝ

has been incorrectly engraved instead of

ΗΑΙΟΤΡΟΠΙΚΟΝ

whose translateration would be

HELIOTROPICON

referring to the sunflower as a heliotrope or follower of the sun. The title would then be translated as 'A sun-turned hour-dial'.

The central inscription is surely to be read as Dukes suggests.

The second line of the lower inscription seems to me to read as:

'Omnia Solisequa haec Simia Solis agit', where the engraver has slipped in spacing the start of 'haec'. I would render these lines:

The Sun in his circuit shows years, seasons and hours

And drives all these Solisequa, the apes of the Sun.

'These' and 'the' could obviously be exhanged. A greater problem is the reading of Solisequa as a neuter plural. I have seen it used as a feminine singular, referring to Venus in her role as evening star or Hesperus, but that makes poor sense in the sentence. In any case the poet who thus used it was perpetuating an astronomical error resolved, allegedly, by Pythagoras about two and a half thousand years ago. His Latin also may have been as shaky as mine.

GEORGE WYLLIE

* * * * * *

See also page 40 for other errata.

THE HORNIMAN TRAIL

JOHN MOIR

On 19th March 1994, after of of inclement weather, the sun kindly appeared over Forest Hill to grace the opening of the Horniman Museum Sundial Trail.

The events commenced with a lecture by our Chairman which was enthusiastically received by the audience of Friends of the Museum and others, including several BSS members. A conducted tour of the dials then followed, see Figure 1.

FIGURE 1: The BSS Chairman with Dr. Angela Hodgeson

Firstly we saw the west-facing wall dial of Ray Ashley, in blue and gold lettering, see Figure 3. The solstice lines form the basis of the 'cooling-tower' shape of this most elegant dial. Next we came to Dr. Angela Hodgson's splendid bowl dial, Figures 1 and 2. It rises sinuously from its base like an old gnarled tree, its shiny golden bowl presenting a stunning contrast. The delineator, Dick Andrews, shown in Figure 2, said that due to the lack of datum lines in this 'organic' design, he resorted to marble-rolling to establish the lowest point!

Following this we saw the stained-glass vertical decliner of Roselyne Loftin (Figure 5), delineated by David Young and set in the magnificent Victorian Conservatory. This window depicts aspects of the Museum's work and the restricted use of complementary colours is very effective.

The final dial to be seen was an analemmatic, Figure 8, unusually calibrated for B.S.T., but since it will be visited mostly in the summer, this may cause less confusion than G.M.T.! Its location is particularly pleasant being on high open ground.

For the future, Dr. Elizabeth Goodhew of the Museum is planning explanation panels and a booklet and further details are intended. I have myself designed a polar and horizontal dial both based on the Horniman 'logo', see Figure 8. The proposed motto

"... . and hours run mad
e'en as men might"

is not Shakespeare(!), but an anagram of "The Horniman Museum and Gardens", teased out after much sweat and tears.

FIGURE 2: Mr. Dick Adrewes with the Bowl Sundial

On a final note, several B.S.S. members have given practical and financial support to the new trial and are pleased to be able to help in this exciting project.

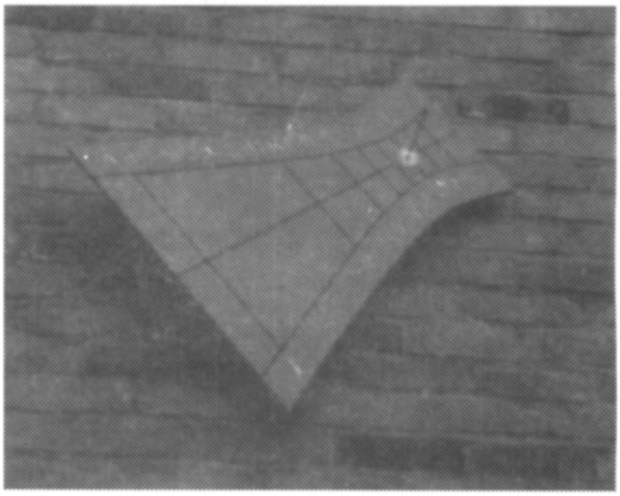


FIGURE 3: West facing dial made by Ray Ashley

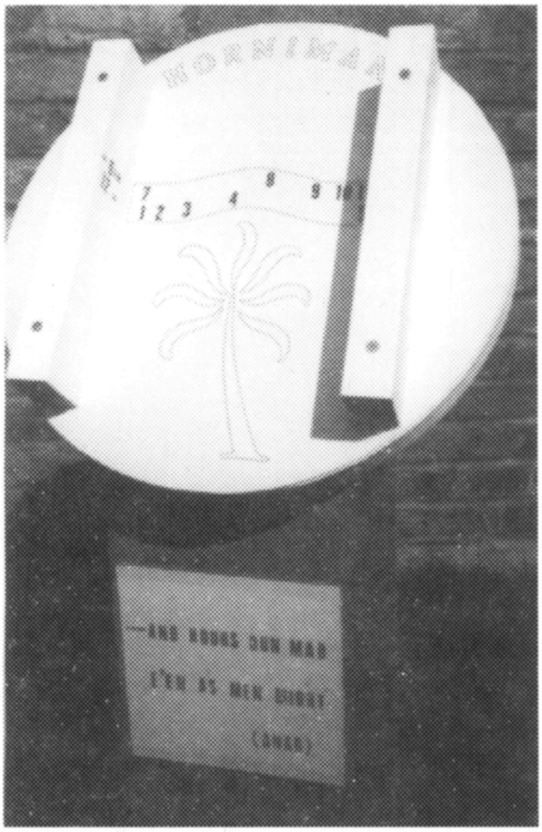


FIGURE 4: Model of polar dial by John Moir

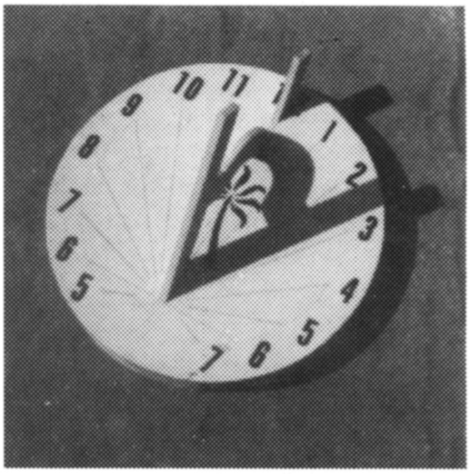


FIGURE 6: Model of horizontal dial made by John Moir

FIGURE 7: Analemmatic dial set out in the Horniman Museum garden

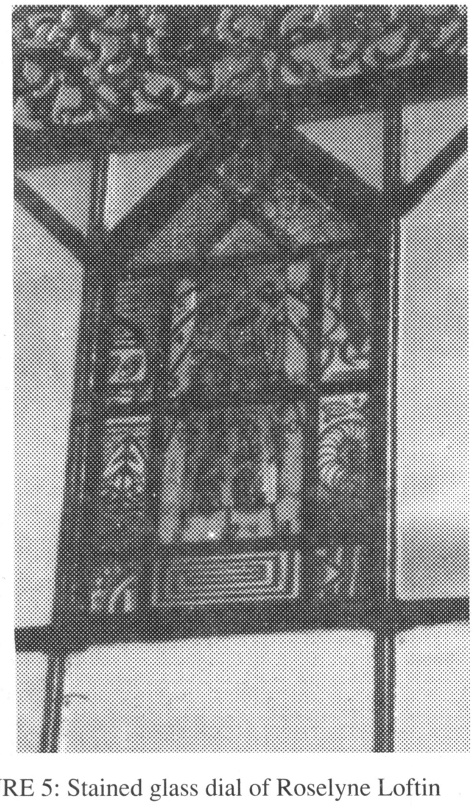


FIGURE 5: Stained glass dial of Roselyne Loftin

FIGURE 8: The logo of the Horniman museum

THE SECRETARY'S NOTEBOOK

Having just returned from our conference at Urchfont Manor I must thank the Director (our member Dr. Patricia Howell), and her staff for the very friendly atmosphere they helped to create, making this meeting one of the most pleasant we have had.

The following events are planned for the future:

23rd July, 1994
One day meeting at the Horniman Museum, Forest Hill, London. Organised by the Mass Dial Group but of general interest. Guest speaker, Karlheinz Schaldach on Medieval Dials. Information from Edward Martin whose address will be found inside the back cover. This is a chance to see the new dials at this location.

16th to 22nd September, 1994
Ireland Tour starting and finishing in Dublin. Visits to dials, gardens, castles, scenery etc. with some evening lectures. Just a few places left - contact me or directly to Owen Deignan, 72 Lawrence Road, Clontarf, Dublin 3.

Spring 1995
Annual General Meeting and Conference. We like to move about the country to give as many members as possible a chance of attending. In 1995 we are considering the North East of England. In view of the success of the Urchfont meeting we might consider a similar sort of venue (eg. another Adult Education Centre or, an Agricultural College). Suggestions for possible places to me please. Offers of talks/lectures from 10 minutes to an hour are also welcome.

16th June, 1995
Proposed weekend trip to Paris to explore by coach and on foot some of the sundials in that city. Guide will be Andrée Goteland, author with George Camus of 'Les Cadrans de Paris'. Organiser: Jane Walker. (See separate sheet).

I understand that David Pawley will be organising another of his excellent one-day meetings in Newbury in 1995.

COMPENDIUM

This is the title of the publication of the new North American Sundial Society, the Editor of which is Frederick W. Sawyer III. He is, of course, already well known to BSS members as the author of several erudite articles in past Bulletins. The Chairman of NASS is Ross McCluney of the Florida Solar Energy Centre at Cape Canaveral, and the Treasurer is Robert Terwilliger.

A brief synopsis of the contents of the inaugural issue (intended as an evaluation copy) is:

Introduction by Ross McCluney, the Waugh Collection (dialling books), U.S. Dialling Patents in 1993, European Sundial Societies, Calculating the Equation of Time, Organization (giving details of the NASS aims, structure and regulations).

A Basic program is listed which will produce a tabular output of the equation of time, as well as the solar declination.

Four issues a year are planned which can be obtained as a print edition or as a Digital Compendium which requires the use of an IBM compatible computer with at least 640K RAM and MS DOS 3.1 or higher, EGA/VGA colour graphics, a hard disc and a Logitech or Microsoft compatible mouse. The digital form will be on a $3^1/_2$ in disk. The cost of membership is 25 dollars for 1994 membership for either print or disc, or 35 dollars for both. Air mail delivery is another 10 dollars. Payment to be sent to:

Robert Terwilliger, Treasurer NASS, 2398 SW 22nd Avenue, Miami FL33145, U.S.A.

On behalf of the British Sundial Society, the Editor of the BSS Bulletin wishes the new society well. With the mathematical, computer, and other abilities available to the new society, it is expected that the Compendium will rapidly become of great importance.

In the next issue will be the "Design and Construction Forum" which will present articles for those who wish to build sundials for public display or for personal achievement. The approach will be mathematical and require the use of a calculator, trigonometrical tables and BASIC computing facilities where applicable.

PARIS 1995

A weekend visit to Paris is being arranged for June 16th-18th, 1995. See enclosed sheet for full details.

LOOKING AT SUNDIALS

The Education Group has produced a 15 minute long video which shows 38 dials which are classified by type, together with graphic sequences on their essential features. The comparison between sun time and clock time is also discussed. The video **Looking at Sundials** is suitable for showing to schools as well as to general interest groups of all ages. It is available from Mrs. Jane Walker (address inside back cover), price £12.00 which includes postage, packing and VAT. Please make cheques payable to British Sundial Society.

not necessary. For this latitude Blagrave gives directions on how to fit an additional rete with a circle of hours and a Horizon Circle constructed by Stoeffler's method with the arcs of 12 hours. He actually made instruments for specific latitudes.

The place of the Planets so necessary to Astrologers was found with the help of Planetary Tables and a small circular attachment affixed to the Mater with rivets. Blagrave gives no sketch of this proposal. On the back of the main instrument which would otherwise be blank, Blagrave intended to have an ORGANON VRANICVM or Calendar of the Heavens for the year but seems to have abandoned this idea and recommended a scale of months indicated by their initial letters placed outside the ecliptic.

For the measurement of altitudes commonly secured by astrolabes, the instrument had to be suspended vertically by a cord in the usual way and a centrally pivoted alidade provided with two vanes for the sightings.

This is where the large instruments favoured by Blagrave showed their disadvantages in use because such an instrument in the open air can never settle to give a reading, being constantly buffeted by even light currents of air. At sea these instruments were useless. The seaman preferred a small instrument which was very heavy to overcome the motion, the loss of accuracy with the smaller scales being made up for by the steadier observation. Even when constructed in solid brass, Blagrave's instrument would have been of little practical use at sea except for study or teaching purposes. How such an instrument could be used at night puzzles the writer since he finds it difficult to read the heavenly chart with rock steady conditions under a bright light, evidently the observers of formers days were made of sterner stuff. The instruments constructed by pasting the printed plates on pasteboard can only have been used for instructional purposes, they would soon deteriorate in outside use although if varnished this would give some protection. The use of these printed plates enabled the penurious to be able to make instruments of a sort at a fraction of the cost. The expense of the engraved copper plate meant that a lot of the printed plates had to be sold to recover the cost, and of course the plates were pretty well useless without the purchase of Blagrave's book. The excellent craftsman James Kynfin [his shop was near St. Paul's] made such instruments in brass for Blagrave, Thomas Blundeville stated it was too elaborate for use by seamen. The paste-board instruments still needed a brass plate to make the rete usable since card was too flimsy on its own.

BLAGRAVE'S COMMENTS

To end this short account we will conclude by giving John Blagrave's own views:

"The ears of my conceit being continually troubled with such a noise and clamour for my Uranical Astrolabe, so long and largely promised, as greedy auditors are won't to make at a Stage play: calling "Come away now", with boys throwing volleys of stones rattling the gates of my otherwise busy employments, make me here in haste (God grant to your liking) to come up the Stage with this rare piece of Mathematic, to stay your languishing expectations, and sufficient to entertain the time until Midsummer when the stately Comedy of Queen Uranya her pageants shall offer themselves to your pleasant view. Solace yourselves I pray you here-with, and be bold with me if in anything you doubt. You shall have me, God willing, once every term in London reading to your wish at a poor lodging within Maister Green's Wharf near unto Charing Cross and at Master Jackson's at the sign of the Swan in St. Paul's Churchyard or at Mr. W. Matt's, stationer at the sign of the Plough, who hath the impression of this book, you shall ever know whether I be at any time in the City: with whom I have taken order to furnish with these instruments and their supplements to any that shall want them".

His words imply that he anticipated a great interest in his instrument and it is true that his instruments were still held in great regard many decades later. Nevertheless his reputation largely hinges on The Mathematical Jewell and not the Uranical Astrolabe. In regard to his abilities he wrote:

Where gathered he his skill? What tutor tolde him in?
    The Universities deny that ere he dwelt within
And London laughs to think She scarce doth know his face.
    How comes he then to link with Uranes worthy grace?
My answer shall be short, my pain this piece hath pend
    God lent it to my lot, And he shall me defend.
The Psalms say sucklings young his Glory shall disclose
    Which warrants me among my wrangling wrabbish foes.
I.B.

[Wrabbish = perverse or difficult to manage]

EPILOGUE

In 1658 Joseph Moxon's catalogue of books and instruments at his shop on Cornhill under the sign of Atlas, included copies of *The Catholick Planisphere called Blagrave's Mathematical Jewell: made very exactly on Past-Boards; about 17 inches Diameter*. The instrument was republished by J. Palmer MA who was Rector of Eaton and Ecton near Northampton, he did this at the request of Joseph Moxon and took the opportunity to add some improvements of his own. The title page of Palmer's book is of interest (see Fig 4) as in the upper left corner is a portrait of Blagrave in his Elizabethan ruff collar, in the right hand corner is the worthy Palmer in the usual cleric's garb of the times. Of course the word Catholick is intended in its meaning of universal and has nothing to do with the Catholic Church. The angel in the top centre with two trumpets is sounding the fame of Blagrave.

The inscription accompanying John Blagrave's monument reads:

JOHANNES BLAGRAVIUS TOTUS
MATHEMATICUS
CUM MATRE SEPULTUS OBIIT
9 AUGUST 1611

Here lies his corps, which living had a spirit.
    Wherein much worthy knowledge did inherit
By which, with zeal, one God he did adore,
    Left for maid-servants, and to feed the poor;
His virtuous Mother came of worthy race.
    A Hungerford, and buried near this place,
When God sent death their lives away to call,
    They liv'd belov'd, and died bewail'd by all.

At some time in the future, a further article on John Blagrave will be penned should this present article have been of interest. It will deal with the work *The Arte of*

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