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   A.E. Waugh: *Sundials, their theory and construction,* Dover, New York, (1973).
   D. Colchester: 'A Polarized Light Sundial', *Bull BSS,* **96.2**, 13-15 (1996)
   A.A. Mills: 'Seasonal Hour Sundials', *Antiquarian Horol.* 19, 142-170 (1990)
   W.S. Maddux: 'The Meridian on the Shortest Day', *NASS Compendium,* 4, 23-27 (1997).

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Front cover: *A painted French dial from Bergheim in the Alsace. Dated 1711 and restored in 1977, it is a fine example of the use of declination lines and reminiscent of the Queens' College, Cambridge, dial seen in the last issue. There are two sets of declinations lines here. One is labelled with the periods of night-time and daylight vertically down the centre. The other set, with arrow-heads at either end, is for the signs of the zodiac (sun's longitude) shown by the signs on the innermost vertical band each side. Also shown are the times of sunrise ('ortis solis') and sunset ('occasus solis') and the months. See inside for two articles on declination lines. The dial is on the itinerary for next September's Sundial Safari to the Alsace. Photo: Mike Cowham.*

Back cover: *An angel holding a dial, believed to be Anglo-Saxon, at Yate, Gloucestershire. The dial is now mounted just above a doorway. Photo: Mike Cowham.*

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CONTENTS

EDITORIAL

I always think that declination lines on a sundial add extra interest and give the design a lift above the ordinary—see the cover picture as an example. Some diallists find that laying out these lines is rather more difficult than just drawing the hour lines so, in this issue, we have two papers (p.128 and p.137) giving quite different methods by which it can be simply done. These methods are in addition to the more numerical methods which adherents to computer spreadsheets may prefer. The choices for the location of the origins and the directions of the *x*- and *y*-co-ordinates are different in the two papers but they give the same answers—we've checked! So, you sundial designers, let's see some more dials with these lines, please.

I would like to start a new semi-regular feature on 'New Dials'. In recent issues we have highlighted dials from, for example, David Brown and Joanna Migdal but I would like to spread the net much wider. The new feature is intended to be mainly pictorial and feature dials from both professional and amateur makers, including non-BSS members. The dials may be public or private: for the latter, the owners should give permission but the exact location need not be disclosed and the dials do not need to be viewable either by members or by the public. So, please send me a couple of pictures whenever you know of a new dial being 'unveiled', together with a few details of why the dial was made, what it's made from, where (roughly) it is, who made it and so on. Over to you!

A REVIEW OF THE HELIOCRONOMETERS BY PILKINGTON & GIBBS

Part 4. THE MECHANICAL EQUATION TABLE

GRAHAM ALDRED

Introduction

In Part 3[1] we discussed Pilkington's elegant development of the Sol Horometer in which he sought to improve and simplify the Helio-Chronometer (HC)[2] that had been designed by his partner Gibbs. This led to considerable disharmony in which Gibbs was ever-ready to seek royalties for infringement of the Helio-Chronometer patent.[3] The most significant 'improvement to sundials' cited in both patents was the method of automatically applying an adjustment to indicated solar time in order to obtain mean time. Pilkington's solution of two concentric unequal scales in juxtaposition was sufficiently different to Gibbs' earlier method of a sighting vane whose datum was offset by means of a lever and EoT cam, to allow the Sol Horometer patent[4] to be accepted. But the story does not quite end there although the instrument described here is not a sundial. Possibly emboldened by his success with the Sol Horometer and his recently acquired understanding of the relationship between solar and mean time at any longitude, Pilkington decided to develop his unequal scale idea and produce an extremely neat device that many modern sundial enthusiasts might wish to own. The resulting patent demonstrates some nice engineering ingenuity but quite unexpectedly includes use of an EoT cam groove, just as described in the HC patent registered to Gibbs. (The groove was not implemented on the production models of the HC, probably for cost reasons.) I have never seen Pilkington's device nor is the BSS currently aware of any in museums, although it is hoped that this article may lead to an identification. The only source material available is a P&G promotional leaflet and the two implementations described in the patent, circa 1914.[5]

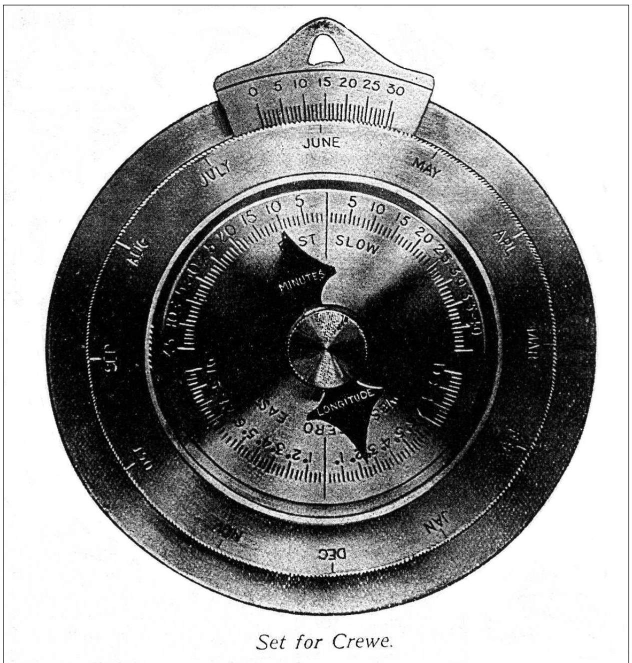

Fig. 24. Photograph of "The Mechanical Equation Table" from the P&G promotional leaflet, circa spring 1914. Used for relating mean time and sundial time on conventional sundials.

It is fitting to conclude this introduction with the words from the P&G promotional leaflet, which, although rather romantic in parts, are just as relevant now, nearly 100 years later, as they were to the 'hustle and bustle' of 1914.

There can be no question, the old-fashioned Sundial of our fathers' days still retains its place in the hearts and affections of a great number of people. Its beauties and associations have been told in song and story for many generations and to try to oust it from its place of honour would be looked upon as a piece of vandalism from which even the present go-ahead generation would shrink. There is still in us a vein of sentiment that draws us to a quiet corner of the garden to which our fathers loved to retire and where - as a centre of interest - one invariably found "The Sundial."

It may be for better, it may be for worse that times have changed, and, instead of placid, quiet lives, we live lives full of hustle and bustle; whatever it may be, there is no doubt our days are ordered on more strenuous lines than of yore and to know ***"what is the time"*** *is now an imperative essential.*

Realising and respecting the sentiment attaching to the old sundial, and in response to an oft-repeated question, "Can you not give us something to enable us to easily read correct time (clock time) from the sundial?" we have devised a little instrument which we call

"The Mechanical Equation Table"

By the aid of this little contrivance the old sundial is brought into use as an actual Standard (Clock) Time dial.

Description

The purpose of the device was to provide a mechanical method whereby the EoT of the day could be added algebraically to the longitude correction so that the result could be indicated on a signed scale of minutes. The Mechanical Equation Table seen in Fig. 24 is actually a circular metal assembly about 3.5inches in diameter with various scales

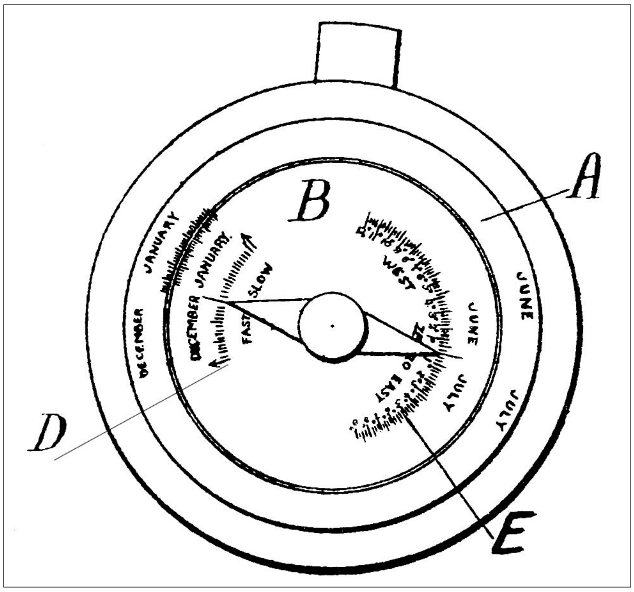

Fig. 25. Front view of version 1 of the instrument as drawn in the patent. This EoT system with two unequal day scales is borrowed from the Sol Horometer. B is the movable scale. The result of the algebraic sum of EoT plus Longitude is indicated by the pointer on the innermost scale.

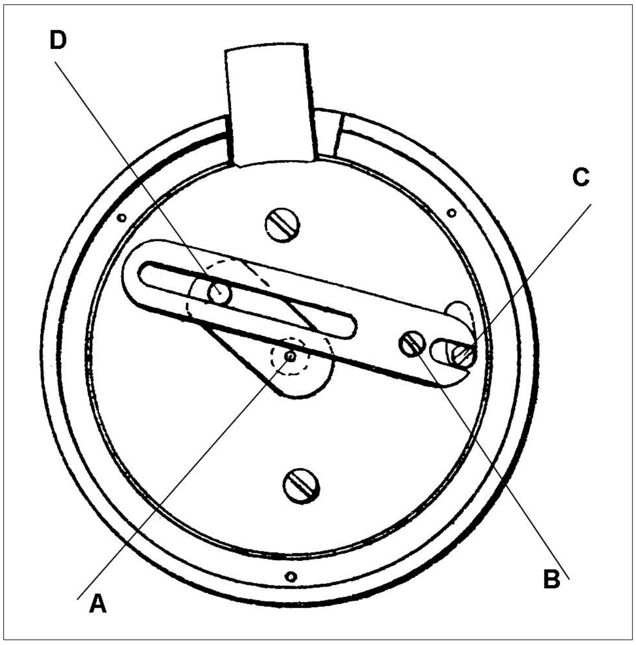

Fig. 26. Rear view of the movable plate showing the lever system that transmits the rotation for EoT to the pointer spindle. The long lever is pivoted at B, the peg at C is the fixed datum protruding through a slot equal to EoT range.

and a pointer. It was intended that it would be either carried in the pocket of a dialling enthusiast or fixed permanently in the proximity of a conventional sundial to allow a user to obtain the appropriate adjustment for the day in order to obtain mean time from the indicated sundial time. Two implementations of the concept were described in the patent[5]: the image in Fig. 1, a scan of an actual photograph, is the second version (V2) which was actually manufactured and offered for sale. Therefore V1 may not ever have been produced except as a prototype. Nevertheless, since almost all design is evolutionary, it is important to examine V1 which is the child of the Sol Horometer and then see how and why this led to V2 which owes so much to the Helio-Chronometer. Could it be that this convergence of the two designs in this one little instrument signalled a reconciliation between the partners?

Version 1

The front view is shown in Fig. 25. As with the Sol Horometer, there is a pair of concentric discs with scales in daily increments for each month arranged around the abutment circle. Scale B has regular divisions whilst scale A is divided to recognise the current EoT value. The inner disc (B) can rotate relative to the fixed outer disc on a circumferential bearing but is mechanically restricted within the limits of EoT range. The user must align the current date on each of the scales. There are two other scales on the inner disc. These have central zeros to provide positive and negative readings and are arranged in suitable arcs for the sweep of the double ended pointer. Scale D provides the output reading of the instrument, which is the result in minutes of the algebraic sum of EoT plus Longitude correction. Initially it is assumed that the longitude setting on scale E is zero degrees.

Fig. 26 shows the back of the instrument with a cover removed. This reveals Pilkington's compact solution to the problem of how to communicate the variable EoT offset, available from the date conjunction, to the pointer spindle to provide the difference reading. There is a circular backplate which retains the inner disc on its circumferential bearing with two screws as shown. The projecting tab at the top of the Fig. 26 restricts movement to the EoT range. When the inner disc is rotated the backplate and all its components move as well. The pointer is screwed into a boss (A) on the small crank at the centre of the figure. The slotted lever is pivoted on peg B mounted on the backplate. Peg C is screwed into the fixed body of the device and this provides the datum for the relative motion. It protrudes through a slot as wide as the annual EoT range in the moveable assembly to engage with the short slot in the long slotted lever. When the assembly is rotated peg C causes the long arm to swing relative to the backplate on its pivot at B. The motion of the inner disc is thus transmitted via peg D to the crank into which the pointer is screwed at A. This causes the pointer to rotate in relation to the EoT value derived from the unequal scales. In fact, by analysing the relative dimensions of Fig. 26 given in the patent and ratified by the photograph at actual size (Fig. 24), the mechanism doubles the EoT input angle at the pointer. This would certainly help with the division separation on the output scale which is only on a 20mm radius circle and would be difficult to use accurately.

The fixed longitude value is provided by manually rotating the pointer in the threaded boss (A) by the required amount either East or West. The backplate assembly shown in Fig. 26 is unaware that the pointer has been moved away from its zero datum, consequently the longitude correction in minutes is now included in the algebraic sum. Although the longitude scale is marked in degrees, the major scale interval would equal 4 minutes because both scales share the same pointer arm.

Design Review

We must assume that Pilkington had made a prototype V1 and had reluctantly recognised all the practical production problems relating to the very small scales that he had proposed. Basically, he was trying to make a Sol Horometer pair of unequal scales at a radius of about 21mm. This was to be the source of the vital EoT correction, a small angular displacement to be transmitted through a lossy mechanical system, involving two non centric circles of even smaller and different radii. On the larger parent Sol Horometer (SH) the date scales are at 80mm radius giving fixed scale days at about 1mm intervals. Even so, on the SH movable scale, November is only about 2.5mm longer than the fixed month in arc length. This is a measure of the small angular difference that must be shared amongst the 30 day divisions on the unequal scale. Consequently on the new device, at a quarter of the size, the two Novembers would only differ by about 0.6mm arc distance over the whole month and the fixed days would be at about 0.25mm separation including the division line. Pairs of Sol Horometer type scales at this radius are just not practical either to manufacture or to use; the fundamental lack of accuracy would have defeated the purpose of the instrument.

A Difficult Decision

But Pilkington persisted with the concept and having been forced to reject his own unequal scale system as quite impractical at the chosen size he must have turned to the HC

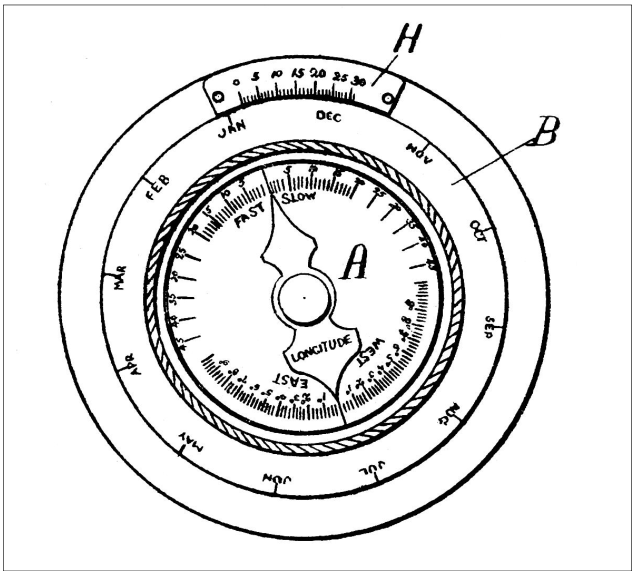

Fig. 27. Front view of version 2 of the instrument as drawn in the patent. This EoT system with a month plate, cam and single day sector is borrowed directly from the Helio-Chronometer. The month plate B *is movable. The algebraic sum is indicated by the pointer on the Fast/Slow minute scale. 'Fast' means clock is fast relative to sundial.*

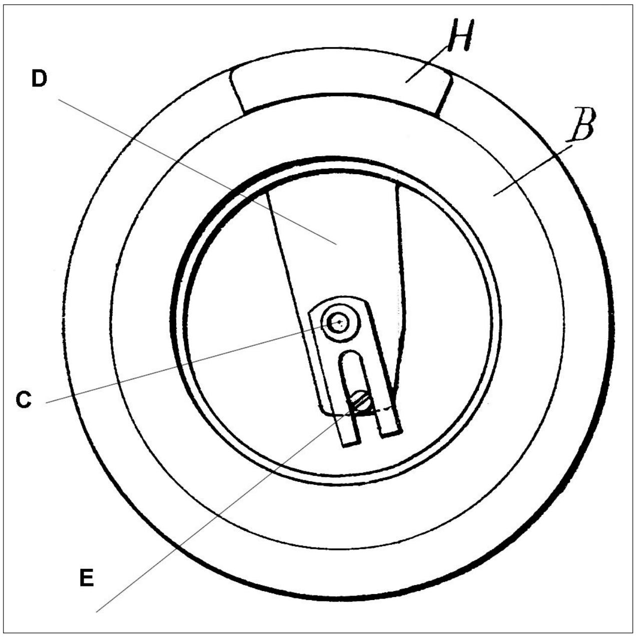

Fig. 28. Version 2 with the fixed disc removed. The small forked crank is not attached to plate D*, it is retained by the pointer shaft screwed into the boss at* A*. Peg* E *communicates the motion of plate* D *to the fork.*

design with gritted teeth. A grooved cam would provide the EoT displacement, with a month disc and a day sector at 32mm radius for longer day intervals and more precise registration. This simplification provided more space for the output and longitude scales, with the radius increased from 13 to 18 mm. In isolation, the Gibbs month plate and single 31 day scale system was always much cheaper and simpler to manufacture than Pilkington's two scale method which involved dividing 24 months into days in a very complicated way. In addition, by then P&G as a company understood the problems of the EoT cam. They had struggled initially to perfect the profile; they had recognised the requirement of synchronising the cam displacements with the month sensing during manufacture and they understood the EoT zero offset caused by initial manufacturing tolerances and subsequent wear. However, the cam would have had to be re-calculated to suit the geometry defined by the new linkages as the known HC cam could not just be scaled down and used in the new device.

Version 2

The version 2 is shown in Fig. 27. In this concentric arrangement the month annulus (B) moves on circumferential bearings retained by the fixed central disc (A) that carries the pointer and the output and longitude scales. The day sector (H) is fixed to the outer body: comparison of Figs. 25 and 27 shows how the space was gained by choosing the cam method for EoT rather than the unequal scales method. The underside of the month annulus carries the cam groove either machined or cast into it, following the HC design exactly. Fig. 28 shows the inside with the centre disc (A) removed. The small forked crank receives the pointer screw at the boss C - this fork is not attached to the lower triangular plate D, it simply engages with a peg E fixed to the

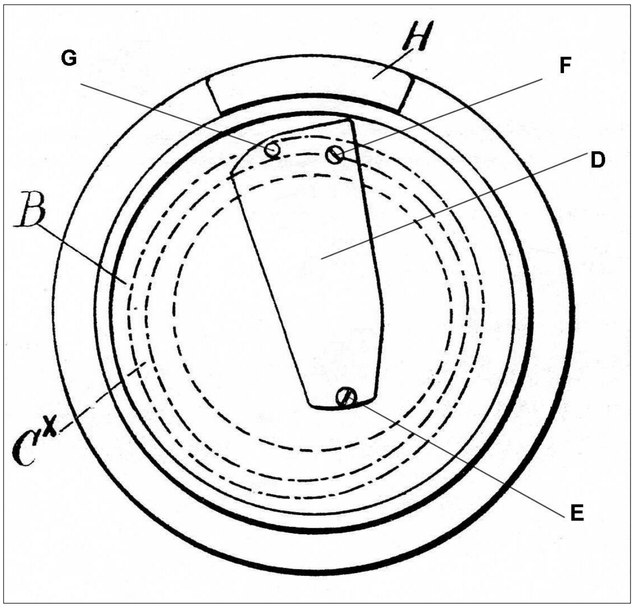

Fig. 29. Version 2 with the month disc removed, but showing an image of the cam groove C^X *from the underside of the month disc.* D *is pivoted to the back plate at* F, G *runs in the cam groove, peg* E *copies the motion of the forked crank.*

plate. Fig. 29 shows the inside of the device with the month plate removed but the image of the cam groove is retained for explanation. Plate D is pivoted at F on a peg that is screwed into the stationary backplate of the device. G is the cam follower peg that faces upwards and this will run in the cam groove when the month plate is reassembled. Plate D will pivot in sympathy with EoT and the resultant swing of peg E will be picked up by the slotted fork in Fig. 28, which will cause the pointer to move on the output scale. The longitude input to the sum is achieved in a similar manner to V1 by loosening the thumb screw on the pointer centre and offsetting the pointer from zero in the appropriate direction. The geometry of the linkages magnifies the EoT displacement arc by about a factor of 3 and this allows the output scale (at only 18mm radius) to be somewhat more precise and user-friendly than in V1.

The Patent

Did Gibbs co-operate on this development? Sadly the evidence says he did not because once again[3] he wrote on his copy of the patent "The second attempt at escaping payment of royalties to GJG!" Pilkington may have been devious: he fully described V1 in the patent in detail as if it was the preferred implementation but then casually described V2 as a 'modification' or possible alternative implementation, as designers often do in patents to protect and cover all possible options. This might just have deflected the attention of the patent assessor. One would need a better understanding of patent infringement criteria but the clue might lie in the claimed purpose of the invention. The Helio-Chronometer patent[3] describes a radically new sundial that will automatically indicate mean time, whereas the Equation Table patent[5] describes an ancillary device to complement all sundials of the 'old type' so that a user can calculate mean time.

Closing Remarks

Probably only version 2 was manufactured for the reasons given. But the accuracy of such a physically small instrument must be in question since the core has the elements of the HC EoT system, but at a fractional size. Unfortunately we do not have an actual instrument for analysis. In any case the Helio-Chronometer has inherent limitations exacerbated by size and space as we have discussed earlier in this series. As quantity production products, the HC and SH were made to a cost determined by raw material prices and common lathe capacity and this determined their basic size of about 9 inches diameter. Both instruments should be bigger not smaller to provide more precision and resolution in the scales, and more space to accommodate a larger cam to make it less sensitive to profile discrepancies and wear. The Sol needs a much larger circumference to do justice to the unequal scales and the one minute divisions of the output scale. In the case of the Mechanical Equation Table both versions are feasible designs but at 3.5 inches they are not very practical.

Version 2 of this little instrument in gunmetal went on sale at 15 shillings in spring 1914, a time that did not bode well for the launch of non essential products although Pilkington would not have known this. Being able to adjust the indicated time of an old sundial to give mean time would have diminishing appeal despite the advertising case made by P&G quoted above. As August approached and the 'hustle and bustle' developed into the madness of world war, very few people in the world would pay any serious attention to sundials of any type for the next 60 years, until education, curiosity, affluence and leisure led to the advent of the various European sundial societies and the growing realisation that there is much more to Time than the frantic vibrations of a tiny crystal.

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5. British Patent No. 2956 AD 1913: 'Improvements in or relating to Sundials', W R Pilkington, (Accepted 5 Feb 1914).

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HOUR ANGLE, VELOCITY AND ACCELERATION OF THE SHADOW MOVING OVER A SUNDIAL

ALLAN MILLS

Frank Cousins, in his well-known book on sundials[1], includes explanatory diagrams showing how the equiangular equatorial dial may be projected upon other planes. This forms the basis of a much-used graphical method for delineating sundials at a given location, and Figure 1 illustrates the resulting pattern for a direct south vertical dial at a latitude of 52° N. Unusually, this is drawn to include the night hours for reasons that will be apparent later.

It will be seen that the hour angles are unequal, being widest around 6 am and 6 pm and then bunching-up around 12 noon and 12 midnight. The angular velocity of the shadow of a matching gnomon must therefore be at a maximum or minimum at these times, diminishing from 6am to 12 noon and then increasing from 12 noon to 6pm.

Although sundials may be perfectly well drawn by graphical techniques, there are occasions when alternative methods give greater accuracy, permit derivation of further data, or suggest new applications. Thus, Robert Hooke showed that the mechanical rotating joint now commonly associated with his name produced a cyclic variable motion of its output shaft that could be arranged to match the motion of a shadow over a sundial. Such a 'Hooke's joint' could therefore be used to delineate dials, or be driven by a 24^h clock movement to move a pointer over a dial graduated in the manner of Figure 1 to give a 'sundial-clock'.[2]

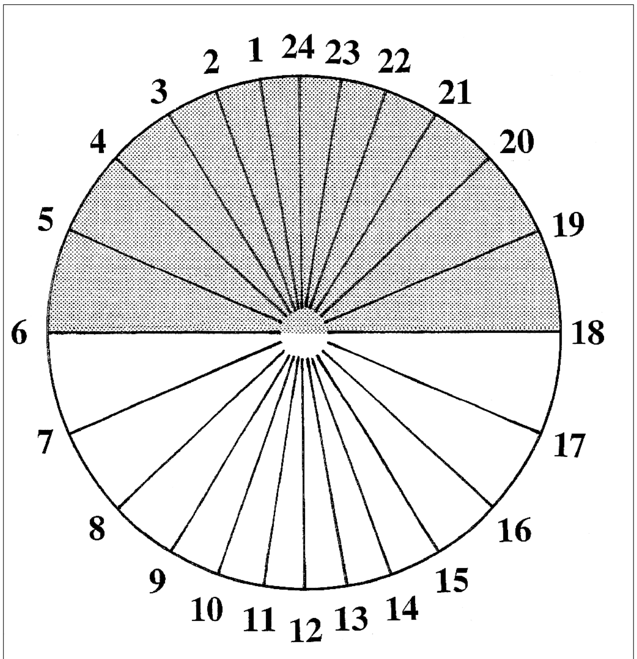

Fig. 1. The complete pattern for a direct south vertical dial at a latitude of 52° N.

The Poncelet Equation

Two ordinary joints may be coupled together to give a 'double Hooke's joint' and, in appropriate relative positions, will annul the varying output velocity of the single joint. This 'constant velocity' arrangement constitutes a vital part of the transmission of most automobiles, so has stimulated considerable theoretical analysis by engineers.[3] A pioneer in this field was J.V. Poncelet, who in 1836 derived the equation of motion of the single Hooke's joint to be:

$$\tan \beta = \tan \alpha \cos \gamma \qquad (1)$$

where α = angular rotation of the input shaft,
β = " " " " output shaft and
γ = angle of inclination ('articulation') between the shafts.

The zero of rotation conventionally adopted by engineers is 'top dead centre', where the radius vector of a rotating component points vertically upwards. (This dates back to steam engine days.) On a sundial this corresponds to the Sun at 12 noon on the meridian. Poncelet's equation therefore also quantifies the direct south vertical sundial at a latitude γ, or a horizontal dial where this is the co-latitude. The former will be understood in the following discussion.

Calibration of Sundials

Application of Equation 1 enables hour angles to be calculated exactly for any given location, although in the absence of a vernier protractor this is of doubtful advantage when laying-out practical dials. It does, however, enable a number of other properties of the moving shadow to be examined. A mid-England latitude of 52° N will be employed in the subsequent examples. Graph I in Fig. 2 shows how the hour angles β for this vertical dial vary with α, oscillating about the sloping dashed straight line representing the equiangular equatorial dial. Note how:

i) $\beta = \alpha$ at 0°, 90°, 180°, 270° .... i.e. every 90°,

ii) α exceeds β from 0 – 90°, whereas β exceeds α from 90 – 180°.

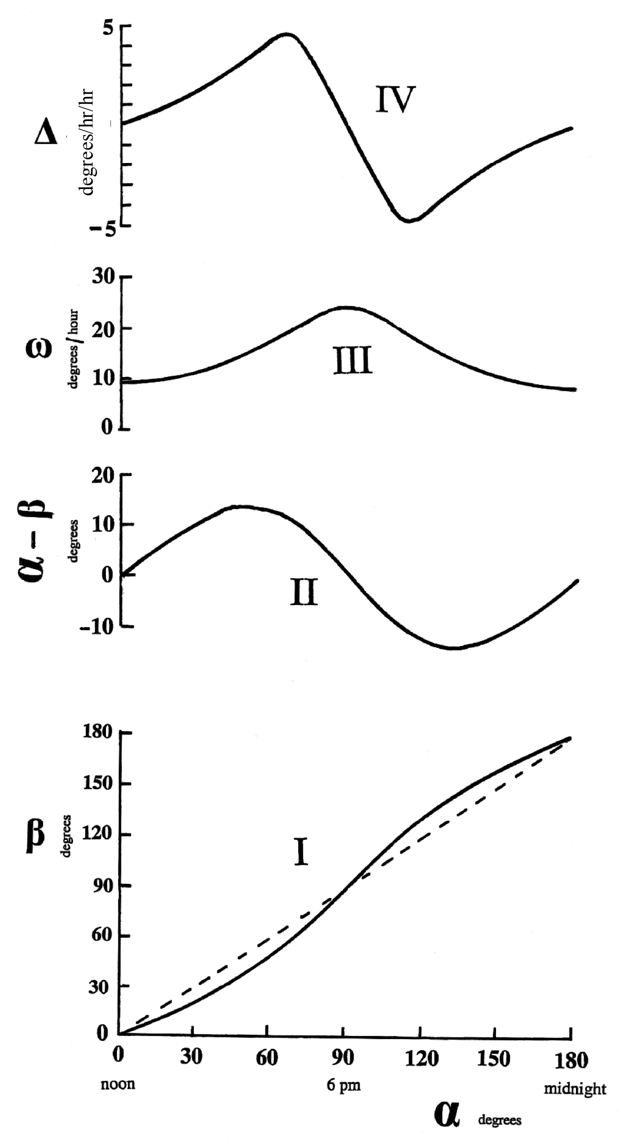

Fig. 2. Hour angle I, differential angular position II, angular velocity III, and angular acceleration IV of the shadow moving over the dial shown in Fig. 1. The horizontal axis is common to all the plots.

Difference between α and β

$(\alpha - \beta)$ represents the disparity between the hour lines on our 52° N vertical dial and corresponding 15° markings. This quantity is plotted as graph II in Fig. 2. It will be observed that:

i) $(\alpha - \beta)$ is zero at 0°, 90°, 180° . . . . i.e. every 90°.

ii) The curves between these values are *not* symmetrical, the difference between α and β reaching a maximum at about 50° and 130°. (Also around 230° and 270° in the complete 360° cycle.)

iii) It may also be shown that both amplitude and degree of asymmetry increase with γ.

Angular Velocity ω

This is represented by the slope of graph I at any point. Quantitative values are best found by differentiating the terms in the Poncelet equation.[3,4] In a Hooke's joint with input velocity $\omega_1 = d\alpha/dt$, and output velocity $\omega_2 = d\beta/dt$, this procedure gives:

$$\frac{\omega_2}{\omega_1} = \frac{\cos\gamma}{1-\sin^2\gamma\sin^2\alpha} \tag{2}$$

In a sundial, with the Sun moving clockwise uniformly around the polar axis, ω_1 equals 15° per hour, so that:

$$\omega_2 = 15\times\frac{\cos\gamma}{1-\sin^2\gamma\sin^2\alpha} \quad \text{°/hour} \tag{3}$$

This gives graph III in Fig. 2. In particular, the above expression goes through minima and maxima given by:

ω_{min} = 15×cos γ at $\alpha = 0°, 180°$ . . .. (i.e. every 180°)

= 9.2° per hour at noon and midnight.

ω_{max} = 15/cos γ at α = 90°, 270° . . . (i.e. every 180°)

= 24.3° per hour at 6am and 6pm

From the graph, 15° per hour is registered instantaneously between these points when α approximates 50° and 130° at a latitude of 52°. These points of equality α_e are found more accurately[4] by putting $\omega_1 = \omega_2$ in the equation above, from which $\alpha_e = \cot^{-1}\sqrt{\cos\gamma}$ at angles less than 90° and $\tan^{-1}\sqrt{\cos\gamma}$ at greater than 90°. At latitude 52° this gives angles of 51.9° and 128.1°. (The near equality with the latitude does not occur elsewhere.)

Angular Acceleration Δ

This is given by the second derivative of β with respect to time, and may be written:[3]

$$\Delta = \omega_1^2 \times \frac{\cos\gamma\sin^2\gamma\sin 2\alpha}{(1-\sin^2\gamma\sin^2\alpha)^2} \tag{4}$$

However, before applying this equation note must be taken of the fact that trigonometric functions are fundamentally based on the radian system of angle measurement which, being a ratio, is independent of the units chosen.[5] In this system 2π radians are equivalent to 360° so 1° = 0.174 rad and 1 radian = 57.3°. Thus with ω=15°/hr (0.262 radian/hr), ω^2 = 0.068 rad/hr/hr and eqn 4 eventually becomes (for γ =52°):

$$\Delta = 1.50\times\frac{\sin 2\alpha}{(1-0.621\sin^2\alpha)^2} \quad \text{degrees/hr/hr} \tag{5}$$

This is plotted as graph IV in Fig. 2. It may be seen that the acceleration of the shadow is instantaneously zero at noon, but then rises to a maximum of 4.8 degrees/hr/hr at 65° (4:20pm). It then diminishes to another instantaneous zero at 6pm.

Maximum Articulation of a Hooke's Joint

Geometry would prevent a simple Hooke's joint driving through 90°, but mechanical limitations come into play well before that point. The maximum practical articulation angle of a single joint is around 60°, for above this the stirrup of one component tends to strike the shaft of the other. A double joint is still limited to this angle within either component, so the best it can do is an unhappy 120° between the shafts. Around 90–100° (45–50° at each end) is more practicable.

Summary

The equation of motion of Hooke's joint may be applied to give hour angle, angular velocity and acceleration of the shadow over a sundial. It may be shown that for dials at a latitude of 52° we have:

	Vertical S dial	Horiz. dial
Max angular velocity in °/hr (at 6am and 6pm)	24.3	19.0
Min angular velocity in °/hr (at noon and midnight)	9.2	11.8
Points where shadow moves at 15°/hr.	51.9°; 128.1°	41.6°; 138.4°

ACKNOWLEDGEMENTS

I am grateful for the assistance of Sarah Symons, Fred Sawyer, Jonathan Maxwell, Tony Wood and the referees with the preparation of this paper.

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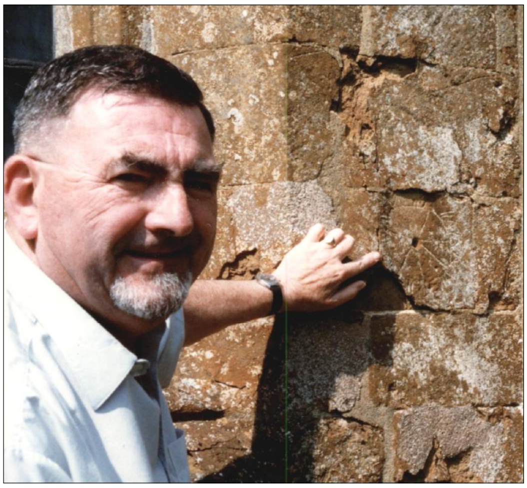
OBITUARY

Edward Rankine Martin 1925 - 2007



Edward Martin, who died in February this year, was the founder of the Mass Dial Group within the Society. He was a true pioneer in that he saw the opportunity to collect all information about the dials into one place where previously it had been scattered in county-based publications. Additionally, he had the vision to see that the information could be stored on computer so that it would be readily accessible to all for research and record purposes.

Edward was born in Aberdeen and went to Oundle School, and then on to Cambridge, studying Physics and Chemistry. The outbreak of the War in 1939 resulted in him volunteering for the RAF before graduating and he worked in the Meteorology Service throughout. After the War he entered industry and was responsible for developing plastic moulding techniques and machinery, becoming Technical Director and writing standard works on the subject.

On retirement he devoted his time to mass and Saxon dials with the inevitable accompanying study of church architecture and history. Using his enthusiasm for caravanning, he actively recorded dials all around the country and on the formation of the Society in 1989, joined it and took the lead in setting up a Mass Dial Group, with a small but devoted following. His conscientious replies to all correspondence resulted in the countrywide recording of the dials, now with photographs and the prospect of a National Register.

Edward's vision in this matter should not be under-estimated. His proposal to write a program to store dial records and provide a picture was realised with help from his son and over a thousand dials were entered. This truly original work has been passed into the present Register and Edward was able to see the first counties entered and printed – one page per dial and colour pictures. As ever, he was supportive of the efforts of others who were able to carry on this work when illness and family cares prevented him from being active himself.

He married Ursilla in 1947 and there were three children: Mary, Frances and Andrew. I give thanks to Andrew for his recent help. John Lester attended the funeral on behalf of the Society; it is hoped that Edward's legacy may be marked in some way by the Society.

A.O.Wood

Noon Cannons – A Sundial Conceit

Piers Nicholson

The picture (right) shows my recently acquired noon cannon being fired for the sixth time at the recent BSS conference at Fitzwilliam College, Cambridge. The noon cannon is oriented to true North with the aid of the small sundial at the right hand side of the picture. The sun's rays are focused by the magnifying glass, which is adjustable so that the focused spot of light is directed exactly onto the touchhole of the cannon.

D Le Conte

Nowadays, one is not allowed to buy 'black powder' (gunpowder) unless one has obtained a special licence for it, but there is a black powder substitute called Pyrobex,

which will work equally well. While this does not require a licence, one may have to go to Bisley to get it. And then it is recommended that you keep it in a box made of wood and 2 inches thick!

To prepare for a firing at noon, the sundial is first lined up to true north, which can be done the day before. The cannon is filled to about half its length with explosive, and a small piece of wadding (such as a twist of tissue paper) is rammed in after it to ensure a good bang. To ensure a successful firing, I also put a little of the explosive powder in the dimple surrounding the touchhole. The smoke in the picture is from this explosive igniting; it is followed very quickly by a flash, and then more smoke from the mouth of the cannon.


J. Davis

As a method of marking noon, it does not offer great accuracy, and it does of course require considerable individual preparation for each occasion. However, it is very much more fun than using an alarm clock.

My noon cannon was made by F. Barker and Son of London for the American firm of Abercrombie and Fitch of New York, and the gnomon is set to an angle of 40° showing that it was intended for the American market. Confimation is given in tiny mirror-writing hidden underneath the gnomon. The dial is mounted on three pad feet and measures 24.8cm in diameter. Originally they were supplied in plush lined carrying case and examples with the case do occasionally come up for auction (for example, at Christies on 21 June 1990).

The sundial is set in a compass rose, and then two scrolls enclosing the motto

> "The hours unless the hour be bright
> It is not mine to mark
> I am the prophet of the light
> Dumb when the hour is dark"

There is also an elaborate table of Equation of Time corrections round half the circumference of the instrument, centred on the noon cannon.

A few noon cannons dating from the mid-17th century are known. These are typically mounted on a marble base, like the one below by Rousseau, now in the collection of C. St. J. H. Daniel.

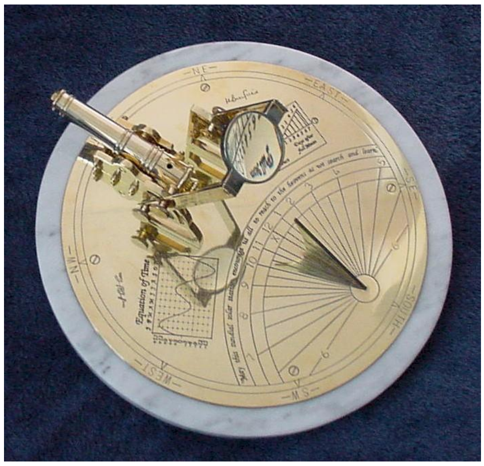

C. Daniel

The 18th century appears to have been the heyday of the noon cannon. Since then, demand for noon cannons seems to have had a marked decline. There does not seem much possibility of reviving this innocent diversion. In England, any firearm however small has to be sent for proofing to the Worshipful Company of Gunmakers in the City of London, and there are severe restrictions on offering new noon cannons for commercial sale. One


H. James

purpose-made example is the noon cannon and armillary sphere made in 1968 by the workshops of HMS Excellent, Whale Island, Portsmouth (SRN 4350). It is a memorial to Baron Chatfield (1873-1967) and features a lens which swings against a date scale.

There are also some examples of modern noon cannons in other countries, such as this interesting example (right) made by the commercial dialmaker Malcolm Barnfield in Johannesburg, South Africa (www.sundials.co.za) for Ms Janie Wells of Fairview of Tennessee, USA.



J. Wells

I have always been fascinated by noon cannons, ever since I read about the romantic first 'White Rajah' of Sarawak


P. Kimball

who defeated the rebel uncle of the Sultan of Brunei with the aid of the single cannon mounted in the bows of his yacht, the 'Royalist', and was rewarded with the gift of the whole of Sarawak. In his capital, Kuching, a cannon was fired every day at noon, ostensibly so that people could set their watches, though it probably also served to remind people how they had come under the rule of a benevolent line of white Rajahs.

Noon cannons are still fired in some parts of the world, though not in the now-democratic Kuching. The picture shows the noon cannon being fired in Halifax, Nova Scotia, where the locals delight in the surprised reactions of the tourist to the loud bang echoing over the downtown area. Nearer home, there is also a noon gun fired every day in Edinburgh.

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See also pages 127 and 140.

ASTROLABES
Part 2 – European Astrolabes

TONY ASHMORE

Note: The numbering of figures and references in this and subsequent parts of the series continues in sequence from Part 1.

Having explained the principles of the standard Planispheric astrolabe and the method of use to determine time, we can proceed to consider some of the noticeable variations of designs in instruments originating in different cultures and areas of the world. The scales appearing on both the front and the back also reflect these different origins.

Part 1 used illustrations of three European, or Western, astrolabes. In this part I shall consider the European instrument in a little more detail with respect to its general features and the main scales likely to be found on it.

CHARACTERISTICS AND SCALES OF EUROPEAN ASTROLABES

The most immediate and noticeable characteristic of Western instruments is the use of the Latin script and numerals. The earlier engravings can be difficult to read due to the type of lettering, for example Lombardic evident in Fig. 1 and gothic black letter fonts, Fig. 7, (similar to that which will be familiar to anyone who was taught German well into the 20th century). The early European notation for numerals is shown in Appendix XIX of reference 1 and is commonly found until the late 14th century, also Fig. 7, after which our familiar numerals predominate. Whatever their style, the lettering and numerals are, however, clearly distinguishable from those found on non-European instruments. Fig. 7 is unsigned but probably of English make and is of the style sometimes referred to as 'Chaucerian', being similar to that described in Chaucer's famous treatise.[2]

Fig. 7. 14th century European astrolabe with gothic lettering and numerals.

The *throne*, the piece connecting the suspension ring and shackle, or swivel, to the circular limb is usually fairly small and simple with only plain decoration. Some Flemish astrolabes from the 16th century Louvain school of instrument making include a pair of reclining satyrs, Fig. 8, which are a feature of a small group of makers from this source. This instrument, by Arsenius and dated 1565, also shows the throne is made separately and then screwed to the limb, a less usual arrangement. On Western instruments the throne may also incorporate a small magnetic compass, as in the example in Fig. 6. Such compasses may have the magnetic deviation marked which can be an aid to dating the instrument.

There is no 'standard' strapwork of the *rete*, the design being at the whim of the individual maker, perhaps after some discussion with a patron commissioning the instrument. Early retes tend to be relatively simple but it has been said that 'Mercator [1512-1594 and best known

Fig. 8. Flemish astrolabe, 1565.

for his cartographic work] was responsible for turning the rete into an art form by his use of a delicate structure of interwoven strapwork'.[3] An exception to the individualism in rete design is again to be found in a group of Flemish makers based in Louvain, not necessarily using satyrs in the throne, who tended to use a distinctive common pattern based on its characteristic tulip-shaped motive, Fig. 6, but with detail variations involving ornamentation, strapwork thickness and complexity included in the loops. Compare Figs. 6 and 8.

The number of stars included in retes varies from less than twenty to more than fifty. In general, the larger the astrolabe the greater the number of star pointers. There are exceptions, however, the most notable probably a 2 foot diameter instrument by Humphrey Cole, dated 1575, in the Physics department of St Andrews University and which has no star pointers on the rete! European instruments use flame-shaped pointers to show the star positions. The number of pointers sometimes exceeds the number of stars. For example, it is not unusual to find seven pointers against the name Ursa Major (the Plough or Great Bear), one for each of the seven stars in the constellation. An interesting variation on the use of flame-shaped pointers is the use of zoomorphic characters, Fig. 7, the head of a dog to show the position of Sirius, the Dog Star, (at the bottom), a bird for Vega (near the zenith) and a dragon's head with its tongue indicating Antares (top right).[4]

SCALES ON THE BACK

Zodiac/Calendar: In Part 1 these scales were used to determine the sun's position in the ecliptic in order to find the time. In earlier astrolabes the zodiac and calendar scales were concentric, as in Fig. 5. The zodiac scale is divided into 360 parts, 12 signs of the zodiac of 30 'days' each, a relatively easy task and, hence, also used to divide the ecliptic circle of the rete. The calendar scale has to be divided into 365 parts which are not exactly equal due to the eccentricity of the earth's orbit. The period between the vernal and autumnal equinoxes is longer than between the autumnal and vernal ones by nearly 8 days, Ref. 1, Appendix 1, column 7. Thus the arc for spring and summer needs to be longer than that of autumn and winter. These uneven 365 graduations give rise to alignment complications with the evenly divided 360 zodiac scale graduations.

With the increasing knowledge and understanding of mathematics, astronomy and 'science' from the 15th century onwards, a method of positioning a circular, evenly divided calendar scale eccentrically inside the evenly divided zodiac scale was devised which removed the alignment complications, Fig. 9. It will be noticed the two circles are very close together in early July and furthest apart in early January, the centre of the calendar circle being offset from the centre of the instrument towards the 11 o'clock direction, to use the 21st century jargon. This offset direction is because the plane of the earth's tilted axis is not parallel to the plane of the major axis of the earth's orbit, technically referred to as the *Line of the Apsides*. This means the aphelion and perihelion, the furthest and closest positions of the earth to the sun, occur approximately 13 days after the solstices. It is for this reason that sunrise continues to occur later for these few days after the winter solstice although the day length itself increases from the solstice, see Appendix XII of Reference 1. [Note: There is a typographical error in this appendix – 4 June should read 4 July and the corresponding declinations, if needed, are found in Appendix XIV.]

Fig. 9. French gothic astrolabe with eccentric calendar circle.

Shadow Square: This is found on the back of the great majority of ordinary astrolabes, normally suspended from the horizontal diameter. For convenience, the basic square is usually duplicated either side of the vertical centre line to form a rectangle, each part being a mirror image of the other, Fig. 9. The horizontal scale of the square/rectangle is known as the *umbra recta* whilst the vertical side is the *umbra versa*. Unlike Fig. 9, these terms are frequently engraved along their respective scales.

The shadow square is essentially a surveying device and has no astronomical or time finding function. Each side is divided into a number of equal parts, frequently but not always 12. It tended to be used to find the height of objects using the principle of similar triangles. Fig. 10 illustrates this use, the left diagram showing a matchstick man (not as good as L.S. Lowry's men!) finding the height of a tower, sighting through the pinhole sights of the alidade, and the right sketch an expanded corresponding view of the alidade across the shadow square. Triangles ABC and abc are similar. If the observer knows, or measures, how far he is

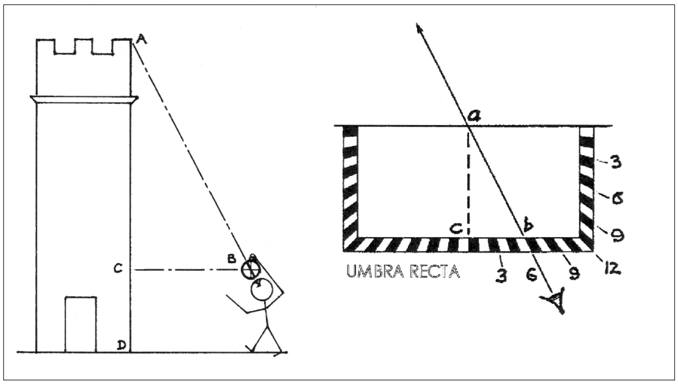

Fig.10. Height finding using the shadow square.

from the tower, distance *CB*, this is equivalent to *cb* – 6 units - on the umbra recta. The height AC is equivalent to ac – 12 units - on the umbra versa. The top of the tower, therefore, is twice the distance from C as he is from the tower. To the calculated value *AC* must be added height of the instrument centre, *CD*, to give the true height of the tower. For less elevated objects the alidade sight line may lie across the umbra versa in which case the umbra recta 'units' would be 12 and the umbra versa less than 12. The instrument can also be used horizontally in the manner today we might use a theodolite to measure horizontal angles. There is a well known drawing in various Renaissance works showing the shadow square being used, looking downwards, to determine the depth of a well. As wells were often narrow but deep, this gives the impression of an author looking for a problem to solve. A stone lowered on the end of a length of string would seem to be both quicker and more accurate.

Unequal Hours: Unequal hours, sometimes called Planetary Hours, are obtained by dividing the period between sunrise and sunset into 12 equal parts and similarly dividing the period of darkness into 12 equal parts. As the length of daylight, and darkness, varies each day throughout the year, the length of an unequal hour varies from day to day and there is a difference between the lengths of day and night unequal hours on the same day, except on the equinoxes.

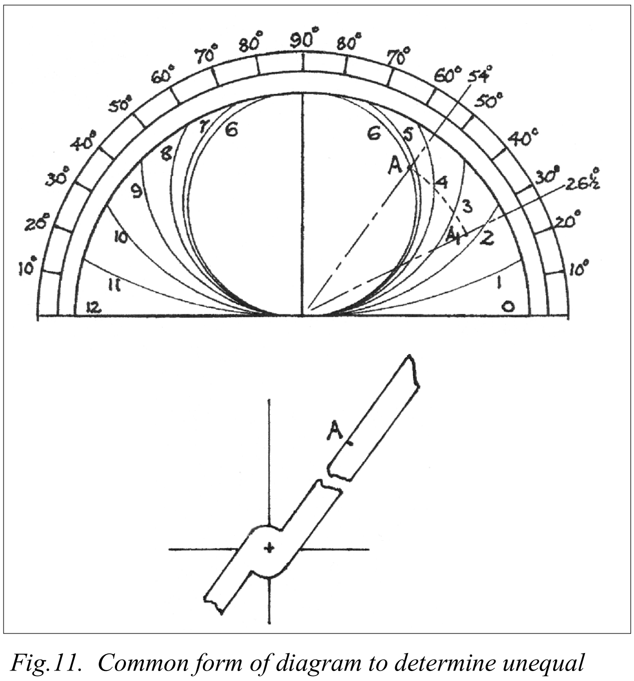

Fig.11. Common form of diagram to determine unequal hours.

Three different methods may be found on astrolabes for the determination of unequal hours, although not more than two will be found on any one instrument. Fig. 11 is the most common on the back of ordinary Western astrolabes and normally occupies the space above the shadow square, as may be seen in Fig. 9. To use this device the maximum altitude of the sun for that day needs to be found. This is easily done, on the front of the instrument, by setting the sun's zodiacal position on the rete ecliptic circle onto the north-south meridian line and reading off the altitude from the almucantar directly under that point on the ecliptic. As an example, if the maximum altitude is found to be 54º the alidade, on the back, is then set to that altitude on the degree scale at the edge of the instrument, Fig. 11. As the maximum altitude occurs at solar noon this is the same as the sixth unequal hour, halfway through the daylight period. The alidade will cross the 6 arc at the point A. This position, A, on the alidade is noted, or marked if the alidade does not have a suitable engraving at that point, Fig.11 lower diagram. At any time of the day the sun's altitude is measured and the alidade moved to that altitude, say 26½º. Where the noted, or marked, point on the alidade lies in the numbered arcs, point A_1, gives the unequal hour at that time, 2¼ hours after sunrise as drawn. Knowing whether the time is before or after noon the alidade is set to the right or left of the meridian line, giving the unequal hour less than or greater than 6. Since the design is symmetrical, only one half of the figure needs to be drawn, the numbered arcs being engraved with the two numbers corresponding to the same arc in the complete figure – 1 and 11, 2 and 10, ……, 5 and 7, 6. Since the use of this design only depends on knowing the sun's noon altitude it can be used in any latitude.

The centre of the circle may be filled by such devices as a coat of arms, tables of astrological data, solar cycle and so on.

The second design, Fig. 12, which can be used to convert between equal and unequal hours, is also found on the back

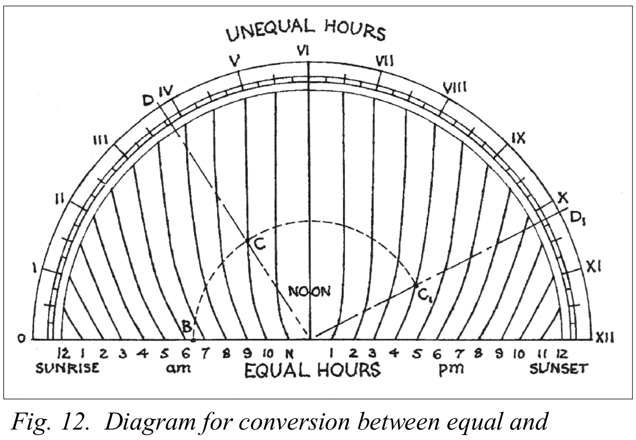

Fig. 12. Diagram for conversion between equal and unequal hours.

of the instrument and in the upper half instead of the circular scale described above. This is less frequently seen and utilises knowing the times of sunrise and sunset, on the day, instead of the noon altitude of the sun. These two times are found by placing the ecliptic zodiacal date on the horizon arc and reading the equal hour from the rule position on the limb. Like the circular design, this is also useable for any latitude.

A scale of equal hours, in conventional Arabic numerals, is marked along the horizontal diameter with noon at the centre and each half divided equally from 1 to 12. To the left of noon the hours represent midnight to noon, and so include the hour of sunrise, whilst to the right of noon are represented the hours from noon to midnight and include sunset. The outer arc shows the unequal hours, starting at zero on the horizontal line and inscribed 1 to 12, usually in Roman numerals, at the end of each unequal hour. One edge, at least, of the alidade is engraved with lines and numbers from 1 to 9 or 10 corresponding to the equal hours reading from sunrise. They stop short of 12 due to the central boss of the alidade.

As an example of the use of this design, if the sunrise is at 6.30 am, point B, this position on the alidade will follow the dashed line as the alidade is rotated. If the clock time found on the front of the instrument in the usual way is, say, 10am, the alidade is moved until the sunrise mark coincides with the 10am equal hour line, point C. The end of the alidade then indicates the unequal hour, approximately 3:50, point D. Similarly for times after noon, point C will be to the right of the noon line, at C_1 for 4pm sun time and the unequal hour will be 10:10, point D_1.

The process can easily be reversed to find the equal hour equivalent to a given unequal hour. Like the circular design described earlier this device is symmetrical about the noon line and so only half needs to be drawn, if a quadrant on the back is desired for some other purpose, with the unequal hours having two numbers – I and XI, II and X, ……, V and VII.

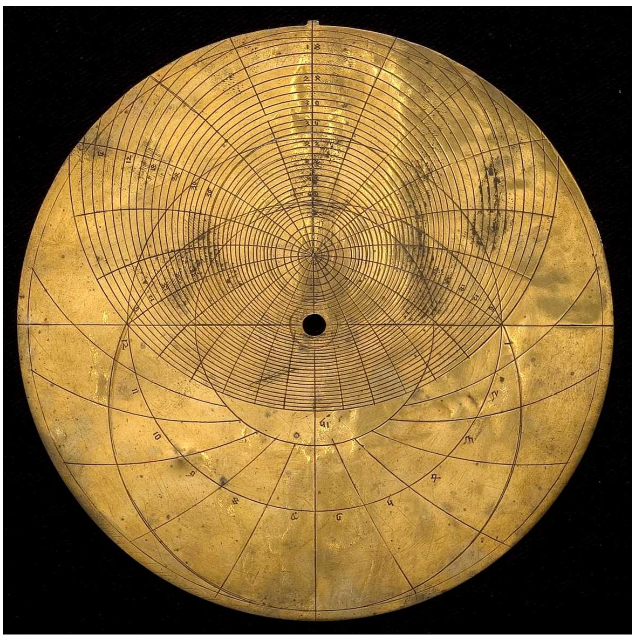

Fig. 13. Plate of Fig. 7 with unequal hour lines.

The shadow square normally being immediately under the horizontal diameter, there is not space to engrave the numbers etc, that I have shown, for clarity, in that position. The equal hour numbers are engraved in the body of the design across the actual hour lines and *HORÆ ÆQVALES* engraved across the pattern of lines to make it clear that these are the equal hours. *Horae ante meridiem* and *Horae post meridiem* may also be included to clarify for the user the before and after noon periods.

The third provision for finding an unequal hour is to be found on the latitude plates. As the plate is engraved for a specific latitude, the unequal hour measurement is only applicable to that latitude. Fig. 13 is a view of the plate for latitude 51º 34' (inscribed in the centre just under the horizon line) that is shown under the rete in Fig. 7. The unequal hour lines are the 11 curved lines drawn between the Tropic of Cancer and the Tropic of Capricorn circles and labelled with the early European number symbols. These numbers are inscribed in the middle of each hour but refer to the lines on their left, the end of that hour. In this figure the crepuscular line, the one with dots on it (see Part 1 of this series) crosses the engraved equatorial circle just before the end of the second unequal hour and just after the beginning of the eleventh hour. To find the unequal hour at night, the sun having set, the rete is positioned in the usual way for time finding by placing the observed star pointer on the almucantar of the measured altitude. The unequal hour for this instant is then read from the position of the zodiacal 'date' among the unequal hour lines. Using Fig. 7, if the zodiacal date was 10 Gemini (a little to the left of the vertical meridian line) the unequal hour would be at the start of the ninth hour. The clock or equal hour would be 1:20am, given by placing the rule over 10 Gemini and reading the time on the outer scale – a little behind the dog's head. During the day with the sun, and therefore the zodiacal date above the horizon, the same process applies except that the point on the ecliptic opposite the date, in this case 11 Sagittarius, which will be below the horizon, is used to give the unequal hour. Note that 10 Gemini is about the end of May, when the day is long, 11 Sagittarius is near the outer edge of the plate and will traverse the unequal hour lines nearest their widest spacing. By definition, this long day from just after 4 am to just before 8pm is still divided into only 12 parts giving long unequal hours.

Astrologers divide the sky into 'Sky Houses' and these are often drawn on the plates. Below the horizon the lines for these are rather similar to the unequal hour lines but should not be confused with them. As explained above there are 11 unequal hour lines (the horizon being the twelfth) numbered with Arabic numerals and which stop at the Tropic of Cancer circle. There are only 6 house lines below the horizon, numbered with Roman numerals, and they do not stop at the circle for Cancer but continue through a common point in the middle of the horizon and across the grid of almucantars and, if plotted, the azimuth lines. These 'house lines' are not included in Figs. 7 and 13.

ACKNOWLEDGEMENTS

Figures 7, 8, 9 and 13 are reproduced by courtesy of the Director of the Museum of the History of Science, Oxford.

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To be continued

READERS' LETTERS

Rowhedge Dial

I was surprised to see Ian Butson's Photographic Competition entry (bottom left, p.58 of the June *Bulletin*) as it is a dial which I made over 30 years ago! It was made in response to a request from something to mark the opening of the new quay at Rowhenge, Essex, on 11 September 1976. It was 'unveiled' by the Olympic gold medal sailor Reg White who arrived by smack from Brightlingsea to the sound of a brass band. The dial (SRN 0311), which is of stainless steel and features adjustment for summer time, seems to have worn well.

Robert Scott Simon
Woodbridge, Suffolk

I. Butson

Gravestone Dial

No doubt many readers will be familiar with the ITV series 'Diamond Geezer' featuring David Jason. For those who are not, and for the record, an incident occurred at the close of the episode screened on Monday April 16th titled 'Old Gold' with a more than ordinary gnomonic interest. Our hero plays the part of a loveable rogue, an arch-thief (hence the title of the series). In this episode he sets out to recover gold bullion, whose whereabouts are revealed in a code hidden in a painting in the Russian Embassy. After many adventures and vicissitudes the trail leads to Lime Street cemetery and the tomb/mausoleum of one Ilianic Koylekov. Above the memorial inscription there is a vertical sundial with a curved gnomon the like of which I have never seen, nor am I ever likely to see. What follows clearly indicates that the script writer knows little or nothing about sundials, and probably assumed that they record the hours as on a clock-face. David Jason grasps this gnomon, which turns out to be pivoted at its root, and turns it successively to the three numbers (that is hour lines) on the dial face, namely 12, 6 and 9:30. After an anxious pause, behold a stone panel on the face of the tomb slides open to reveal gold bars to the value of £6,000,000! The choice of numbers for his code reveals the author's ignorance of gnomonics. On a typical sundial the gnomon is already aligned on 12 o'clock (noon) and would not need to be twisted into place, and there would be a choice of two 6 o'clock positions. Altogether, this must be the most bizarre application of gnomonics in the history of literature, but very appealing and original nevertheless. In parenthesis, there is no reason why a gnomon could not be made to pivot and to align itself with a numeric code: one needs only to be careful in the choice of one's numbers!

John Wall
North Yorkshire

Brass or Bronze?

I found the article 'Brass or Bronze?' in *Bulletin* 19(ii) very interesting particularly as such studies might lead to data that could corroborate a speculative sundial date. Reflecting that the information that turns a sheet of metal into a usable sundial and identifies it is often held tenuously in the first half millimetre of the skin, then these metallurgical techniques will be very important.

1) In analysing the dial plate of the 1685 Lyme horizontal equinoctial dial, I was able to discern the last two digits of the date (as described in detail in my article in *Bulletin* 17 (iv)pp.160-167). The plate is very heavily corroded but there was a legacy of the engraving actually in the blue green patina itself. I described a green sea in which there are many black islands, which may indicate the original level of the metal, a description that applies to many dial plates. It seems that the trench of the original engraved cut is somehow maintained or memorised entirely in the patina

continued on page 123

ISLE OF WIGHT SUNDIAL MYSTERY SOLVED

ELIZABETH HUTCHINGS

In *Bulletin* 18(iv) p.176 (' Poetic Interlude', December 2006), Tony Wood described a sundial pedestal at Farringford. In the *Readers' Letters* of the following issue, Tony Ashmore suggested an explanation for the image on one side of the pedestal. Now, Elizabeth Hutchings gives the definitive story. Elizabeth is a member of the Farringford Tennyson Literary & Arts Society and author of *Discovering the Sculptures of George Frederick Watts O.M., R.A.* and *Busts & Titbits - Woolner Busts & Freshwater Fragments. Ed.*

Farringford in Freshwater at the western end of the Isle of Wight was the home of Queen Victoria's Poet Laureate Alfred, Lord Tennyson from 1853 until his death in 1892. He and his wife Emily had two sons, Hallam named after Tennyson's much loved friend Arthur Henry Hallam, and Lionel who died at the age of 32. Tennyson's long poem *In Memoriam AHH* was written over several years following the tragic early death of Arthur who had been engaged to Alfred's sister Emily. It included (canto cxvii) the poem *The Sundial.* One of the Tennysons' many friends was the painter and sculptor G.F. Watts. He married Mary Fraser Tytler, an accomplished artist from the shores of Loch Lomond and they made their home at Kensington, with a country home at Compton, near Guildford where you can now find the famous Watts Gallery.[1] There they found a rich seam of clay and Mary taught the villagers the art of pottery. Her garden ornaments were much sought after and included sundials. An example currently in the Watts Gallery is shown in Fig. 1.

Fig. 1. A scaphe dial by Mary Watts currently in the Watts Gallery, Compton. Photo: D. Bateman, with permission.[3]

The Sundial

O days and hours, your work is this
To hold me from my proper place,
A little while from his embrace,
For fuller gain of after bliss:

That out of distance might ensue
Desire of nearness doubly sweet;
And unto meeting when we meet,
Delight a hundredfold accrue,

For every grain of sand that runs,
And every span of shade that steals,
And every kiss of toothéd wheels,
And all the courses of the suns.

The poem has connections to Shakespeare's Sonnet 77, *Thy dial's shady stealth* and Sonnet 59, *Five hundred courses of the sun.*

The plate and gnomon are missing though they can be seen in Freshwater photogapher Ken Merwood's 1951 picture of the sundial half hidden in a bed of flowers. The pedestal

Fig. 2. The Watts' pedestal in its current location at Farringford.

was subsequently moved and now stands above a small oranmental pool flanked by two conical golden cupressus (Fig. 2).

Some compensation for the missing dial is that a mark can clearly be seen in its recess in the pedestal (see Fig. 3) which I had thought was that of the mason but Veronica Franklin Gould[2] has identified it as Mary's. She wrote to me: "The sundial was clearly designed by Mary Seton Watts relating to the memorials and sundials made by her potters at Compton. Mary introduced this grey terracotta to harmonize with stone architecture, red to accompany brick. The style of lettering resembles Mary's more mature work or that of her Compton calligrapher." I had hoped it was made to celebrate the marriage of Hallam to Audrey Boyle in 1884. At first Veronica thought it was probably designed by Mary while the Watts were staying at Freshwater in 1890. But after much discussion between us we think it was most likely made after Emily's death in 1896. Veronica writes: "My feeling is that it is in memory of the poet and his wife, with a vision for the future, as it were, through Hallam and Audrey." The poem is obviously a memorial but also looks to a future meeting.

Fig. 3. The top of the Farringford pedestal showing (right) Mary Watts' sculptor's mark in the recess.

Fig. 4. Close-up of the side with Audrey's likeness (described by Tony Wood as 'something Egyptian'!) showing the heart on the end of Audrey's quill with a boat with eight occupants and two suns above it.

The pedestal is constructed in four separate sections. At the top is a capital in two sections. The upper section, in which the dial was inset, has a motto on its top surface reading: *horas non numero nisi se*[*renas*]. This roughly translates as 'I can not tell the hours unless there are clear skies'.

The lower section of the capital has the second two lines of the second verse of *The Sundial*, starting facing north and reading anti-clockwise, *and unto meeting - when we meet - delight a - hundredfold accrue.*

The upper section of the shaft has a carved figure on each of the four faces. They are ALFRED, EMILY, HALLAM and AUDREY whose names are at the base of the shaft. The lower section of the shaft has the last four lines of the poem starting below *hundedfold accrue*, facing east.

Thus Alfred holds an hour glass above the line 'for every grain of sand that runs'. Emily holds an upright sundial similar to one of Mary's in the Watts Gallery above the line 'and every span of shade that steals'. Then Hallam holds a clock above the line 'and very kiss of toothed wheels'. Above the line 'and all the courses of the suns' Audrey holds a quill. On the end is a heart-shape with a picture of the heavens above a small boat in water with eight tiny figures in it. The Flood is featured in nearly all cultures and there are always eight survivors, though in the Koran Noah's wife does not survive.

The best news is that Martin Biesly and Rebecca Fitzgerald, the new owners of Farringford, plan to have the sundial restored.

REFERENCE & NOTES

1. *www.wattsgallery.org.uk*
2. Veronica Franklin Gould, the author of *G.F.Watts: The Last Great Victorian (Yale University Press 2004),* is writing the definitive biography of Mary Seton Watts.
3. A similar dial, on a matching pedestal, was offered by Christies in their 'Furniture and Decorative Objects' sale, May 2007.

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SNIPPET FROM A CHURCH LEAFLET

"Sadly in 1772 the mediaeval churchyard cross was made into a sundial – the mason being paid 3 shillings for this act of vandalism."

But now in 2007, even more sadly, the sundial is no longer there and the cut-down cross stands bare among the tombstones in the churchyard of St Garmon's Church in Llanarmon in North Wales. It has disappeared in the last twenty years.

Irene Brightmer

STRANGE LONGITUDE

FRANK EVANS

Over the entrance to the Grammar School in Hawkshead, Cumbria, is a dial, SRN 1134 in our Register. The building, now a museum, is famous as the school attended by young William Wordsworth. But the dial, dated 1845, although old is from well after his time. It was first recorded for the BSS in 1990 by Robert Sylvester, when it was seen to be in poor condition. In 1997 a good and faithful restoration was completed by Scobie Youngs of Dacre, near Ullswater. The dial currently looks very well, although the hour lines and equation of time values are in blue and rather hard to pick out, in contrast to the gold hour numbers. The dial plate fills a framed space above the door. It declines a little from south but is further canted eastwards to show time from five in the morning to three in the afternoon. Sylvester thought this odd arrangement may have been to allow the early hours of the school day to be shown.

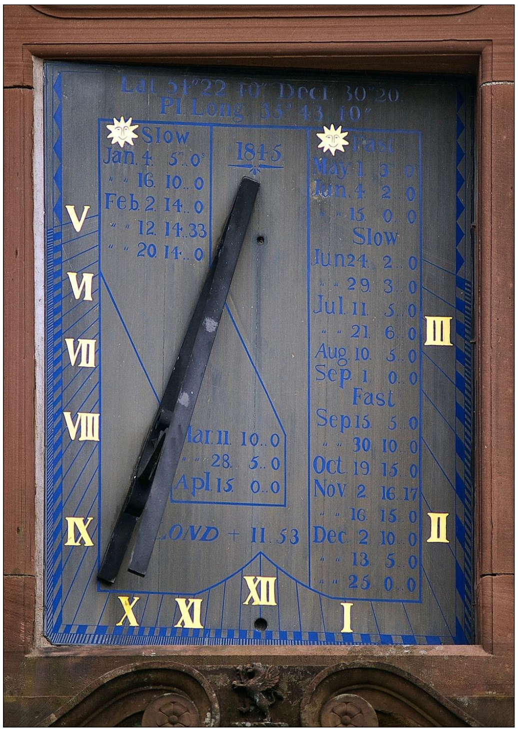

Fig. 1. The Hawkshead dial.

At the head of the dial plate, as has now become clear, are the inscriptions:

Lat 54º 22' 40" Decl. 30º 20'.
Pl. Long. 35º 43' 40"

At first not all of this could be made out. The cited latitude accords well with the location of the dial but the longitude was a curiosity and a puzzle which the museum curator, when I met him recently, was unable to explain. Hawkshead is almost exactly 3º west of Greenwich. Furthermore I originally misread Pl as PL. The declination was only spotted later on a photograph.

In an opening enquiry to the Sundial Mailing List on the internet I wrote of the dial: “Longitude eastward of Greenwich lands us in an unremarkable location in the middle of Russia but westward takes us close to Recife, formerly Pernambuco, on the eastern tip of Brazil. No significant place on the coast there (lighthouse, etc) fits but I am wondering if there is or was an observatory in or near the middle of the town. And what can the letters PL mean? Any suggestions for this strange longitude citing?”

The communications that followed have been energetic and remarkably numerous, with over forty postings. Correspondents, many of them well-known names in the sundial newsgroup, have gnawed at the significance of the longitude value but were misled by the misreading of Pl as PL and by my omission in my earlier messages of the word “Long” immediately following these letters. Nevertheless, attempts were made to discover a suitable location from which the longitude measurement may have been derived. I, as noted, suggested Recife but St. Petersburg was more plausibly proposed by Tom Kreyche, although he had reservations about such a reference for an English dial at that date.

However, in an early nautical publication we find that the St. Petersburg Observatory is given as 30º 18' 23" east of Greenwich which, making allowance for the 3º further west for Hawkshead, still leaves a deficit of over two degrees towards the 35º 43' 40" quoted on the dial. In view of the precise values on the dial plate such a wide discrepancy presents a fatal objection.

There followed a very neat proposal from Gianni Ferrari. He suggested that the supposed longitude was actually the polar latitude. This quantity, attractively suggestive of the supposed PL of the dial inscription, he proceeded to derive and figure from a quantity called the reduced latitude, which in turn is related to an earth figure compressed from the spherical. The result he obtained, using an appropriate compression, was startlingly close to the quoted value of 35º 43' 40" However, it did not explain the word “Long” in the caption, and so again a difficulty remained.

Eventually, a better photograph communicated by Fer de Vries revealed the value heavily shaded by the dial framework: Decl. 30º 20'. From this value and the given latitude he was able to calculate the style angle, the substyle angle and, critically, the hour angle in angular measure. Gratifyingly the calculated hour angle of 35.75º was encouragingly close to the quoted longitude value, here recalculated in decimal degrees, of 35.7277º. In units of time the difference was six seconds. As he announced in modest triumph in his message to the newsgroup: “Bingo!”

And indeed we seemed here to have reached a large part of the solution. While hour angles are usually expressed in units of time here we have an angular hour angle. I summarised the results in a message of thanks to correspondents when I said: “If the hour angle is presented as an angular measure it works out at 35.75º or, in time, 2hrs 23mins as opposed to the cited longitude of, in time, 2hrs 22mins 54secs. In other words, at 9:37am the sun will be directly over the style and the cited longitude is the hour angle. This explanation has the added advantage that no geographical longitude is involved; longitude values must be rare indeed on dials of 1845.”

In photographs the line of the gnomon is indeed seen to be set at this morning value. Moreover, Robert Sylvester has been able to return to a post-restoration photograph of his, which was dated and timed, and showed that with due allowance for Hawkshead's longitude and the equation of time the dial time agreed with GMT to within four minutes, confirming that the dial plate was correctly aligned.

But we still lacked explanation of the letters PL (or P1, as on the dial). Frans Maes noted that Waugh uses the symbol P in his treatment of declining dials, referring to his “computational treatment of the declining dial on p.80 of his standard work. The P values for each hour line in table 10.2 are ‘what Holwell (in Clavis Horologiae, London, 1712) calls the polar angles’. The polar angle for noon equals the so-called difference in longitude DL. Converted to time, this is the time of the sub-style line. So here is at least a link between P and Long.”

I have several further comments to hand concerning PL or Pl. Firstly, John Davis wrote: “I note that the letters ‘PI’ (as well as PII and PW) appear as one of the centres of Oughtred’s Horizontal Instrument. They are actually engraved on the instrument made by Elias Allen.” Oughtred was of course the famous seventeenth century inventor of the double horizontal dial.

Secondly Gianni Ferrari noted that in *The Art of Shadows* by John Good (London 1731) the author always used the quantity ‘Plane’s difference of Longitude’ or ‘Planes Longitude’ (Good’s apostrophes are haphazard) to calculate a declining sundial.

We are now getting close to Pl. Finally, Frank King pursued Good’s book in more detail and reported: We can be certain that John Good used the abbreviation Pl for ‘Plane’s’ and that ‘Pl Long’ was his abbreviation for ‘The Plane’s Longitude’.

For a vertical dial plate, King noted that this longitude refers to the point 90º distant on the earth’s surface at right angles to the dial plate. Moved to this point, with its orientation preserved, the dial plate would lie horizontally. Pl Long is the angle at the pole between the meridian passing through this point and the meridian of the dial.

He too noted a discrepancy between the ‘Pl Long’ quoted on the dial and the ‘Pl Long’ derived from the cited latitude and declination but the discrepancy is too small to affect the argument. Concurring with Ferrari, King concluded: “It seems highly likely that ‘Pl Long’ on the Hawkshead dial is the same abbreviation, namely ‘The Plane's Longitude’.”

And there, at last, we have it, with what we may call the gnomon hour angle having the same numerical value as the plane’s longitude. The meaning of both ‘Pl Long’ and the value it refers to have been found. Remarkably, this whole Hawkshead debate, involving a score of knowledgeable dialists, was begun, solved and finished in a little over a week. We are now able to offer the curator of the Hawkshead Grammar School a solution to the enigma of the dial. And Frank King concluded that this explanation has the added advantage that (contrary to my statement) it does involve a geographical longitude.

He wrote: “The Pl Longitude is the geographical longitude where, at 12 noon local sun time, anyone way to the west in Hawkshead could see the shadow of the gnomon falling along the sub-style of this dial. Thus ‘longitude’ has its conventional geographical meaning.

“Just think, pupils at Hawkshead Grammar School could be taken outside for a break and told to watch for when the shadow fell along the sub-style. “Look at that, boys”, the schoolmaster would say, “It is now 12 noon everywhere along the Plane's Longitude”.

Bingo indeed!

ACKNOWLEDGEMENTS

I am indebted to all my correspondents for their contributions but not least to Robert Sylvester who first reported the dial. Later, in *Sundials of the British Isles,* published by Mike Cowham (2005), he supplies a picture and a very informative general account of the dial. Acknowledgement is due to John West, retired curator of the museum who contributed so much to the dial’s present condition, including the retrieval of the decayed inscriptions and, with the help of the Royal Greenwich observatory, the recovery of the table of equations of time for 1845. I am also further indebted to Frank King who has taken a great deal of trouble to suggest improvements to my manuscript.

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A RARE DIAL IN THE FAR NORTH
Sumburgh, Shetland Islands

VICKI DE KLEER

A few years ago I travelled to Shetland and stayed at the Sumburgh Hotel, at the tip of the southern Mainland of the Islands. When I checked in I noticed a plaque attached to the upright part of the registration desk at a level of about two feet above the floor. On closer inspection it appeared – of all things – to be a sundial! Later, the manager was kind enough to remove it to a table where it could be seen properly.

It was marvellous: a beautifully made brass dial, 13½" in diameter, in excellent condition and showing good detail (see Fig. 1). A brass rubbing, later turned into a drawing (Fig. 2), proved most useful for taking measurements. It was then carefully returned to its place, vertical rather than horizontal and out of reach of the sun.

Fig. 1. Photograph of the Sumburgh dialplate.

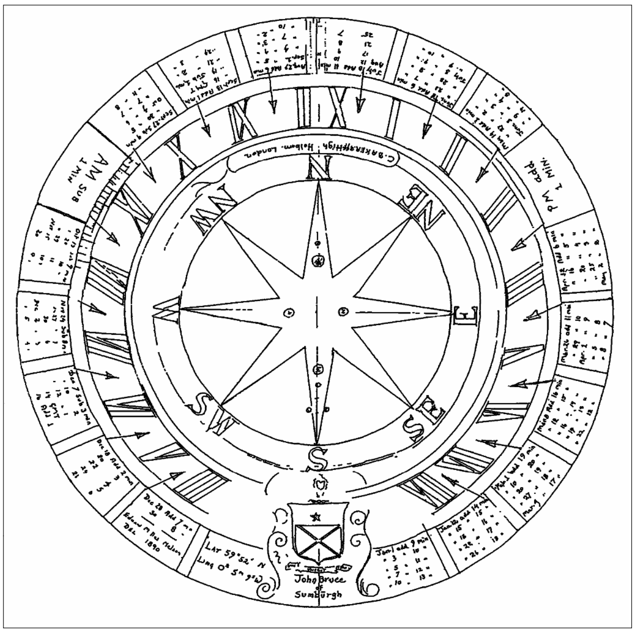

Fig. 2. Drawing of the Sumburgh dialplate, made from an original brass rubbing.

At that time I could find very little of its history. There was a curved wall in the garden where it had originally been mounted on a pedestal. About 30 years previously, the garden had been vandalized and the dial was found on the ground some distance away. The gnomon was never recovered. Neither the current owner nor anyone in the local historical society could provide any further information.

Fig. 3. John Bruce's arms on the Sumburgh Hotel.

It was easier to learn about the history of the hotel and hence the original owner of the dial. It was built in 1867 as a country house. The Laird, John Bruce, lived there from 1881 until his death in 1904. During that time, in 1890, the dial was constructed. His coat of arms, which has as its crest a hand holding a heart and includes the motto 'Omna Vincent Amo', is displayed on the building and is also engraved on the dial itself (Fig. 3).

I checked the location of the hotel using a current Ordnance Survey map and, as expected, the positions agree exactly with a latitude of 59° 52' 10" N. Curiously, the longitude is not marked as such but the time difference of 00hr 05min 09sec translates to 1° 17' 12" W of the Greenwich Prime Meridian. For a visitor thinking in terms of mileage rather than navigational data, that is about 37 miles west of Greenwich and just 8 miles south of the 60° N line.

The dial is a mine of information. Practically anything you might wish to ask is answered. Three gentlemen are named, the first being the aforementioned John Bruce, Laird. Obviously this dial must have been commissioned by – or perhaps for – him at this precise location. The second name is that of "C. Baker. 244 High Holborn, London". Research reveals the identity of a Charles Baker of 243 & 244 High Holborn where he worked from 1851 until

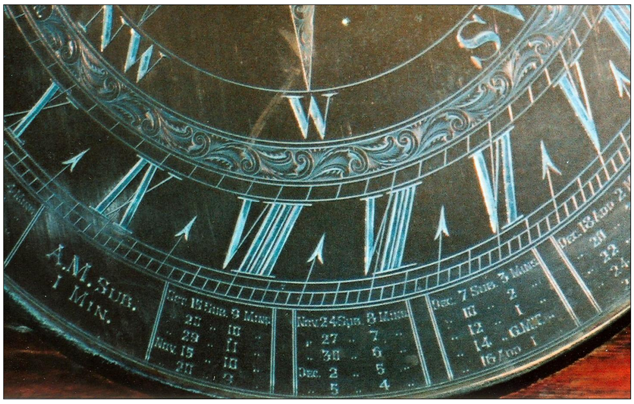

Fig. 4. Close-up of the dialplate showing the time correction ring, the arrowhead half-hour marks and the decorative engraving. Note also the instruction "A.M. Sub. 1 Min." on the left.

1909 as an optician and scientific instrument maker.[1,2] The firm is said to have been founded in 1765. Charles Baker sold a wide range of instruments including those for surveying and for surgical and mathematical applications. Unfortunately, it has not been possible to find out anything about the delineator of the dial other than his name, Edward Miller Nelson.

A particularly useful feature is the peripheral calendar in which corrections for the longitude (5mins 09secs) have been combined with the equation of time, thus simplifying the conversion from solar to standard time. This can be most clearly seen in Figs. 2 & 4.

Engraved in the calendar ring are the unusual instructions "AM Sub. 1 min" and "PM Add 1 min". It is not completely clear what these additional corrections are for but one explanation is that they are an attempt to allow for the bias of the viewer's eye in deciding where the true edge of the shadow is.[3]

Although at the summer solstice the sun rises at Sumburgh at 02:36am and does not set until 21:28pm,[4] the hours defined are limited, running only from 04:00 to 20:00. It has been suggested[5] that, since the dial was made 600 miles to the south, proper allowance was not made. In Fig. 5 I have taken the liberty of adding the earlier and later hours just to see what they might have looked like, very nearly surrounding the dial. Other than its angle and footprint, we have no details of the gnomon design.

It is regretable that such a fine instrument is no longer faithfully recording the hours in its rightful setting and one can only hope that it might eventually be restored. At the time of writing it is apparantly the most northerly dial in Great Britain recorded in the *BSS Register*.

ACKNOWLEDGEMENTS

I would like to thank John Foad for encouraging the writing of this article and Meryl K. Zavitz for the brass rubbing.

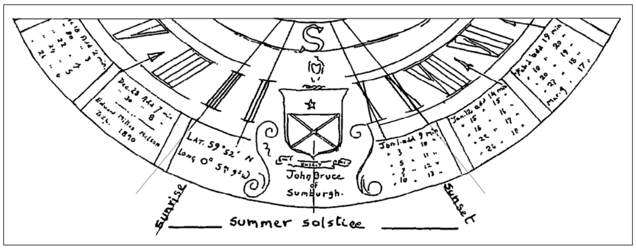

Fig. 5. Expanded diagram showing the coat of arms and the calculated positions of the extra hour numerals.

The staff of the Sumburgh Hotel, Virkie, Shetland, ZE3 9JN were most helpful.

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4. Nautical Almanac, Commercial edition, Paradise Cay Publications (2007).
5. J. Foad: Personal communication.

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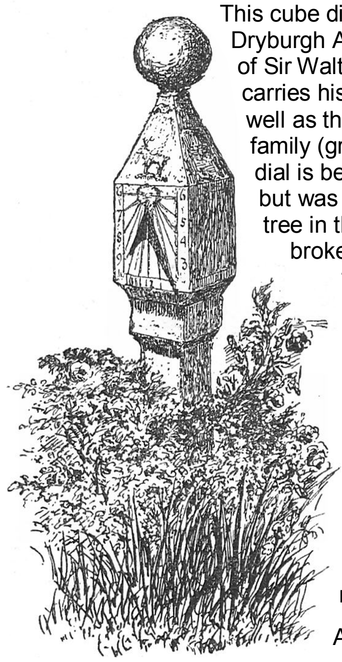
[The dial described here has several features in common with those made and sold by the contemporary firm of F. Barker & Son, particularly the decorative engraving and the layout of the Equation of Time table. It is possible either that the dial was actually made by F Barker but retailed by C. Baker or that both makers used the same pattern books. Ed.]



This cube dial was once at the ruined Dryburgh Abbey, near the remains of Sir Walter Scott and his wife. It carries his motto *Watch Weel* as well as the arms of the Haliburton family (grand-uncle to Scott). The dial is believed to date from 1640 but was knocked over by a falling tree in the Victorian era and left broken for a considerable time.

It was gifted from Nenthorn House in 1987 and is now to be found at Abbotsford House in the Scottish Borders, fitted with four new gnomons. It was last recorded (SRN1462) by Andrew Somerville in 1988. Time for a new report?

After *Gatty*.

HOW BIG - HOW HIGH?

MIKE COWHAM

Many of us go out recording dials for the BSS Register or for our own amusement. Often when we come to a church we want to know how high the dial is up the tower and how big it is. At such a distance it is often difficult to judge these sizes correctly. What we need are some simple-to-use aids to measurement. We could, of course, use (often expensive) surveying instruments but my preference is to use simple home-made devices which are often just as effective. Without any aids we will subconsciously try to estimate height by imagining a man standing below the dial and how many times his height will go into the dial height. In many cases we will be fairly accurate. However, in looking through records in the BSS Register I have noted differences of perhaps 2:1 between different reporters. Some are therefore better estimators than others. Ideally, we want to get a simple method giving results within ±10% if possible, but certainly closer than ±20%.

Firstly, to measure the height of the dial. We can do this by trigonometry. This is all very well, but I have forgotten most of mine. What I need is something very simple. I fall back on the old device known as a Shadow Square. This was used for hundreds of years for solving exactly the same sort of problem. Yes, it does use trigonometry but in a 'painless' sort of way. It actually uses tangents - but we don't need to know that.

Construct your own shadow square by drawing two equal length lines at right angles on a card or board so as to form two adjacent sides of a square. Divide each into the same number of equal divisions. This can be any number but for simplicity of mental arithmetic use 10 or even 20. If you really want accuracy go for 100. Fig. 1 shows the shadow square on a quadrant divided by 50 (perhaps not an ideal figure for mental arithmetic). From the apex of the device add a plumb line. Along one edge of the device add pinhole sights or you can simply sight along its edge. You can see one of the sights on the top right of the old quadrant.

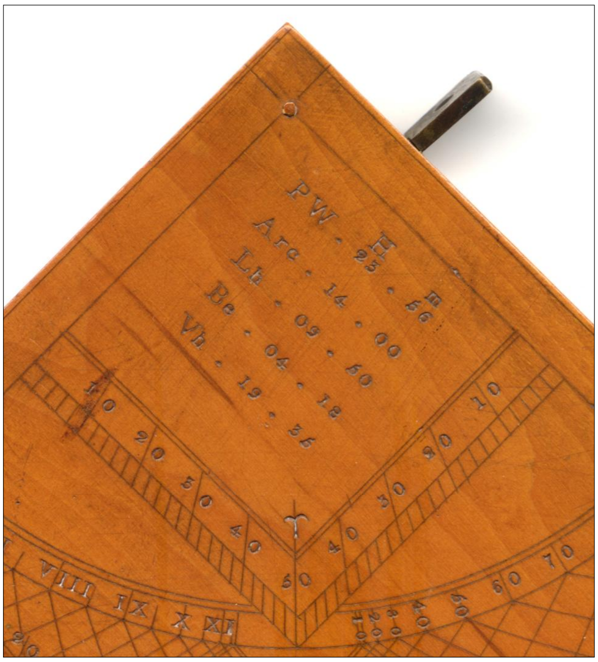


Fig. 1. Shadow square on 18th century quadrant.

In use, measure your distance from the church tower by pacing (you can even measure your paces later) or better still by using a tape measure. Pacing may not give you the accuracy that we seek. Ideally, position yourself such that the dial is at about 45° up, but this is not critical. Due to walls, gravestones and trees you may have to work at any angle. Sight along the edge of the device to the lower edge of the dial then clamp your thumb against the plumb line. Read the figure on the shadow square where the line crosses it. All you then need to do is to calculate the ratio (tangent) of the number divided by the full length of the scale. For example, if the line crosses 8 along the horizontal scale (assuming a 10 division scale), the dial is at 8/10

Fig. 2. Picture of the Anglo-Saxon dial (just above the lower window) at Barnack, Cambridgeshire. The image has been distorted so that vertical lines are now parallel. The dial width can easily be related to a measurement of the door at ground level. There is also some spherical distortion caused by the camera lens but this has been ignored here.

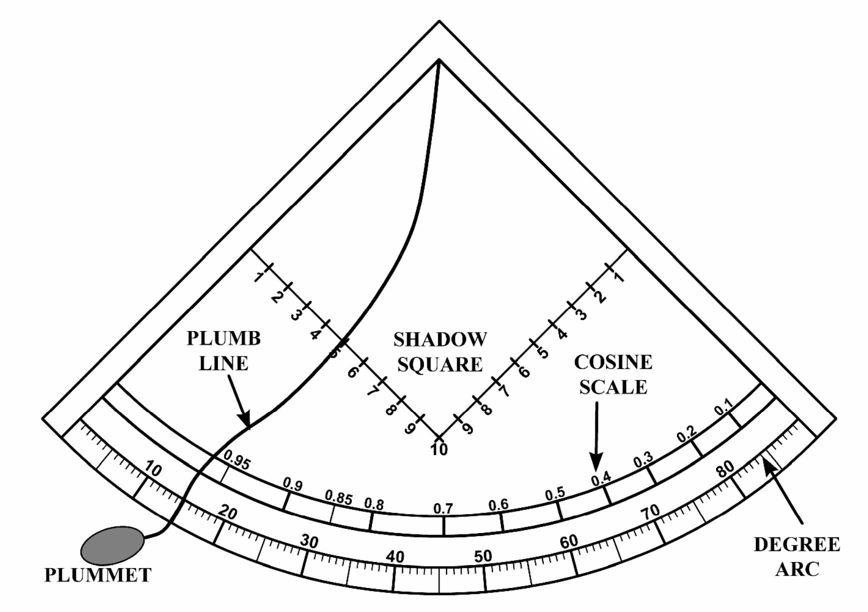


Fig. 3. Design of simple quadrant for surveying.

(or 80%) of the distance that you measured from the base of the tower, but don't forget to add the height of your own eye level to the result (1.72 metres in my own case). If, however, the line crosses the vertical scale at 7, then the opposite ratio is used giving 10/7 (or 143%) times the distance from the tower.

If the dial is not too high then a further reading taken from its top will give its approximate height when the lower edge reading is deducted, but this is often not suitable for smaller, very high dials. The way to proceed then is to find something that will relate to the dial. It may be surrounded by bricks or stones. Are these the same size as those at the base of the tower? If so, a simple measurement of one can be multiplied by the number of bricks/stones across the dial. Another way is to measure the width of the tower and estimate how many dial widths will go into that width, bearing in mind that a tower is often wider at the base than the top, but its sides are usually stepped, so parallel in each section. A sure way to do this is to take a photograph and work it out later. You may even want to adjust the picture to show the sides of the tower to be parallel by using suitable software as in Fig. 2. Otherwise, you can draw in lines parallel to the outside of the tower towards a vanishing point (remember these from school perspective lessons?). It doesn't matter that the dial may now be distorted as it is just the ratio that you need to get its size. Unless the dial is round, do not attempt to work out its height due to foreshortening, unless you want to use trigonometry.

On my quadrant, Fig. 3, I have added a cosine scale to let me do this simply but I hardly ever need to use it and I will delete it in the future. I can always refer to these tables later in the comfort of my home with less liability for error. Its omission will also let me increase the size (and hence accuracy) of my shadow square.

A dial mounted on a brick wall is probably the ideal. All that we need to do is to determine the size of the bricks including the mortar layer and the result is simple to find by counting brick layers and lengths. Unfortunately, bricks do not always seem to be of the same size, so a measurement at each site is really essential. When I was a lad, I was told that bricks were 9" long, 4" wide and 3" high but now that they are made in metric sizes this does not apply. Also, older bricks tended to be significantly smaller, particularly in Medieval churches.

I find that the need to measure the distance from the dial to my observation point is a bit complicated. Do I really want a tape measure to carry around? Will I find someone to hold one end of the tape for me? Will I need to stand several tape measure lengths away from the tower to get a good view of the dial? The alternative, to pace the distance, does lead to errors so perhaps this is not the best idea for the accuracy that we require. I have therefore come up with a much simpler method using basic height comparison. All that this requires is a mark on the tower at a known height. Of course, we should not deface the tower or wall with a real mark, not even a chalk one, but we should try to find an existing mark that is perhaps the height of part of our own body, perhaps the top of our head or at our eye level. We can easily measure ourselves later to get this figure. The next thing to do is to stand back and estimate how many times this height will be needed to reach the lower edge of the dial. This is all very well but we need to keep the observing angle small, certainly less than 30°, or we need to start correcting for perspective. This process requires fairly complex (for me) mathematics, so I would try to avoid it. However, I have produced a chart showing the correction factor over a range of angles. This is reproduced graphically in Fig. 4. Tony Belk has kindly looked at my graph and and has produced the following formula for it:

Correction Factor = $\tan\Theta/\Theta \times 180/\pi$

or

Correction Factor = $57.2958 \times \tan \Theta/\Theta$

Here you will see that even at 30° elevation the error is only 10%, but this is already at the limit of our desired accuracy. As angles increase above this the correction necessary increases dramatically with 27% at 45° and 65% at 60°. Even with the corrections from this chart I would prefer not to use elevation angles of much more than 45°. If we want to do this accurately, then we need to use the degree scale to our quadrant. However, I think that many of us can estimate an angle fairly accurately, and if this is only around 30° the error is going to be insignificant. If we estimate 20° instead of 30° the error will only be 6%.

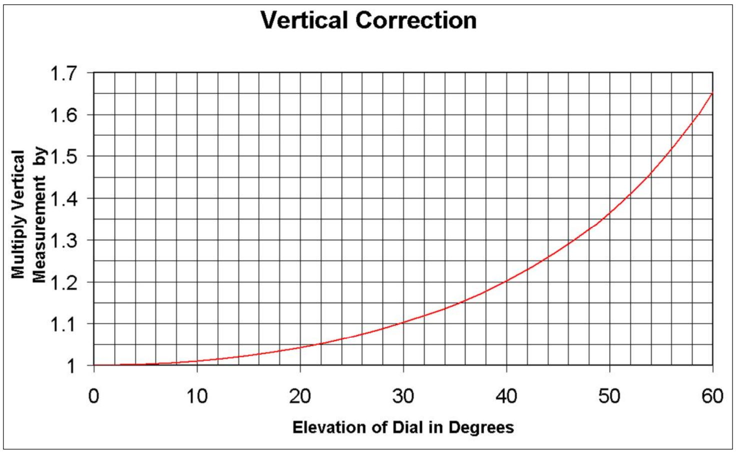


Fig. 4. Correction to vertical measurement as angle is increased.

Fig. 6. Using a convenient object as a makeshift size reference: in this case, a wallet.

PRACTICAL RESULTS

I have talked at length about the theory and methods but now feel that some practical examples of what can be achieved will show the flexibility of the methods proposed.

I went to photograph the pair of dials at Magdalen College, Cambridge. Fig. 5. Luckily the dials were mounted on a brick wall - but I had forgotten to take any measuring instrument. I could have used a person for reference but fumbling in my pocket I pulled out my wallet and placed it against the bricks, taking the all-important photograph (Fig. 6) of it for reference. From later measurements I determined that the size of each brick was 6.28cm high and 20.8cm wide. Furthermore, the height of a brick with mortar is 7.44cm. From the photograph I counted 78 courses to the lower edge of the motto which works out to be 5.8m above ground level. The dials are 13.3 courses from top to bottom, making them 1m high. One brick plus one end-on

Fig. 5. Pair of vertical dials mounted high on a brick wall at Magdalen College, Cambridge.

Fig. 8. Tripod marked with 10cm measurements.

Fig. 7. Correction of perspective revealing that the two dials really are of different sizes!

brick plus mortar = 31.6cm wide. The left dial is therefore 948mm wide and the right 896mm wide. This is probably 950 and 900 respectively as these are modern dials and would have been made to metric dimensions. The difference in width of the two dials is surprising. However, now that *I know this,* looking at the photograph shows it quite clearly. Another 'trick' of digital processing allowed me to correct for twist and perspective. The result (Fig. 7) gives a straight-ahead view. Note that in doing this sort of correction that it will only work in one plane (that of the dials in this case) and that the gnomons sticking out will be incorrectly positioned in the result. I have left the original boundaries of the photograph intact so that you can see how much 'correction' has been applied.

Another very useful tool has been added to my armoury. I usually carry a tripod so that I can get good shots through a telephoto lens of those really high dials. I have marked clearly along one leg measurements in increments of 10cm. (It could equally well have been a walking stick or we could use the height of a person.) The whole tripod when extended is just over 1.2m long. Now I have a *real* ruler to measure things. Fig. 8. It was ideal for measuring the doorway at Barnack, Fig. 9. From this measurement the dial at Barnack was found to be 0.55m diameter. This technique

Fig. 9. Measuring the doorway at Barnack Church.

can also be used quite simply for determining heights of dials. It is just necessary to lean it against the wall below the dial and to photograph it. Fig. 10 shows a simulation of measuring the height of the vertical dial at Sandringham. Here the tripod has been used as the basic reference. However, due to perspective the dial will be somewhat higher than we think. When we try to add together multiple tripods we effectively see each one at the same distance as if they were in an arc in front and above us. In this example we are measuring about 5.8 tripods but the observing angle to the lower edge of the dial is about 45°. From our chart in Fig. 4 we find that the dial is actually 1.275 times higher, or 7.4 tripods high. As this is a simulated example I am not going to give real measurements in this case. However, one error has crept in here. This is due to the number of tripods *below* our eye level. Let's assume that this is 1.5 tripods. We know that with such a small angle, perhaps less than 10°, we can ignore any errors of perspective, therefore the perceived height is 5.8 - 1.5 = 4.3 tripods. We then multiply by

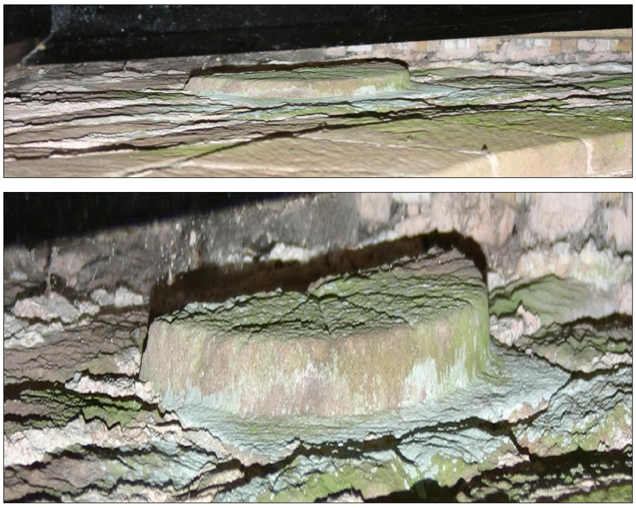


Fig. 11. Original (top) and expanded (bottom) photographs of early dial at Castle Frome, Hereford.

1.275 which gives 5.5 tripods to which we must again add the 1.5 tripods below eye level making a total of 7 tripods. A small error, if not corrected, of around 6%.

COMPUTER MEASUREMENT TECHNIQUES

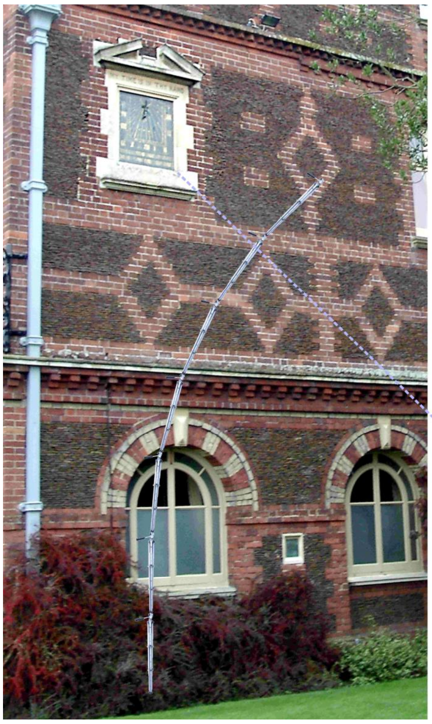
In the above examples I have used Paint Shop Pro™ software for determining size ratios between objects. Other photo handling software will operate in a similar fashion but my notes refer to Paint Shop Pro.

With my photograph on the screen I set a frame exactly around my reference (usually a tripod) and crop the picture. The software will tell me how many pixels high (or wide) it is. Returning to the complete picture I do the same with the dimension to be measured, noting again the number of pixels. A simple mathematical division will then give me the exact ratio between the two objects.

The same software allows me to straighten, untwist and generally manipulate images. Naturally such 'distortion' of images needs to be used with care but it can be very useful. A recent example is the early dial at Castle Frome in Herefordshire. This is inside the church porch and is now covered by a dense wire mesh to protect it from pigeons. A photograph through the wire proved virtually impossible. However, I noticed that the dial could be seen behind the last wooden beam through a gap, perhaps no more than 50mm wide. I took the photograph in Fig. 11a. When this was stretched using my software (Fig. 11b), I could see quite clearly that the dial is divided into 6 segments. Admittedly this is not a good picture and I plan to return and, with permission, remove the wire mesh to make a proper record of the dial.

SUMMARY

The techniques described in this article can be quite simply applied to dial size and height measurement without recourse to higher mathematics. Our aim, to keep errors below 10%, has been more than achieved on most occasions. Other variations on these techniques will be found that should simplify future measurements still further.



45°

Fig. 10. Using tripods to measure the height of the dial at Sandringham.

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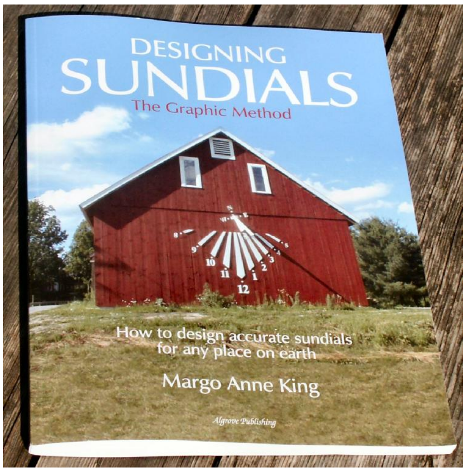
BOOK REVIEW

Designing Sundials: The Graphic Method by Margo Anne King, Algrove Publishing Ltd, Ontario, Canada, 2007, ISBN 978-1-897030-60-8. 9" ´ 11¾". Distributed by Lee Valley Tools (www.leevalley.com). Price $15.50 USD.

This new soft cover book of 121 pages is subtitled 'How to design accurate sundials for any place on earth'. The introduction to the book makes the statements that it 'is for the mathematically unsophisticated, deals with a wide variety of sundial types, provides all necessary technical information in plain language, gives the information necessary to make dials for anywhere on earth, and provides clear concise step-by-step design instructions'. The book has excellent clarity of printing with some 147 figures to assist the reader in the design processes, allied to the usual tables for the equation of time and longitude correction.



The book is divided into two parts. Part One covers the basics of dialling and deals with fundamental information such as the gnomon and systems of time keeping, basic types of sundial, and optional features such as adding special dates to the sundial furniture. The figures give the reader very clear information regarding why the angle of the gnomon relates to latitude, how different dial formats are derived, and a few diagrams to illustrate how the basic layout of the dial face may be manipulated artistically to give a different look to the dial. In the introduction the author makes the comment that 'no attempt has been made to deal with the endless possibilities for artistic design ..', and in this respect I feel that the book has missed a trick in that it seriously lacks any examples of dials to give the reader inspiration!

Part Two concentrates on the instructions for designing and laying out a dial in its various formats. It starts with General Instructions and then Specific Instructions for the range of dial formats from equatorial to polar. The Specific Instructions section separates dials into two groups: convergent hour line dials and parallel hour line dials. The first group covers the equatorial, armillary, horizontal, and vertical dials, the second group covers various formats of polar dial. Some 86 pages are given over to covering all of the necessary graphical instructions which are extremely comprehensive. However, it is this very comprehensiveness which throws up one of the difficulties with this book which is that it is overloaded with cross referencing of instructions making it tedious to use.

Following on from the Specific Instructions section are four appendices. Appendix A contains information for correcting for longitude, appendix B covers converting to Mean Time with tables for the equation of time and declination of the sun, appendix C deals with Daylight Saving Time, and appendix D deals with various methods for finding north. The book is completed with a glossary, acknowledgements and sources. The 'sources' section does not give any indication of what part or pages of each reference were used to guide the author, nor does it indicate where it was used in the book. Several Internet source addresses are also provided but without a descriptor attached which would help to provide the reader with an indication of the relevance of the reference. In addition, Internet addresses are notoriously unreliable inasmuch as they change without warning or disappear completely, thus a descriptor which can provide key words for future information searches is a necessity.

There are some disappointing issues with this book. In the section 'Drawing double-S hour lines on convergent-hour line dials' on page 22, no explanation is given for the eccentric circles in the design or their derivation, which would be very confusing for a beginner to the subject. Also on page 38, instruction 12 states 'you may use a batten for this if familiar with its use', but there is no explanation as to what a 'batten' is for a reader unused to such terminology. Of more significance however is that within weeks of the book's publication Roger Bailey, Secretary of the North American Sundial Society (NASS), found a significant error in the section on vertical declining dials which has resulted in the publisher issuing three pages of errata. However, the publisher has stated that the next printing will contain the revisions.

To summarise; this book is an 'instruction book', it is not a book to read or peruse for inspiration. It is a very comprehensive text for those diallists wishing to carry out all of their sundial design graphically. However, the book is a paradox. On one hand it states an intention to be a simple alternative to the trigonometric approach and yet on the other hand, as a result of the very comprehensive cross referencing, it is not the easiest book to use. It is not clear to the reviewer at whom this book is aimed. The very detailed instructions will probably be easily understood by a dialling enthusiast with experience, who doesn't really require a step-by-step graphical approach, but they will prove somewhat daunting for a newcomer to sundial design and construction. If the intention was to encourage the newcomer, afraid of mathematics, to the subject of dial design then it should really have contained some inspirational illustrations as well!

Martin Jenkins

Redacted

READERS' LETTERS

continued from page 111

even though the continuous metal depletion causes the patina level to sink. This retention does not occur on the black islands so the available patterns are fragmentary. Perhaps there is an optical technique that might allow more fragmentary lines to be retrieved. There are certainly more lines on the Lyme plate than I was able to decode. I had always assumed that the differential corrosion (green seas/ black islands) indicated a distribution of alpha and beta phase metal in the casting. If that is the case then the dial plate is most probably brass rather than bronze as I had first imagined before reading the article.

2) I have examined many P&G heliochronometers (HCs), which were claimed to be cast in gunmetal, and have removed the corrosion on several using a proprietary metal de-corroder. This is often necessary in order to achieve the required mechanical movements or to make the scales and divisions readable. My subjective view is that the early HCs are rarely destructively corroded, but the later Mk.2 version can be. After cleaning, the exposed metal is often speckled with small light and dark zones. I have assumed that this was evidence of differential response of the two phases to the same corroding agents, where metal lost is discoloured whilst metal protected stays bright. But the article explains that the two phases cannot exist in gunmetal. One possibility is that as tin became more expensive brass was substituted for gunmetal. Analysis of samples will provide the answer.

Graham Aldred
Disley, Cheshire

An Armillary Dial

This photograph of the novellist Edgar Wallace (1875-1932) was taken in May 1928 in the front garden of his residence 'Bella Vista', Bourne End, Bucks. Together with his wife and children Michael (11) and Penelope (5), it shows a rather fine armillary sphere.

Wallace was born in Greenwich and wrote over 170 novels. They were mainly thrillers and included the *Four Just Men* series. At the time of his death he was in Hollywood working on the script for *King Kong*.

An armillary of the same design, including the rather unusual 'bell-and-sphere' supporter, is currently in the Topiary Garden at Hever Castle, Kent (SRN 2178). The Hever dial is on a different, though equally elaborate, pedestal and is accompanied by a plaque suggesting that the dial dates from 1730. Are there two 'production' dials of this design from such a relatively early date or is it the same dial?

JD

DRILLING BRASS WITHOUT TEARS

TONY MOSS

Anyone who has had cause to drill holes in brass may have mixed feeling about doing so again. The main reason for this is that many of the copper alloys can be described as 'greedy metals' i.e. what is a 'drill' for iron and steel behaves like a coarse-pitch 'screw' when used on brass. This results in savage 'dig-ins' with the metal flying around with the drill or in some cases shooting up the drill shank if insecurely held. *ALWAYS* use a hand vice when drilling brass sheet. Delicate surfaces can be protected with masking tape.

A very simple modification to any standard drill will transform this process from hazardous to totally benign but does require two sets of drills with one set modified for brass only. (Fig. 1.) My brass drill box is painted yellow and, as each drill is modified for use, I replace it point down to distinguish it from the untreated ones. Special drills for brass can be obtained but are a rarity in tool shops. (Fig. 2.)

Fig. 1.


Fig. 2.

So how is this crucial transformation arrived at? Very simply by 'blunting' the drill's cutting edge to a vertical 'flat' so that it 'scrapes' rather than cuts. Brass usually prefers to be scraped in most cutting operations. Hold the drill in the vice with its cutting edge vertical (Fig. 3) and some ten strokes with a half-round diamond-coated file will do the job. (Fig. 4.) Begin with the largest drills in the box to develop the necessary skills. Diamond files are now commonly available and inexpensive.

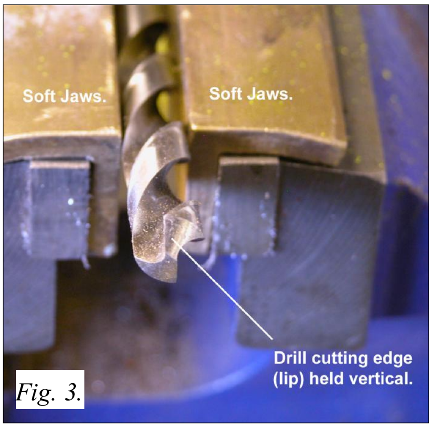


Fig. 3.

That's all there is to it. You will be amazed at the difference a few file strokes can make.

tony@lindisun.demon.co.uk

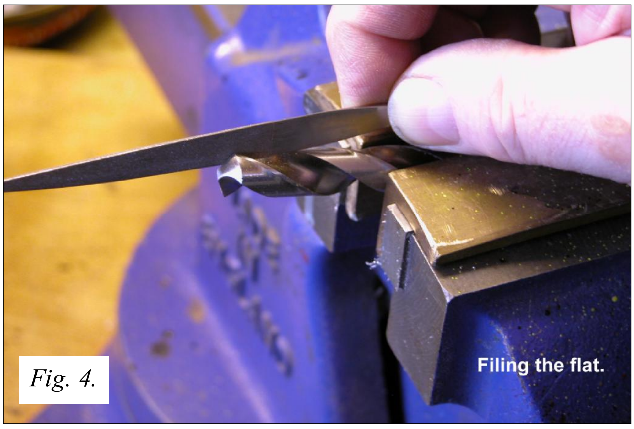


Fig. 4.

SUNDIAL SUPPORTERS REVISITED

ROGER BOWLING

Ten years ago I described[1] some life sized 18th century figures cast in lead and supporting sundials on their heads. I called these, not pedestals but 'sundials supporters'. They were the first mass-produced garden ornaments and six types were sold; two versions of a blackamoor, two versions of Father Time, an Indian, and one which has never yet been found, Hercules. The figures are attributed to the sculptor John Nost (Jan van Ost) or to his one time associate Andries Carpentiere, or to John Cheere who purchased John Nost's stock and carried on selling them using his moulds.

In the intervening years, nine more figures have come to light together with more information on the history of some of them. This article is acknowledgement and thanks to the several BSS members, and two non members, who have found, recorded and told me of them. Their names appear in this article so I thank them all and apologise for any missing. Three of the figures were originally wrongly identified, so I have included here the key characteristics of each. All are made of lead but most appear to have been painted so may look like marble if white or bronze if shiny brown.

The Old Blackamoor wears a feather skirt, kneels on his left knee and looks to the left. It is attributed to John Nost or John Cheere.

Fig. 1. The Old Blackamoor, Wiltshire.

1. Wiltshire. SRN 3802. (Fig. 1) Recorded by Chris Daniel. Painted a shiny brown so it appears to be bronze.

2. West Green House, Hartley Witney, Hants. SRN 4368. I first noticed this in a gardening magazine. It was also recorded by John Davis and Andrew James.

3. Dallam Tower, Milnthorpe, Cumbria. SRN 3978. Recorded by Robert Sylvester after information from Peter Cooper, a non-member. Dallam Tower was built in 1604 and the sundial appeared about 1720. The uncle of the present owner, in a moment of revelry, shot the figure and the gun is still in the house. The actual dial is corroded, but the figure is in good condition, apart from the bullet holes which were repaired in 1983.

4. Yale University, Connecticut, USA. Now lost. The blackamoor figure, representing America, was supposed to be a Red Indian which, with the Asian Indian and other figures never made, was part of a set believed to have been intended to represent the continents. An Indian figure was set up at Hampton Court in 1702, but two months later William III died and no more figures followed so that was the end of the project; anyhow that is the story.

   In 2001, Fred Sawyer bid in an internet auction for some postcards as one was of Elihu Yale's garden at Glemham Hall, Suffolk, with a sundial in the centre of the photograph. Elihu Yale was the founder of Yale University. Fred did not win the bid but later managed to purchase the card from the buyer. I had already listed in my first article a blackamoor figure with dial once at Glemham Hall, now lost. Fred sent me a photograph of about 1940 of the dial in a courtyard of Johnathan Edwards College, Yale, in excellent condition. This blackamoor must therefore have travelled with Elihu Yale back to his home, all the way to America, but now he is lost again and there appears no record of his present whereabouts.

5. Painswick Hall, Gloustershire. In 2007, three BSS members (John Davis, Harriet James and Tony Wood) visited Painswick Hall and met the owner. In the house was a painting, a landscape of the house and gardens in 1748 by Thomas Robins (fig. 2). They were very sharp eyed to notice on the painting the tiny figure of a blackamore with dial on the lawn. John photographed the painting and it shows what I think is the old blackamoor on a square tiered plinth of the correct shape. A different pedestal now occupies the plinth.

John Davis

Fig. 2. The gardens, Painswick Hall, 1748 (detail). Thomas Robins. The painted figure is less than 10mm high.

The Young Blackamoor wears a feather skirt, kneels on his right knee and looks to the right. His face is also younger but he does not look any happier. Attributed to Andries Carpentiere. Surprisingly, no more of these figures have appeared, either new ones or records of lost ones. There must have been far fewer produced than the old version, despite the fact that the old version seems to have been very popular: maybe Andries Carpentiere charged more.

B.G. Kirkman

Fig. 3. The Indian, Pine Lodge Gardens, Cornwall.

The Indian. Wears a loin cloth and turban. Attributed to John Nost

1. Pine Lodge Gardens, St. Austell, Cornwall. SRN 5145, (fig. 3). Recorded by B.G. Kirkman, a non-member. This is only the second Indian figure supporting a dial to appear, although there is a third at Melbourne Hall, Derbys. supporting a salver and urn.

Fig. 4. Father Time, Type 1, Flaxley Abbey, Gloucs.

Tony Wood

Father Time 1 has wings and a beard, and holds the dial with both hands. Attributed to Nost and Cheere.

1. Flaxley Abbey, Gloustershire. SRN 3181, (fig. 4). Recorded by Tony Wood. The only other figure like this is at Blair Castle, Tayside.

Father Time 2 has wings and a beard, and holds the dial with one hand. Attributed to Nost and Cheere. Ian Butson has provided more information about this figure. I previously noted it from a London saleroom catalogue of 1986 which stated it to be from St Osyth Priory, Essex. Ian has found a better photograph from a small book, *Essex Curiosities* by Derek Johnson, and another catalogue, the four day sale of the contents of the Priory in 1920. This lists three dials; one "A fine XVII cent. cast lead figure of Time supporting a sundial, 3' 6" high on a square stone base". In fact it is 18th century and is life size. Clearly, in 1920 the figure did not sell or the new owners decided to keep it at the Priory until 1986. Its present location is still not known.

The above two versions of Father Time are lead figures usually attributed to John Nost, not to be confused with the three stone figures also attributed to him which I described in a later article, which also included versions by other sculptors.[2] Illustrations of some of these can also be found in another article.[3] Those members who attended the BSS Conference in Cambridge may have seen the fine figure of Father Time in the gardens at Anglesey Abbey but, for those who didn't, a photo by David Le Conte appears on p.87 of the June *Bulletin*.

A Father Time figure in stone. Fawley Court, Henley on Thames, Oxon. (fig. 5). Recorded by Ian Butson. I mentioned the figure in the second of my articles, a poor picture of which I found in *Garden Ornament* by Gertrude Jekyll, 1918. There was no attribution or location given. I did not

Ian Butson

Fig. 5. 'Would you want this man in your garden?', Father Time, Fawley Court, Henley, Oxon.

provide a photograph as I had only a very poor print. I noted that the figure was strange, nothing like the others, which show a stern Father Time looking down at the dial on a plinth; this man is evil, cadaverous, cringing and seemingly insisting that he shows you the time. I have not had to alter my opinion. After 90 years he has been rediscovered by Ian at Fawley Court, Near Henley, Oxon. The dial is a poor, broken, modern thing. There is no record of where the figure was before its present location or how long it has been at Fawley Court.

Fawley Court was designed by Christopher Wren and built in 1683. Grinling Gibbons and James Wyatt both had a hand in the decoration of the house and 'Capability' Brown in the design of the park. In 1953 it was bought by the Polish Congregation of Marian Fathers and it now houses a large collection and exhibition of Polish history. It is open to the public on certain days. The Fathers have no knowledge of the sundial's history; presumably it was there in 1953.

In the ten years since my first articles, five new figures have been found. Two further figures, the present locations not known, have been noted and one of these may be in America. A little more information has come to light on one figure that should still be in the country and a stone Father Time dial has reappeared after 90 years. The total of extant lead figures now stands at fourteen but two of these do not carry sundials. There were in 1997 fifteen lost dials, with past locations known. Of these, one reappeared in 1940, at Yale University, only to become lost again. There has been no sighting of the lost Hercules figure even though he existed up to about 1950. Of the life-size or larger stone or Coade stone Father Time figures, I listed seven. The whereabouts of two were unknown, but one has reappeared. It is satisfying when one's small effort bear fruit.

ACKNOWLEDGEMENTS

To Ian Butson, Chris Daniel, B.G. Kirkman, John Davis and Tony Wood for the photographs and Patrick Powers for information from the records.

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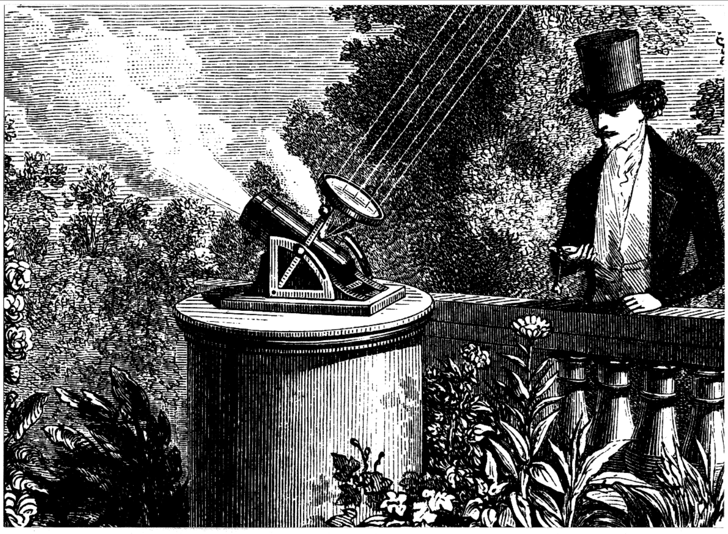

Following on from Piers Nicholson's article on Noon Cannons on pp. 9-10 of this issue, Chris Daniel has supplied a picture of a solar cannon being fired at the Palais Royale Gardens in Paris. It is taken from the English edition of M. Arago's *L'Astronomie Populaire* (Popular Astronomy), c.1870.

Since the gun fires (theoretically) at solar noon, we hope that the French gentleman has already consulted an Equation of Time table before checking the accuracy of his watch!

LINES OF DECLINATION AND TWO SEVENTEENTH CENTURY DIALS

MICHAEL LOWNE and JOHN DAVIS

INTRODUCTION

Of the many lines of 'furniture' to be found on sundials, probably the most common ones are 'lines of declination'. As the sun moves north or south throughout the year its position in declination can be indicated by the shadow of a small index (called the nodus) falling on the appropriate line. These lines can be identified either by declination or by date since declination correlates with the calendar. In the former case, a simple arrangement is to indicate the position when the sun enters a zodiacal sign: often these are reduced to only the solstices (signs of Cancer and Capricorn) and the equinoxes (Aries when the sun is northbound, Libra when southbound). At present, the sun's declinations at entry to each sign are Cancer +23.44°, Gemini and Leo +20.15°, Taurus and Virgo +11.47°, Aries and Libra 0°, Scorpio and Pisces -11.47°, Sagittarius and Aquarius -20.15° and Capricorn -23.44°. Dates can be chosen to represent occasions such as anniversaries: birthdays, weddings….. However, such date lines are not unique to one date, the nodus shadow will fall on a line twice in the course of a year (except at the solstices). For example, lines for both May 8 and August 5 will catch the shadow when the sun's declination is +16º. Declination lines are uncommon on horizontal dials, although present on several very early examples.

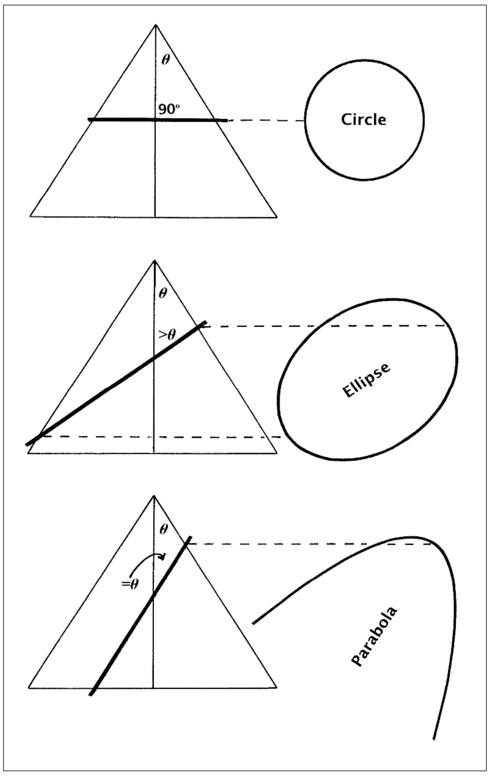

Fig. 1. Conic sections: circle, ellipse and parabola.

CONIC SECTIONS

It is well known that a declination line is a section of a cone called a hyperbola which is represented by the edges of the cone revealed by the section. As shown in Fig. 1, other sections are possible. If the cone is cut perpendicular to the axis a circle is produced. A cut which meets the axis at an angle greater than the cone semi-angle (θ) gives an ellipse, and the nearer the approach of the section to θ the more elongated the ellipse will be. A parabola is given by a cut which meets the axis at angle θ. The circle and ellipse are closed curves since the section cuts across the cone: the parabola is an open curve; the section does not meet the opposite edge.

Fig. 2 shows the case of the hyperbola. The cut is taken meeting the axis at an angle less than θ. Suppose now that an identical cone is placed vertex to vertex and on the same axis: the section will also cut this second cone as shown, producing two branches. Perhaps rather surprisingly, the two hyperbolae produced are duplicates, the one being the reflection of the other in a line midway between them and perpendicular to their centre-lines. In this way hyperbolae have four-fold symmetry and again are open curves. The

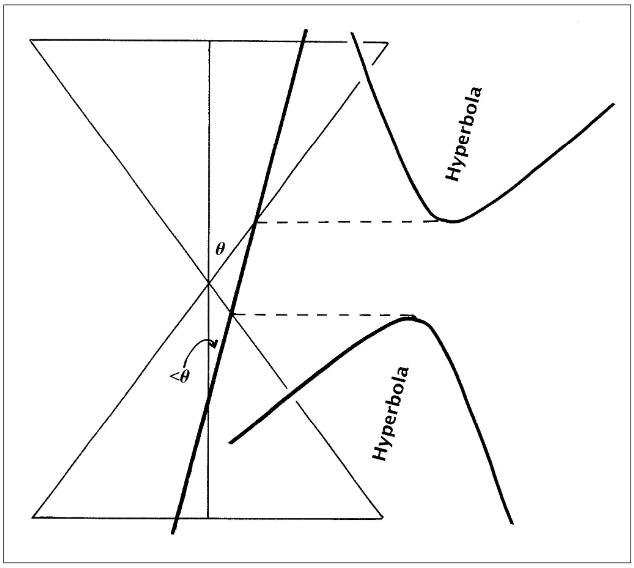

Fig. 2. Conic sections: the two branches of a hyperbola.

parabola is a unique curve and represents the boundary between the infinity of ellipses on one side and of hyperbolae on the other.

The Application Of Conic Sections To Sundials

This article concentrates mainly on horizontal dials. Leaving aside for the moment the cases of circles, ellipses and the parabola, first consider how hyperbolae arise on such dials. Fig. 3 shows a section of a horizontal dial along the meridian and two declinations of the sun throwing shadows of the nodus on the dial plate. As the sun moves across the sky during the course of a day the shadow will trace out a part-cone which is intercepted by the dial. The axis of the cone is the style and its semi-angle θ is (90º-δ) where δ (the sun's declination) is taken unsigned. The angle between the style and the dial plate is of course the latitude φ and if φ is less than θ the arc of the intersection of the cone and the plate will be a hyperbola. If, as shown in Fig. 3, the two declinations are equal but of opposite sign the values of θ of the two shadow cones will be identical. As they meet vertex to vertex at the nodus and have a common axis in the style the conditions of Fig. 2 will be met and the hyperbolae produced will be mirror images. Although it is of course well known that declination curves are hyperbolae, it is perhaps not so well known that arcs of equal but opposite declination duplicate each other in this way. This may not be obvious on an actual dial as the diverging hour lines will tend to disguise it. In Fig. 3 the line passing through the nodus at a right angle to the style is the shadow at the equinoxes which projects onto the dial as a straight line perpendicular to the meridian. The declination arcs are symmetrical about a perpendicular through the mid-point between them, but this is not the equinoctial line.

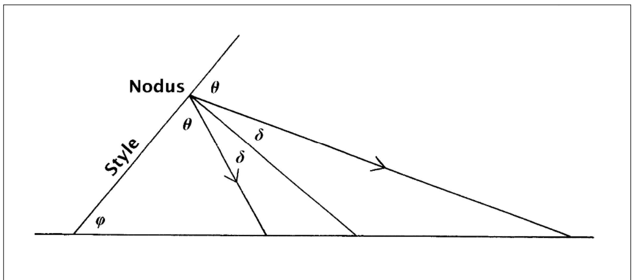

Fig. 3. The meridian shadows cast by the nodus.

Declination lines will appear as other conic sections under certain conditions. For an equatorial dial, the section of the cones of declination by the dial plane is orthogonal to the cone axis and the lines are arcs of circles. For dials at high latitudes, if (90-δ) is equal to the latitude the line is a parabola, and if less than the latitude it will be an ellipse or part of an ellipse.

There can be a choice in the type of the nodus: generally it takes the from of a small nick in the style but is sometimes made as a short cross-piece. The nodus height above the dial plane is also a matter of choice: the greater the height the wider the separation of the declination lines will be but the coverage in time will be lessened.

Delineating The Declination Lines

Methods of inserting lines of declination can be graphical, mechanical or by calculation. Graphical methods are given by Mayall[1] and by Waugh[2] (credited to William Leybourn[3]). A difficulty with such methods is that the construction lines can meet at an acute angle with the likelihood of errors unless very carefully drawn. Trigons are (or were) extensively used: in its simplest form a trigon is a mechanical device with an axis which replaces the gnomon and can be set to the appropriate latitude and declination to sweep out the lines on the dial face.[4-7]

Various methods of calculating the lines have been proposed and in these days of computers (or even pocket calculators) calculation must surely be the preferred method.[2,8-10] Some methods are based on conversion of altitude and azimuth to rectangular coordinates on the dial plane, but the coordinates can be calculated directly from latitude, declination and hour-angle. Here we consider the gnomonic projection on which plane dials with a polar gnomon are based. The nodus is taken to be at the centre of the hemisphere of the sky and positions are projected through the nodus on to the dial plane. The nodus lies within and at the centre of circles which divide the sphere equally (great circles) and project as straight lines. All other circles whose planes do not pass through the nodus (small circles) project as conic sections. In the case of a horizontal dial, azimuths of the sun are reproduced as angles from the sub-nodus relative to the sub-style and are at distances from the sub-nodus proportional to the cotangent of the altitude.

Several formulae for the gnomonic projection on a horizontal dial are possible. One of the most straightforward is:

$$x = n\{\cos P.\tan h/\cos(P\text{-}\varphi)\}, \quad y = n\tan(P\text{-}\varphi)$$

where

$$P = \tan^{-1}(\tan\delta/\cos h)$$

n is the vertical distance of the nodus above the dial plane, φ is the latitude, δ the declination, and h the hour-angle. The expression for P will fail when h=90º ($\cos h$ = 0). In this case take:

$$x = n/(\sin\varphi\tan\delta), \quad y = n/\tan\varphi$$

The coordinates x and y are measured from the sub-nodus as origin, x orthogonal to the noon line and y in the noon line. The signs of y are such that positive values refer to directions to the north of the sub-nodus and negative values to the south. The gnomonic projection reverses these directions: positive y is plotted towards the south of the dial-plate and negative y to the north. Positions in x are symmetrical either side of the meridian and need only be calculated for one side. Points found for integral hours should lie on the appropriate pre-drawn hour lines, but it would be advantageous to calculate positions at closer intervals to facilitate drawing the curves.

The formulae can be adapted to dials in orientations other than horizontal. We note that a vertical direct south dial is effectively a horizontal dial for a latitude (φ') 90º away from the desired location (for example -38º for a dial in +52º latitude) and by putting this effective latitude in the formulae the declination lines can be derived. For declining dials the standard dial formulae will give the required values: the gnomon angle (usually called the style height) is φ' and just as with the normal hour lines the hour positions are taken as (*h-DL*) where *DL* is the difference of longitude. Then in the formulae use φ' and (*h-DL*). The resulting *x,y* coordinates are referred to an origin at the sub-nodus. However, the axes are aligned not to the dial's noon line but to the sub-style line (which is the noon line at the longitude of *DL*).

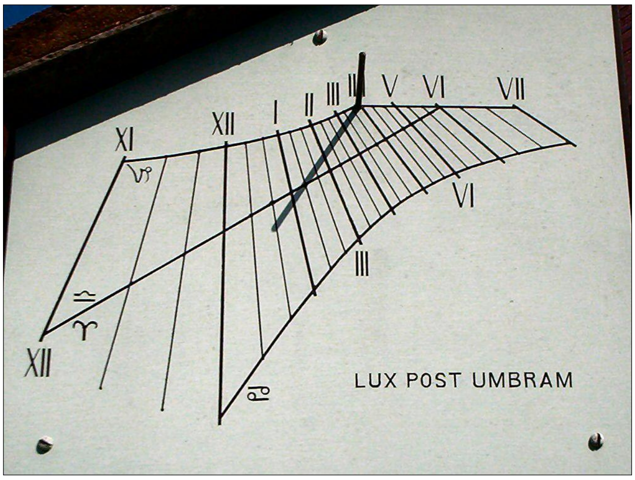

Fig. 4. A pin gnomon dial with declination lines.

Dials which consist of a pin gnomon with its apex as the nodus can be delineated by the gnomonic projection formulae without separate calculation of the time lines. The vertical declining dial shown in Fig. 4 was drawn in this way. The latitude is 50·85º and the declining angle is 52º west of the meridian: the points for the solstices and equinoctial line were calculated and plotted, then joined with the curves for the solsticial lines and straight lines for the equinoctial and time lines. The horizon is represented by the horizontal straight line which passes through the sub-nodus and the intersection of the 6pm and equinoctial lines.

TWO SEVENTEENTH CENTURY DIALS BY ISAAC SYMMES

Declination lines have appeared on English horizontal dials since the very earliest days of dialmaking, although they rather went out of favour on London-made dials after about 1630. Two interesting examples, c.1600, are by the London

Fig. 5. Dial plate of the Symmes dial at the Science Museum. The right hand side of the plate is covered with a transparent overlay showing the correct delineation.

clockmaker Isaac Symmes. (See the appendix for biographical details of Symmes.) The two sundials are in museum collections, one dated 1609 in the Science Museum in London and the other in the Oxford Museum of the History of Science. The two dials are different sizes: the Science Museum dial is 310 mm square with cut-off corners, the Oxford dial is 180 mm square. The Science Museum example is in rather an eroded condition: a photograph of the dial plate is given in Fig. 5, shown with a transparent overlay to assist in the interpretation. The Oxford dial is better preserved and is shown in Fig. 6. The dial plate carries the maker's signature: "Isaack Symmes Gouldsmith and Clockmaker". (The date of 1755 and the initials R + I are

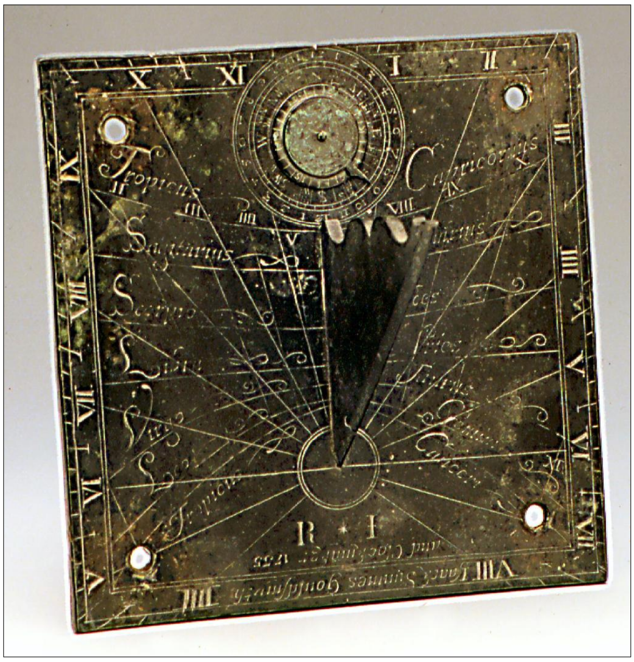

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Fig. 6. The Symmes dial at Museum of the History of Science, Oxford .

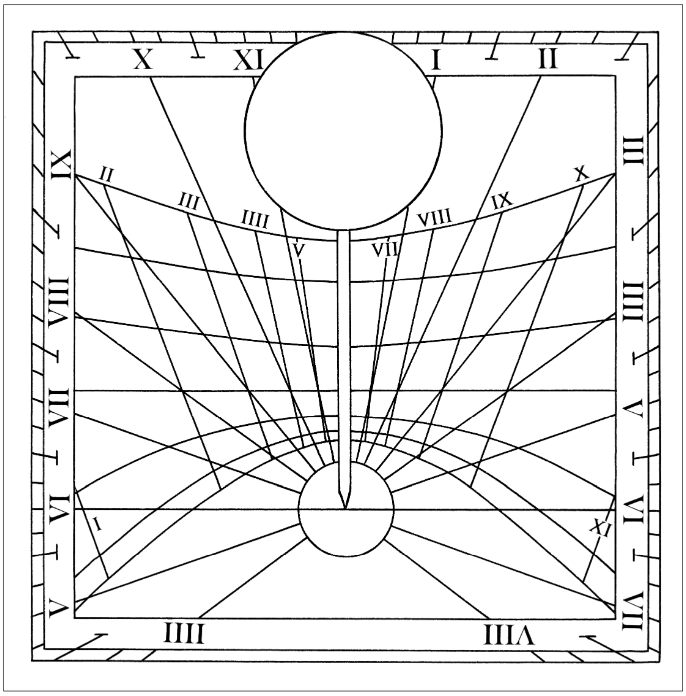

Fig. 7. Drawing of the dial plate of the Oxford dial.

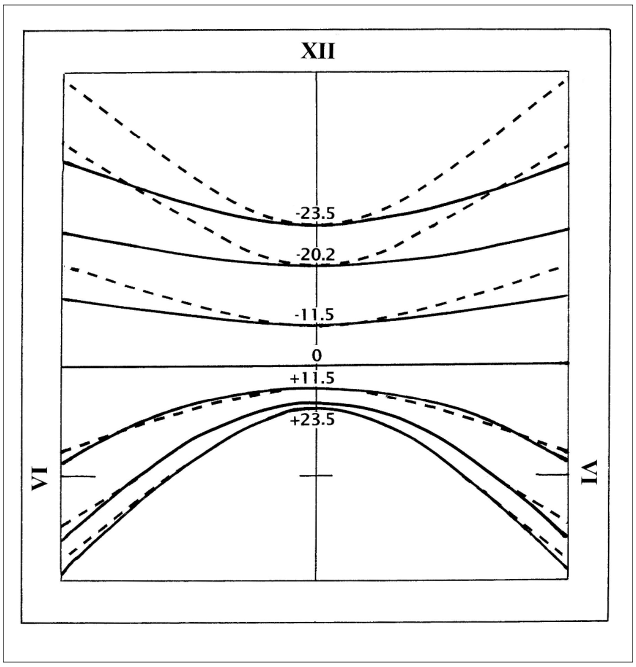

Fig. 8. The incorrect positions of the declination lines on the Oxford dial. Dotted lines show correct shapes, solid lines are the lines on the dial.

apparently later additions.) Lines of declination are given for the entry of the sun into each zodiacal sign, identified in elaborate script. There are also‘seasonal hours’ and a lunar volvelle for time-telling by the moon. Detailed measurement of the angles of the hour lines shows that the Oxford dial is made for a latitude of 52·5º±0·6º. It is also possible to analyse the latitude for which the declination arcs are drawn by measurement of their intersections with the meridian line: again the best fit is obtained at latitude 52·5º with line error ±0·4mm.

For additional clarity, a drawing of the dial plate is shown in Fig. 7 with the lettering and volvelle omitted, but showing the seasonal hours and the declination lines. More about the seasonal hours and the volvelle later, but first look at the declination lines. It is obvious that they do not conform to the necessary conditions outlined above: the arcs for zodiacal signs south of the equinoctial line (Scorpio-Pisces, Sagittarius-Aquarius and Capricornus) are much less curved than the corresponding ones to the north (Virgo-Taurus, Leo-Gemini and Cancer).

Fig. 8 is a drawing of the dial plate showing just the declination lines of the Oxford dial. The arcs as they appear on the dial are solid lines and their correct positions are broken lines. The lines for northern declinations are reasonably in agreement with their correct places, being if anything rather too strongly curved. Although the southern ones are correct on the noon line they depart from their true positions at hour angles away from the meridian. In fact the southern lines are of approximately the correct shape for declinations less than the true ones and are shifted bodily along the noon line so that their meridian positions are correct. Without knowing how the lines were drawn it is not possible to say with any certainty how the error has occurred. It is unlikely that the lines were derived from calculations: at this date they were probably drawn either by some graphical method, from tables, or by the use of a trigon.

The Science Museum dial has similar errors in the declination lines and there is another anomaly in that the latitude for which the hour lines are drawn does not agree with the meridional positions of the declination lines. The hour lines are for latitude 50·0º±0·2º but the best fit for the latitude of the declination lines is 51·5º with line error ±0·2 mm. The gnomon angle is 50·8º ±0·2º, neatly between the two.

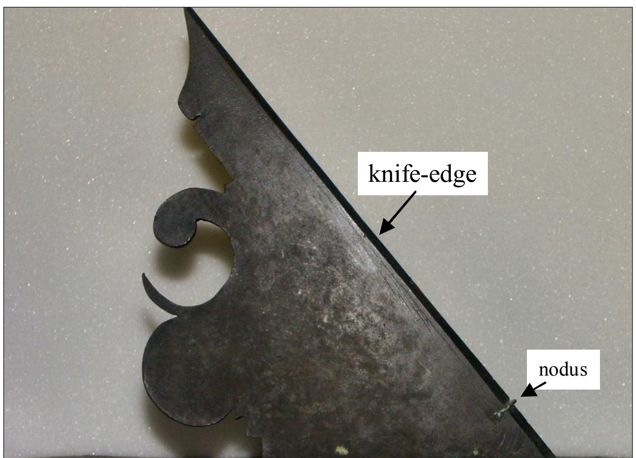

Fig. 9. The gnomon of the Science Museum dial. The chamfered style and the nodus are indicated.

Neither of the dials has a noon gap to accommodate the width of the gnomon. Instead, the style is chamfered to a central edge which will lead to inaccuracies in the time readings near noon, as the shadows will be cast by the shoulders of the chamfer, not the centre. This is not important in the case of the Oxford dial, the hour lines in this area are covered by the lunar volvelle.

The ornate gnomon of the Science Museum dial is shown in Fig. 9. The nodus and the chamfered style are depicted.

The Seasonal Hour Lines

Running between the declination lines for the solstices on the two dials are lines identified with Roman numerals I-V and VII-XI (the meridian line is VI). These are seasonal hours which divide the sunrise to sunset interval into 12 equal parts. The lengths of the 'hours' on any particular day thus depend on the length of time the sun is above the horizon. Since in the latitude of these two dials the sun is up for about 8 hours in midwinter and about 16 hours at midsummer, the length of a seasonal hour can vary from about 40 minutes (of ordinary time) to about 80 minutes.

To delineate the seasonal hours it is necessary only to derive their hour points on the declination lines for the solstices and join them with a straight line. As a check, the line should pass through the intersections of the dial hour lines with the equatorial line: at the time of the equinoxes the sun is up for twelve hours and a seasonal hour is the same length as an equal hour of solar time. The seasonal hours for intermediate declinations do not quite lie on a straight line[11] but their departure from straightness is only a minute or two and is not significant on the scale of the dial face. The method involves first finding the actual hour-angles of the sun at the seasonal hours. These are then plotted at the appropriate points on the dial time calibrations and on the declination lines. The hour-angles could be found by taking the sunrise-sunset interval (the diurnal arc of the sun) from the times given in almanacs divided into twelfths. Since the gnomonic projection does not show the horizon, the times cannot be found from the dial but could be found from a stereographic projection, which includes the horizon. Rohr[6] gives the hour-angle of the sun at sunrise for the solstices over a range of latitudes. These values are also the semi-diurnal arcs, the intervals between sunrise or sunset and the sun's meridian passage. For any declination, the semi-diurnal arc can be derived from

$$\cos^{-1}(\sin\delta/\cos\varphi)$$

and then divided into sixths. Then these points can be plotted as before, or the gnomonic formulae given earlier can be used to derive their x, y coordinates.

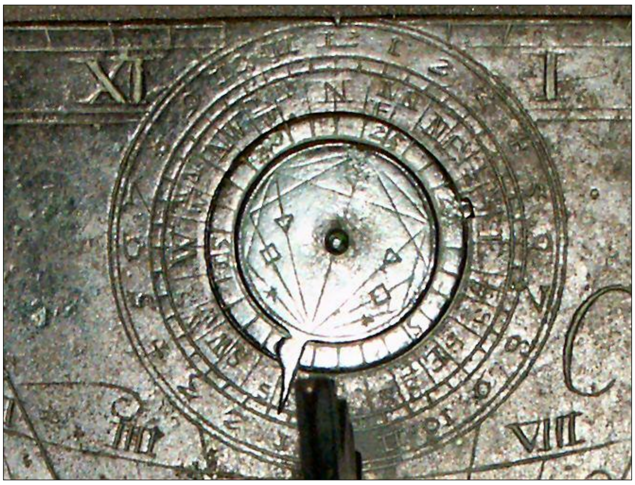

Fig. 10. The lunar volvelle of the Oxford dial.

The Lunar Volvelle

A picture of the lunar volvelle on the Oxford dial is shown in Fig. 10. The operation of this uses the compass bearing of the moon combined with the age of the moon to tell the solar time. From the outer ring inwards, the first shows hours in the 2×12 hours system, the next has a compass rose in 32 points (only alternate ones are labelled). The inner rings rotate independently, the outer one of the two carries the age of the moon from new, 1 to 29 days labelled at 5-day intervals. The space between 29 and day 1 is wider than others to allow for a 29½ day lunation. A small projection next to 29 is an index for setting the compass direction of the moon. The inner ring carries a large index with a straight edge and has symbols indicating some phases of the moon from which the age can be determined approximately if this is unknown. New Moon and Full Moon are adjacent to and opposite the pointer. First Quarter and Last Quarter are shown by the lines through the small squares where these meet the edge of the ring. The other lines with small crossed lines or triangles are the occasions when the moon appears to be one-quarter and three-quarters illuminated.

To use the volvelle, the straight edge of the larger index is set to the moon's age (the setting is valid for any one night) and then both circles are rotated together to set the smaller index to the compass direction of the moon. The time is then read on the outer circle from the point of the larger index.

Apart from the intrinsic inaccuracies in finding time from the moon,[12] this instrument will introduce further errors. The time is found from the azimuth of the moon measured in the plane of the horizon, but should be derived from the hour-angle, in the plane of the equator. With the moon at a high declination and in the eastern or western sky, the additional error could be an hour or more.

The volvelle on the Science Museum is badly eroded and the inner circle is missing, but it evidently operated in the same way, with the addition of a pictorial means of depicting the phase appearance of the moon at any age. This could be used to derive an unknown age or (perhaps more likely) to show the appearance of the moon at any age as a guide to its brightness, to assist night-time travellers.

A METHOD OF DRAWING DECLINATION LINES

Should any diallist wish to draw the declination lines, the method shown in Fig. 11 may be found preferable to the Leybourn method. It is based on the geometric properties of the double hyperbola using the major axis, the linear eccentricity and the focal points.

1. On a horizontal line MM' which represents the dial substyle, draw a perpendicular equal to the nodus height *n*. N is the nodus.
2. Draw the style through N at the latitude angle φ.
3. Draw NE perpendicular to the style and draw a line from E perpendicular to MM'. This is the dial declination line for the equator at δ=0º.
4. From N draw two equal but opposite declination angles $+\delta$ and $-\delta$ to meet MM' in A and B. AB is the major axis.
5. Find the mid-point of AB at O.
6. Draw a line at the latitude angle from O to meet NB at D.
7. Measure the distance ND. (Alternatively, measure NA and NB and take the mean length.) The quantity so found is the linear eccentricity *e*.
8. On MM' measure off the distance *e* on either side of O to give points F_1 and F_2. These are the foci of the hyperbolae.
9. From F_1 draw arcs of circles at arbitrary radii r_1, r_2, r_3……
10. From F_2 draw arcs of radii r_1+AB, r_2+AB, r_3+AB…. to intersect the corresponding arcs from F_1. For clarity, only four intersections on each arc (more would be preferable) on one side of MM' are shown on Fig. 11. Those on the other side of MM' can be drawn at the same time.
11. Joint the points so found with a smooth curve passing through A. This is one branch of the hyperbola. From the properties, at any point P on the curve the distance from the further focus is equal to that from the nearer focus plus the major axis: $PF_2=PF_1+AB$.
12. Repeat the construction for the other branch of the hyperbola through B: $PF_1=PF_2+AB$.
13. Repeat from step 4 for other declination pairs as required.

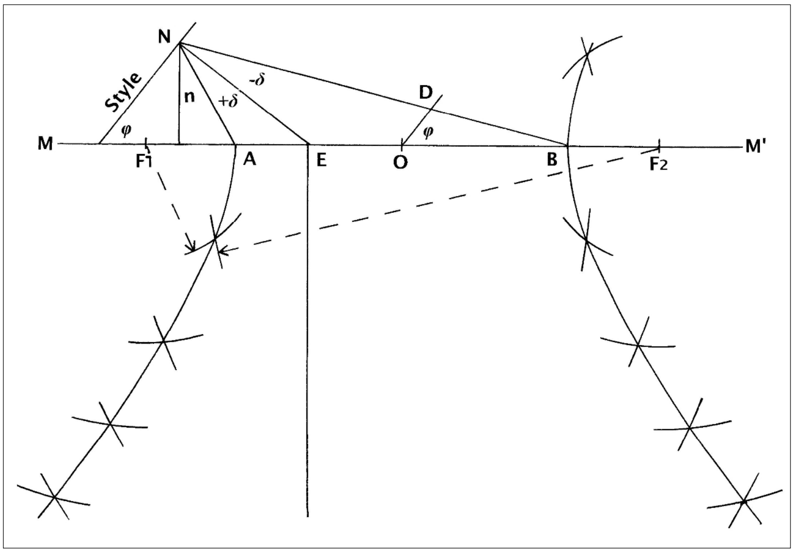

Fig. 11. Delineating the declination lines.

ACKNOWLEDGEMENTS

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APPENDIX – ISAAC SYMMES

Isaac Symmes (born c. 1580, d. November 1622) was a London clockmaker.[13-17] His name is sometimes written Isaack Simmes or countless other variants, possibly because he is said to have been of French descent[15,17] although his father is described on his apprenticeship indenture as "Roger Symes clarke of London". He was apprenticed to John Humphrey of the Goldsmiths' Company in 1596, later being turned over to Richard Lytler and being made free in January 1604. He married Emma Howe in March the same year. They lived first in the area of St Botolph, Aldgate, and, after 1612, at Houndsditch just outside the City. Judging by his will,[18] he became quite prosperous and was a well-regarded member of the community, leaving a number of gifts to the workers and poor of the district.

Just before his death he was one of the signatories to an appeal to King James I for the formation of a separate clockmakers' guild in an effort to keep out 'foreign' workers: the appeal was unsuccessful at the time with the Clockmakers' Company not being granted its charter until 1631.

Symmes is best known as a watch maker though his will indicates that he also made clocks. A particularly fine verge watch with alarm has been described by Thompson.[14] It shows that Symmes was inventive as well as a good craftsman. The two dials with declination lines and moon volvelles studied in this paper are described by Turner[13] who also shows a simpler dial dated 1610 in a private collection. In addition, Loomes[17] found another simple dial, unfortunately with an inappropriate replacement gnomon, which is now in the Clockmakers' Museum, Guildhall. A fifth dial, dated 1614, is said to be at Ridlington, Rutland.[19] Five watches signed by Symmes are known. Some exhibit very fine engraving and gilt-brass plates, as might be expected from someone who trained as a goldsmith; indeed, Symmes describes himself on his Science Museum and Oxford dials as “Gouldsmyth & Clockmaker at London”.

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SOLAR and LUNAR DATA

Data kindly supplied by Fiona Vincent.

For the Equation of Time, subtract 12h from the transit time.

	September			October			November			
Day	Declination	Transit	Moon	Declination	Transit	Moon	Declination	Transit	Moon	Day
1	8° 18' 56"	12:00:06		-3°08'47"	11:49:46		-14°23'40"	11:43:36	LQ 21:18	1
2	7°57'07"	11:59:47		-3°32'02"	11:49:27		-14°42'48"	11:43:34		2
3	7°35'12"	11:59:27		-3°55'15"	11:49:08	LQ 10:06	-15°01'42"	11:43:34		3
4	7°13'08"	11:59:08	LQ 02:32	-4°18'26"	11:48:49		-15°20'21"	11:43:34		4
5	6°50'58"	11:58:48		-4°41'33"	11:48:31		-15°38'45"	11:43:35		5
6	6°28'40"	11:58:28		-5°04'37"	11:48:13		-15°56'53"	11:43:37		6
7	6°06'16"	11:58:07		-5°27'38"	11:47:55		-16°14'46"	11:43:40		7
8	5°43'46"	11:57:47		-5°50'34"	11:47:38		-16°32'22"	11:43:43		8
9	5°21'10"	11:57:26		-6°13'26"	11:47:21		-16°49'41"	11:43:48	N 23:03	9
10	4°58'29"	11:57:05		-6°36'13"	11:47:05		-17°06'44"	11:43:53		10
11	4°35'42"	11:56:44	N 12:44	-6°58'54"	11:46:49	N 05:01	-17°23'28"	11:43:59		11
12	4°12'51"	11:56:23		-7°21'30"	11:46:34		-17°39'55"	11:44:06		12
13	3°49'56"	11:56:02		-7°44'00"	11:46:19		-17°56'04"	11:44:14		13
14	3°26'56"	11:55:41		-8°06'24"	11:46:05		-18°11'54"	11:44:22		14
15	3°03'53"	11:55:19		-8°28'40"	11:45:51		-18°27'24"	11:44:32		15
16	2°40'46"	11:54:58		-8°50'50"	11:45:38		-18°42'35"	11:44:42		16
17	2°17'36"	11:54:36		-9°12'52"	11:45:25		-18°57'26"	11:44:53	FQ 22:33	17
18	1°54'24"	11:54:15		-9°34'45"	11:45:13		-19°11'57"	11:45:05		18
19	1°31'09"	11:53:54	FQ 16:48	-9°56'31"	11:45:02	FQ 08:33	-19°26'07"	11:45:18		19
20	1°07'52"	11:53:32		-10°18'07"	11:44:51		-19°39'55"	11:45:32		20
21	0°44'34"	11:53:11		-10°39'34"	11:44:41		-19°53'23"	11:45:47		21
22	0°21'15"	11:52:50		-11°00'52"	11:44:31		-20°06'28"	11:46:02		22
23	-0°02'05"	11:52:29		-11°22'00"	11:44:23		-20°19'12"	11:46:18		23
24	-0°25'26"	11:52:08		-11°42'57"	11:44:14		-20°31'33"	11:46:35	F 14:30	24
25	-0°48'48"	11:51:47		-12°03'44"	11:44:07		-20°43'32"	11:46:52		25
26	-1°12'09"	11:51:26	F 19:45	-12°24'19"	11:44:00	F 04:52	-20°55'07"	11:47:11		26
27	-1°35'31"	11:51:06		-12°44'43"	11:43:54		-21°06'19"	11:47:30		27
28	-1°58'51"	11:50:45		-13°04'56"	11:43:49		-21°17'07"	11:47:50		28
29	-2°22'11"	11:50:25		-13°24'56"	11:43:44		-21°27'31"	11:48:10		29
30	-2°45'30"	11:50:05		-13°44'44"	11:43:41		-21°37'31"	11:48:32		30
31				-14°04'19"	11:43:38					31

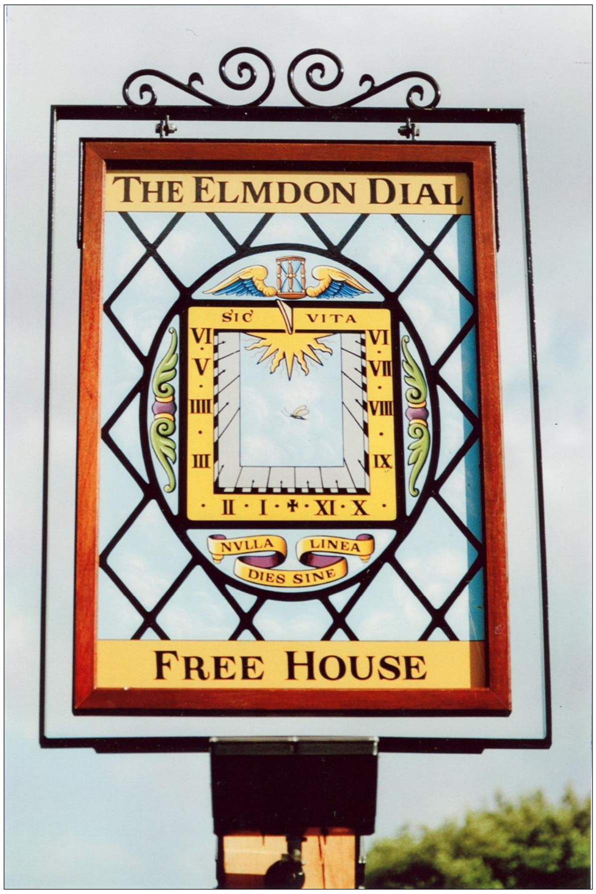
Autumn equinox: September 23rd, 09:51

BSS PHOTOGRAPHIC COMPETITION 2006

Redacted

BAT-Galliu Polar - *Shaul Adam*

Umbrae Sumus - John Lester

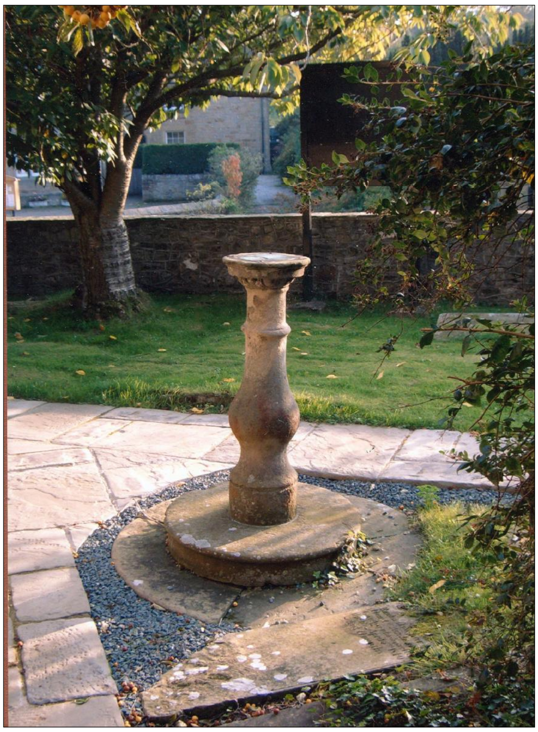


Time Gentlemen Please - *Ian Butson*

Dial with latitude, Cat with attitude - *Mike Shaw*

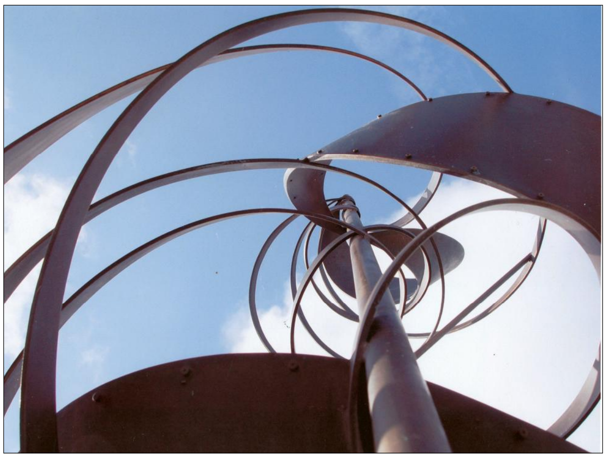
Two projects for the third Millennium - *Piers Nicholson*

Reflexions on Time - John Davis



Lost Time - *Irene Brightmer*

Frosty Dial - *David Hawker*



Wild Time: in a Gloucestershire garden
George White

Celestial Kitchen - *David Westwood*

DECLINATION LINES DETAILED

TONY BELK

INTRODUCTION

Declination lines on planar sundials can be drawn using the formulae giving the x and y co-ordinates from the sub-nodal point on the dial face and requiring the sun's altitude and azimuth to be calculated for each point.[1] This is both complicated and time consuming and does not reveal the relationship between the style height, sub-style line and declination lines.

Earlier work of mine describing the use of direction cosines in the delineation of planar sundials[2] led to the production of a formula giving the distance R of a declination line from the origin of the dial along an hour line in terms of style height SH, the hour angle h_0 and L the distance of the nodus from the origin along the style.

$$R = \frac{L\cos\delta}{\sin(E+\delta)} \qquad (1)$$

where

$$\tan E = \frac{\cos h_0}{\tan SH} \qquad (2)$$

E is the angle between the sun's direction at equinox and the hour line in the hour plane.[2]

Waugh[3] described a graphical method attributed to Leybourn[4] and Lennox-Boyd[5] offered a formula based on this construction in terms of SH and X, the hour line angle, which leads to the same value of E, which he refers to as t.

I have developed my formula, eliminating E, to allow declination lines to be drawn using polar co-ordinates knowing only the style height SH and the hour angle h_0. I have also developed Leybourn's method, producing a protractor to enable declination lines to be drawn simply for any style height and declination angle. Declination lines on planar dials are hyperbolae and I show that these can be plotted with cartesian co-ordinates using only the style height SH and the declination δ. This form also allows previously delineated dial faces to be simply checked for accuracy and their style height and nodus distance determined.

POLAR CO-ORDINATE FORM

The most important simplifying feature is the recognition that the position and shape of declination lines with respect to the origin and the sub-style line on any planar dial depend <u>only</u> on the style height of the dial and the distance L of the nodus from the origin along the sloping style. Inspection of any planar dial with declination lines shows that they are symmetrical about the sub-style line.

Fig. 1 illustrates this for a horizontal, a vertical south facing and a vertical declining dial all reading local apparent time (L.A.T.). They are for different latitudes but all have the same style height and the same pattern of declination lines about the sub-style line. They have different labels on their hour lines depending on their orientation and time zone, but the relationship between the origin, the intersection of the sub-style line with the declination lines and the shape of the curves depend only on the style height SH.

The position of every point on a declination line is given by the polar co-ordinates R and X_0, given by the formulae:-

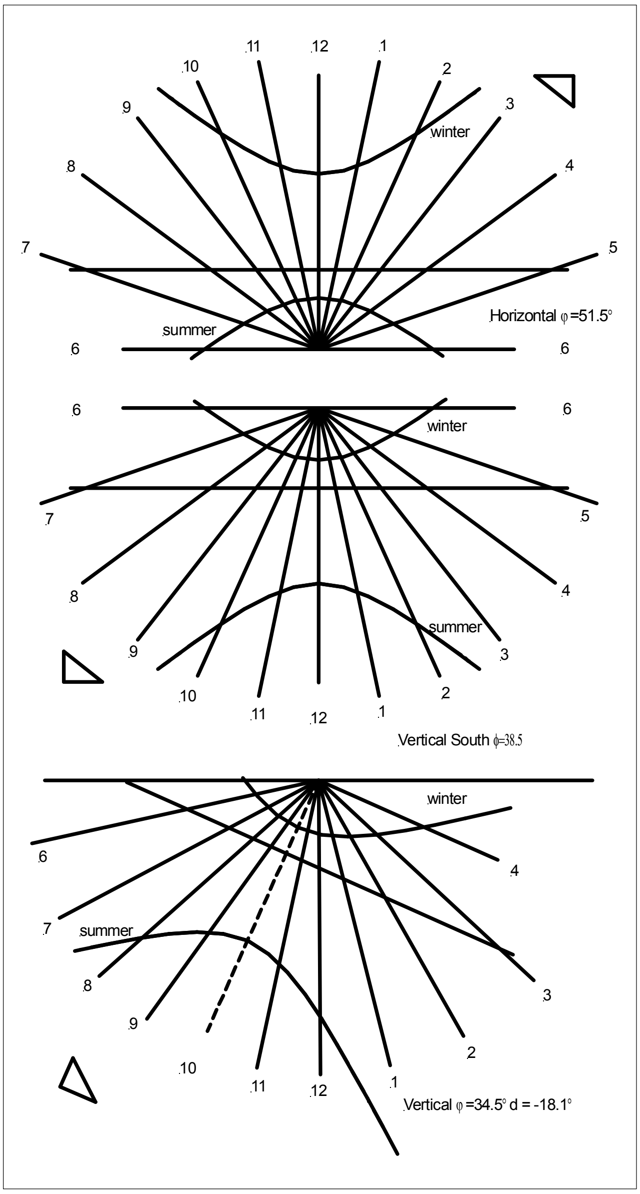


Fig. 1. Horizontal, vertical south facing and vertical declining dial faces all with the same style height.

$$\tan X_0 = \sin SH \times \tan h_0 \qquad (3)$$

$$R = \frac{L\sqrt{(1-\cos^2 SH \times \sin^2 h_0}}{\cos SH \times \cos h_0 - \sin SH \times \tan\delta} \qquad (4)$$

$$h_0 = (T_{24} - 12) \times 15°$$

where

X_0 = hour line angle (X_0=0 at noon LAT)
SH = style height
h_0 = hour angle (on sub-style line $h_0 = 0$)
δ = sun's declination
L = distance of nodus from origin along sloping style.
T_{24} = time in 24-hour clock notation.

The sign of SH is positive for a horizontal dial and negative for a vertical dial, as this gives the correct distances from the origin for the summer and winter solstice lines.

Declination lines can be drawn using the polar co-ordinates R and X_0 shown above.

The position and separation of the hour lines also only depends on the style height but they are labelled in accordance with the relevant longitude or equivalent longitude or standard time zone for dials that are not horizontal or south facing vertical.

HOUR LINE ANGLES

The hour angle h_0 used to determine the declination lines is the hour angle for a horizontal dial indicating local apparent time or a vertical dial indicating local apparent time at the location of equivalent latitude and longitude where the dial would be a south facing vertical dial.[3] To calculate the hour line angles X for a horizontal dial indicating time for a standard time zone or a vertical declining dial indicating local apparent time at its actual location or standard time at that location is quite straightforward. In this case we use the formula:

$$\tan X = \sin SH \times \tan h \qquad (5)$$

a) Standard Time

The formula 5 above applies for all calculations, but the value of h must be chosen to fit the time indication required. If the location is θ degrees east of the standard meridian

$$h = h_0 + \theta$$

If the location is west of the standard meridian the value of θ is negative.

These corrections apply to horizontal and vertical dials.

b) Vertical Declining Dials

A vertical declining dial at latitude φ and longitude λ declining by angle d is the same as a south facing vertical dial at the equivalent latitude φ' and equivalent longitude λ' given by the formulae[6]

$$\cos\phi' = \cos d \times \cos\phi \quad \text{and} \quad \tan\lambda' = \frac{\tan d}{\sin\phi}$$

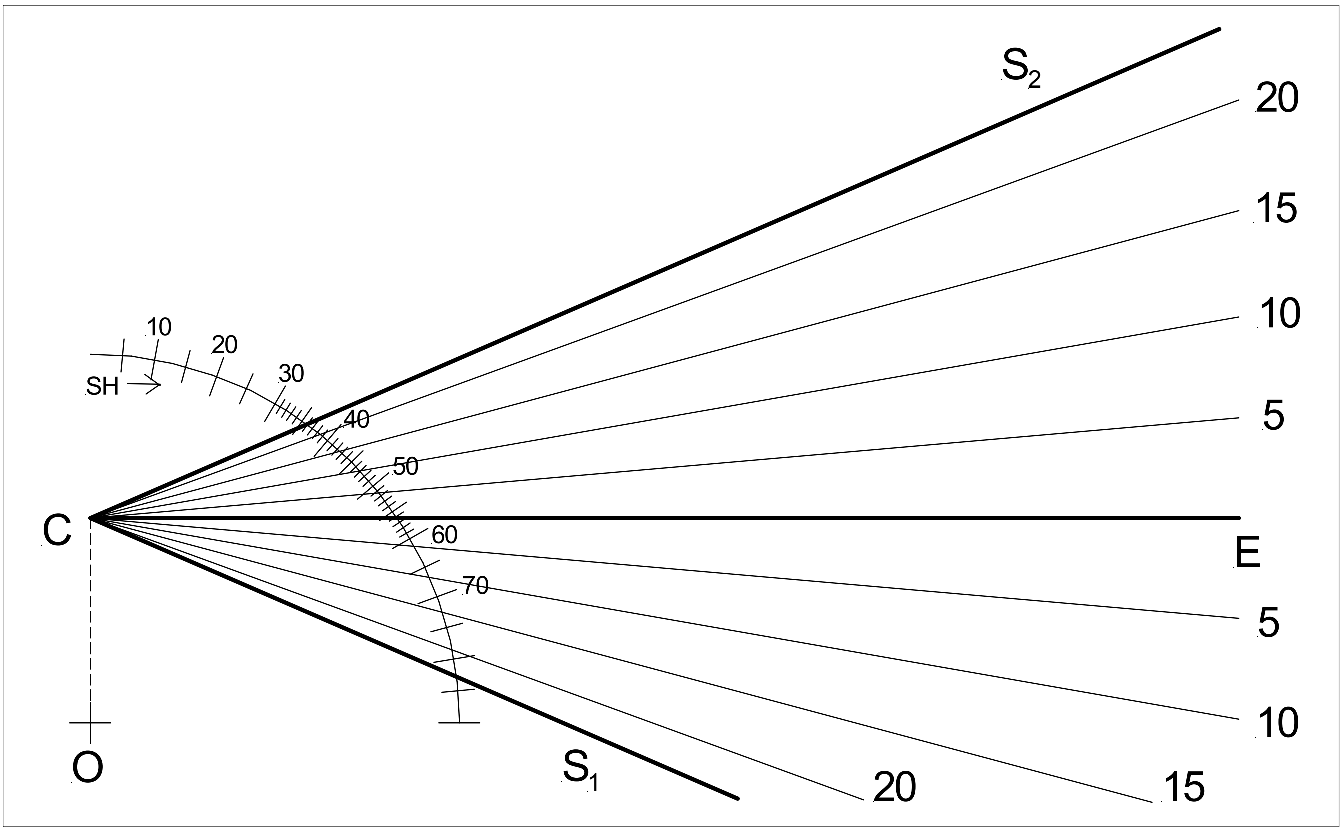


Fig. 2. Protractor for drawing declination lines based on Leybourn.[4]

If the declination d is west of south the value of λ' is positive, if d is east of south it is negative.

So in total we have

$$h = h_0 + \theta + \lambda'$$

And for a vertical dial

$$SH = 90\text{-}\varphi'$$

These formulae allow the hour line angles to be correctly labelled for any type of planar dial. It is for this reason that the vertical declining dial face in Fig. 1 has differently labelled hour lines from the vertical and are valid for different latitudes.

GRAPHICAL METHOD

The graphical solution is simple to perform if a little less accurate. The diagram in Fig. 2 shows an origin **O**, a point **C** where a number of lines converge. The extremes have been put at 23.43° apart to cover the solstices, and lines added at five degree intervals to give declination lines for those angles. A quarter arc protractor is included about **O** which allows the style height to be set. The distance **OC** is the distance L of the nodus from the origin along the sloping style. The resulting dial can be scaled from the actual value of the distance of the nodus from the origin.

The simplest way to use the diagram is to have a piece of tracing paper with a line across the centre, which will be the sub-style line and a line at right angles to it near the left side of the page. Push a drawing pin through **O** from the back of the page and pierce the tracing paper where the two lines intersect. Rotate the tracing paper so that the central line is set with the correct style height SH on the protractor. Mark along the central line the points $\mathbf{W_0}$, $\mathbf{E_0}$ and S_0 at which the lines $\mathbf{CS_1}$, **CE** and $\mathbf{CS_2}$ intersect. The line through $\mathbf{E_0}$, the centre of these, at right angles to the central line, is the equinox line. The other two points are where the two solstice lines cross the sub-style line. The central line and the equinox line are shown dashed in Fig. 3. Now rotate the tracing paper a few degrees and mark with a straight edge, shown dotted on Fig. 3, where the line from **O** to the intersection with the equinox line cuts the lines $\mathbf{CS_1}$ and $\mathbf{CS_2}$. These points are $\mathbf{D_1}$ and $\mathbf{J_1}$ and they are two more points on the solstice declination lines. Rotate the sheet a few more degrees and repeat the process for the next two points. Finally join up all the points $\mathbf{D_n}$ and $\mathbf{J_n}$ to give the solstice lines. Declination lines for other angles can be drawn in the same way using the 5, 10, 15 and 20 degree lines in Fig. 2.

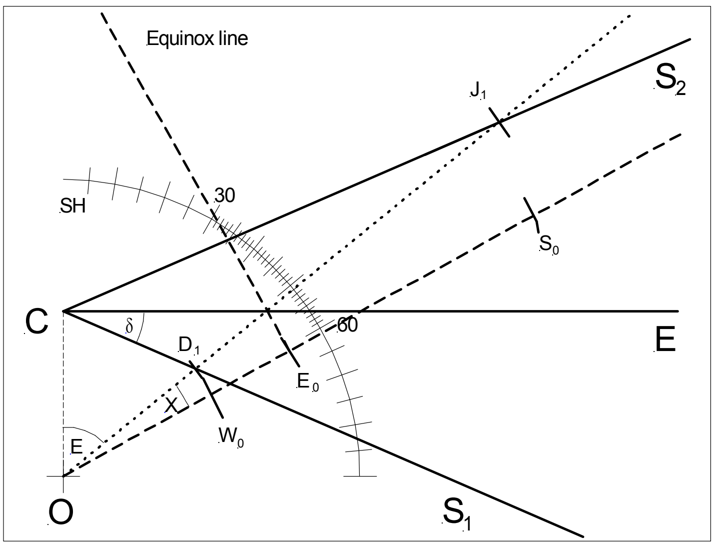


Fig. 3. Use of the protractor shown in Fig. 2 for drawing declination lines.

CARTESIAN CO-ORDINATES

In Fig. 4, an hyperbola with offset origin ($-c$, 0) is drawn and the distances a, b, and c are indicated. The formula for the hyperbola is

$$\frac{(x-c)^2}{a^2} - \frac{y^2}{b^2} = 1$$

or

$$y = \pm b\sqrt{\left(\frac{(x-c)^2}{a^2} - 1\right)}$$

The asymptotes are

$$y = \pm\frac{b}{a}(x-c)$$

For declination lines on a planar sundial the values of a, b, and c in terms of style height and declination are:-

$$a = \frac{L \times \sin SH \times \tan\delta}{\cos^2 SH - \sin^2 SH \times \tan^2\delta}$$

$$b = \frac{L \times \sin SH}{\sqrt{(\cos^2 SH - \sin^2 SH \times \tan^2\delta)}}$$

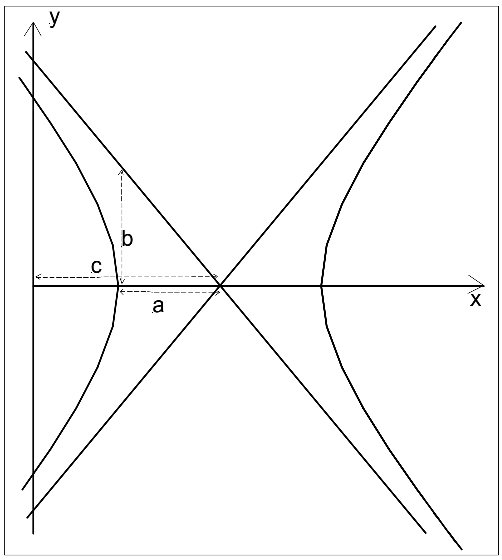


Fig. 4. Hyperbola and asymptotes indicating a, b *and* c.

$$c = \frac{L \times \cos SH}{\cos^2 SH - \sin^2 SH \times \tan^2 \delta}$$

This hyperbola can be drawn based on the origin of the dial and with the *x* axis as the sub-style line for any style height and declination using the cartesian co-ordinates *x* and *y* with the origin at the origin of the dial**.** This method may be found to be a more convenient way of plotting declination lines than the polar co-ordinate method above. The hour line angles are still calculated according to equation 5 above.

EXISTING DIALS

It is possible to check the correctness of the solstice lines on an existing dial such as that in Fig. 5 by measuring the distances along the sub-style line from the origin to the equinox line **OE** and the solstice lines $\mathbf{OS_1}$ and $\mathbf{OS_2}$.

The following relationships follow from the above formulae:-

$$\frac{1}{OS_1} + \frac{1}{OS_2} = \frac{2}{OE}$$

This is always true. In addition we have:-

$$\tan SH = \frac{OE}{2\tan\delta}\left(\frac{1}{OS_1} - \frac{1}{OS_2}\right)$$

$$L = OE \cos SH$$

$$ON_1 = \frac{L}{\tan\delta}$$

$$\frac{S_1S_2}{N_1N_2} = \tan SH \times \tan\delta$$

where the line N_1N_2 is parallel to the sub-style line OS_2.
So for any existing dial the accuracy of its declination lines can easily be checked and its style height and nodus distance found with a few simple measurements.

CONCLUSIONS

It has been shown that the pattern of declination lines on a planar sundial is dependent only on the style height and it is symmetrical about the sub-style line.

Three ways of constructing declination lines are given, all based on the origin of the dial.

a) Polar co-ordinates using *SH* and h_0.

b) A graphical method which can be scaled to any size required.

c) Cartesian co-ordinates using only *SH*.

A simple method of checking declination lines on existing dials is also given which allows the value of *SH* and *L* to be found from a few simple measurements.

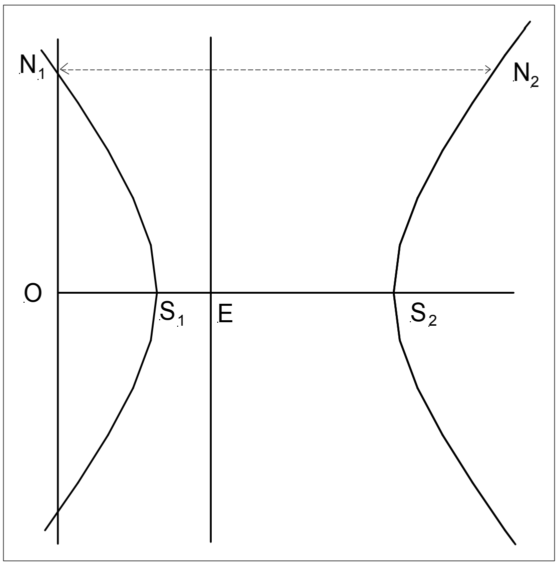


Fig. 5. Measurement points for checking declination lines on an existing dial.

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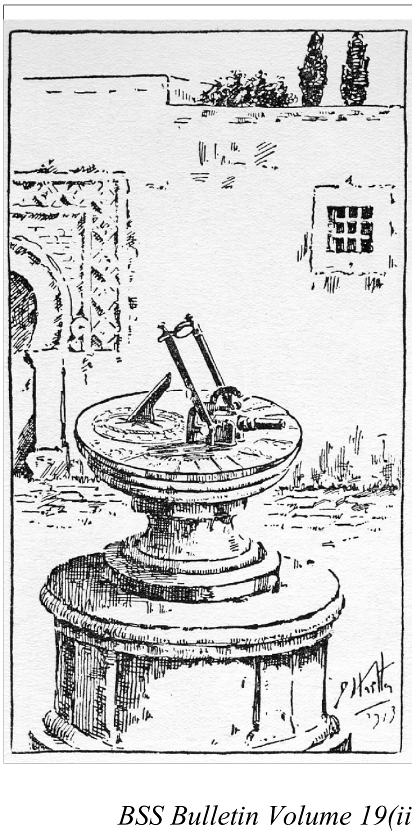

Another noon cannon, this one from Henslow. It looks very similar to the Maidstone museum one illustrated by Warrington Hogg in Gatty so it seems likely that the location here is fictitious.

THE DIAL OF AHAZ

JOHN WALL

The most celebrated instance of a reversal of the motion of the shadow on a sundial to indicate going back in time concerns the so-called Dial of Ahaz as recorded twice in the Old Testament, in 2 Kings ch. 20, vv 8-11, and Isaiah ch. 38, vv. 7-8. King Hezekiah of Judah (reigned 716-687 B.C.) became mortally ill. The prophet Isaiah gave an assurance that the Lord would heal him, but Hezekiah was unconvinced and demanded a sign that this would be so. Unfortunately, the two similar passages in which the ensuing miracle is recorded are amongst the most obscure linguistically in the whole of the Old Testament. A particular and crucial ambiguity is that the Hebrew word ma'a'loth may either be translated as 'degrees' or 'steps'. Thus the Authorised Version of 1611 (AV) translates the passage from Kings as follows:

9. And Isaiah said, This sign shalt thou have of the Lord, that the Lord will do the thing that he hath spoken: shall the shadow go forward ten degrees, or go back ten degrees?

10. And Hezekiah answered, it is a little thing for the shadow to go down ten degrees: nay, but let the shadow return backward ten degrees.

11. And Isaiah the prophet cried unto the Lord; and he brought the shadow ten degrees backward, by which it had gone down in the dial of Ahaz. (A marginal note has 'degrees of Ahaz'. Ahaz was the father of Hezekiah.)

A more accurate and up to date translation of the original Hebrew in the English Standard Version of 2002 (ESV) renders this passage:

9. And Isaiah said, "This shall be the sign to you from the Lord, that the Lord will do the thing that he has promised: shall the shadow go forward ten steps, or go back ten steps?"

10. And Hezekiah answered, "It is an easy thing for the shadow to lengthen ten steps. Rather let the shadow go back ten steps."

11. And Isaiah the prophet called to the Lord, and he brought the shadow back ten steps, by which it had gone down on the steps of Ahaz.

A literal translation of the original Hebrew in the passage from Isaiah indicates even more clearly the difficulty of arriving at the true meaning of both passages:

'Behold, I will bring again backwards the shadow-degrees (or steps) which is gone down in the degrees (or steps) of Ahaz by the sun, backwards ten degrees (or steps). So returned the sun ten degrees (or steps) (by) which it had gone down.'

It should be noted that although the AV includes the word *dial* in the passage from Kings and *sun dial* in the passage from Isaiah, and the ESV includes the word *dial* in the passage from Isaiah (but neither word in the passage from Kings), there is no equivalent in the literal rendering of the original Hebrew text. In fact, there is no Hebrew word for sundial as such. However, the implication is clear – the context does require a '(Sun) Dial of Ahaz' of some kind.

Now let us examine the case for 'steps' as the proper translation of the Hebrew word ma'a'loth. Paradoxically, this rendering is given some credence by the first of six definitions of the word 'degree' in *The Concise Oxford Dictionary:* 'Step (as) of staircase (archaic; perhaps so in 2 Kings xx.9 and in Psalm-title Song of Degrees, Ps. 120-134). The latter is a reference to the only other occurrence of the word ma'a'loth in the old Testament. Again, although these 15 Psalms are titled Songs of Degrees' in the AV, modern translations have 'Songs of Ascents'. They are said to have been sung by processions of pilgrims whilst ascending Mount Zion during the great Temple festivals.

In Mrs Gatty's *Book of Sundials* she writes:[1]

> The word 'degrees' in our translation of the Bible has been in the margin and the revised Version rendered 'steps'; and this reading has given rise to various suppositions. Some writers have thought that a pillar outside the king's palace threw a shadow on the terraced walk, which indicated the time of day. Others have thought that the shadow was cast on steps in the open air 'or more probably within a closed chamber, in which a ray of light was admitted from above, which passed from winter to summer up and down an apparatus in the form of steps'.

We can indeed imagine a staircase in the palace of King Ahaz that did duty as a primitive kind of sundial by placing a pillar in the middle of the top step to act as a gnomon. It was the Jewish historian Josephus (c.37-c.100 A.D.) who first suggested that the stairway of the king's palace might have constituted a type of sundial. During the morning the shadow cast by a pillar-gnomon would shorten and appear to ascend the steps, and during the afternoon the shadow would lengthen and appear to descend the steps.

Readers will have noticed that the ESV translation of Isaiah offers two alternative signs to King Hezekiah: either that the shadow should go forward (or lengthen) by ten steps or go backwards (or shorten) by ten steps. Hezekiah answered that because it would be an easy thing for the shadow to lengthen ten steps, he chose that it should go back ten steps. However, we have seen that if this conversation took place in the morning it would not in fact have been an easy thing for the shadow to lengthen by ten steps – that would have been contrary to its normal motion at that time. If the conversation took place in the afternoon, however, then indeed it would have been contrary to the laws of nature (that is, a miracle) for the shadow to go back ten steps since its normal motion would be to lengthen at that time. We conclude therefore that the 'miracle' must have taken place in the afternoon. It has been suggested that while Isaiah was talking to King Hezekiah the sun's shadow had already moved ten steps; he promised to reverse the forward direction of the shadow and bring it back the distance it had travelled during that conversation.

If the biblical account is to be believed, the greater, causative miracle consisted in a temporary reversal of the shadow-casting *sun's* transit across the sky. In passing, Isaiah would have had his work cut out if he attempted to tamper with the pillar-gnomon so as to create the appearance of a miracle.

Now let us consider the case for 'degrees' as the proper translation of the Hebrew word ma'a'loth. That rendering would in turn strengthen the case for understanding the Dial of Ahaz to be a scientific/mathematical instrument not far removed from the sundial with which we are familiar today; that is, it was not simply a primitive dial with a pillar for a gnomon. We are indebted to the translators of the AV for this interpretation, but their understanding of the word 'degree' may have been rather different from our own. Moreover 'degrees' is dropped in favour of 'steps' in both accounts as rendered in the most up-to-date translation, the ESV. On the other hand the ESV retains the word 'dial' in both accounts, the implication being that it was a scientific instrument and not merely a pillar atop a stairway. If that was the case, then this is the first sundial of which we have a historical record.

If 'degrees' is nearer to the understanding of the meaning of ma'a'loth in the minds of the authors of these two accounts, what exactly was that meaning? The six definitions provided by the *Concise Oxford Dictionary* are helpful here. They possess in common the notion of ascending, stage by stage, numerical or otherwise. Definition no. 5 is most pertinent to our purpose: '(Geometry etc.) unit of angular or circular-arc measurement, …. 1/360 of circumference.' This definition is normally applied to the measurement of the circumference of the earth, that is degrees of latitude or longitude. (We are all familiar with the rule of thumb that one degree of longitude represents four minutes as the earth revolves on its axis during the day.) However, it could equally well be applied to the circular chapter ring of a clock, whether of the 12 hour or 24 hour kind, and crucially to a sundial that records a 24 hour day/night. There are 1,440 minutes in a day, so it is hardly likely that a degree in the context of sundials ever represented such a small unit. Even the most sophisticated sundials are hard pressed to delineate minutes. It is equally unlikely that it ever represented the much larger unit of one hour. In practice the typical unit of a sundial capable of being read with the naked eye is five minutes.

If we suppose that the Dial of Ahaz was sufficiently sophisticated to mark out degree-units of five minutes, and that the shadow cast by the declining sun *was* turned back ten degrees, the participants in the 'miracle' travelled back in time by the space of 50 minutes. In truth, even if the Dial of Ahaz was a scientific/mathematical instrument in the conventional sense, we will never know what precise period of time was covered by ten degrees in the narrative. At the time of King Hezekiah and King Ahaz the cultural milieu of their kingdom of Judah was the Babylonian civilisation that flourished in Mesopotamia on its eastern border, although Babylon in turn was under the political suzerainty of Assyria to the north. The invention of the sundial has been variously credited to the Babylonian and the Egyptian civilisations. "The Dial of Ahaz", writes A.P. Herbert,

Fig. 1. Horologium Achaz. The gnomon, originally held in the astrologer's right hand, is missing.

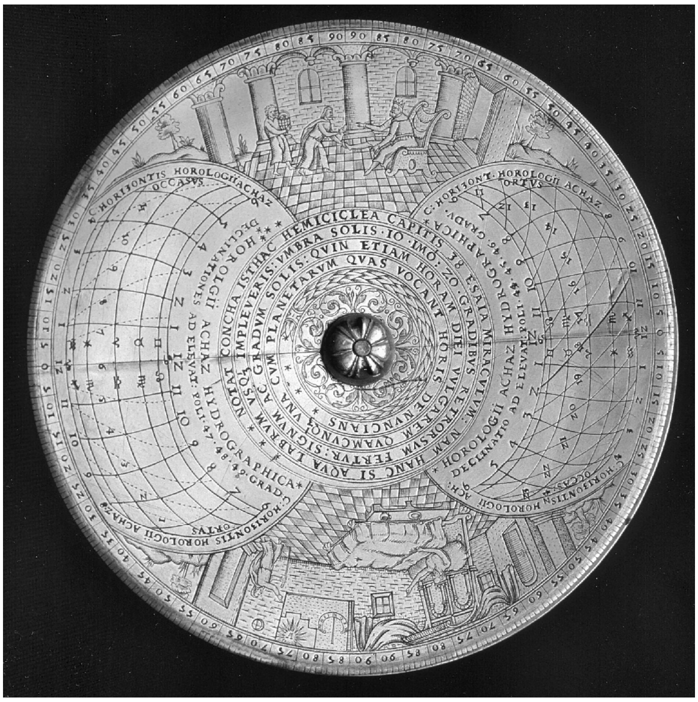

Fig. 2. Horologium Achaz, inscribed base.

"was, almost certainly, an instrument of Babylonian inspiration, and the Babylonians were the first to divide the circle into 360 degrees".

If the proper translation of ma'a'loth is degrees, and if the event recorded in the bible was not in fact a miracle (that is the suspension or reversal of natural law), how might the deception have been achieved? In her book *Sundials and Roses of Yesterday,* published in 1902,[2] the American author Alice Morse Earle devotes an entire chapter to the 'Sun-Dial of Ahaz'. Her explanation depends on the refraction of a beam of light when passing through water. Her story begins with the migration of a mystical German sect, the Rosicrucians (named from Rosy + Cross) to Philadelphia in colonial New England in the year 1696. They brought with them a finely wrought sundial, the work of the mathematician and scientific instrument maker Christopher Schissler, as is evident from an inscription below the rim: *Christophorus Schissler Geometricus ac Astronomicus Artifex Augustae Vindelicorum Faciebat Anno 1578*. (Figure 1) On the rim stands a brass figure representing an astrologer, with extended right hand to hold a gnomon which, when the photograph was taken, was already missing. The under part of the base (Fig. 2) is finely inscribed with scenes from the biblical account, two mathematical diagrams, and a number of inscriptions in Latin, one of which, being translated, contains the extraordinary claim:

> "This semicircular shell explains the miracle of the 38th chapter of Isaiah. For if you fill it to the brim with water, the shadow of the sun is borne backward ten or twenty degrees. Moreover it indicates any common hour of the day, with what is called the hours of the planets."

It is evident that Miss Earle accepts this claim since she writes: "This relic is called the Horologium Achaz, the Sundial of Ahaz; in it is performed the miracle of Isaiah, - the shadow is cast backward ten degrees by the refraction of water."

The upper part of this artifact is the sundial proper. It is 10 inches in diameter, bowl shaped, and about 1¾ inches in depth so as to contain a quantity of water. (Figure3.) Miss Earle comments:

> "By filling this shallow bowl with water or any transparent liquid, it can readily be seen that the indicated time was advanced or retarded by as much as the angle of refraction; thus was the miracle consummated."

The subsequent history of the Horologium Achaz is of unusual interest. When the company of Rosicrucians landed at Philadelphia, it was in the possession of one of their six pastors, by name Zimmerman. The scientific belongings of the last of these Rosicrucians, including the Horologium Achaz, were bequeathed to no less a luminary than Dr. Benjamin Franklin. (His interest in sundials is shown by his introduction of one, as first President of the United States of America, as a symbol in the first coinage of the new nation.) He in turn passed the surviving scientific treasures of the Rosicrucians into the care of the American Philosophical Society. Appropriately, they are now preserved in Philadelphia, including the Horologium Achaz.

The crucial question is whether the Horologium Achaz does in fact cast the shadow of its gnomon backward by ten degrees (or any other amount) through refraction when filled with water. One writer who was highly sceptical from

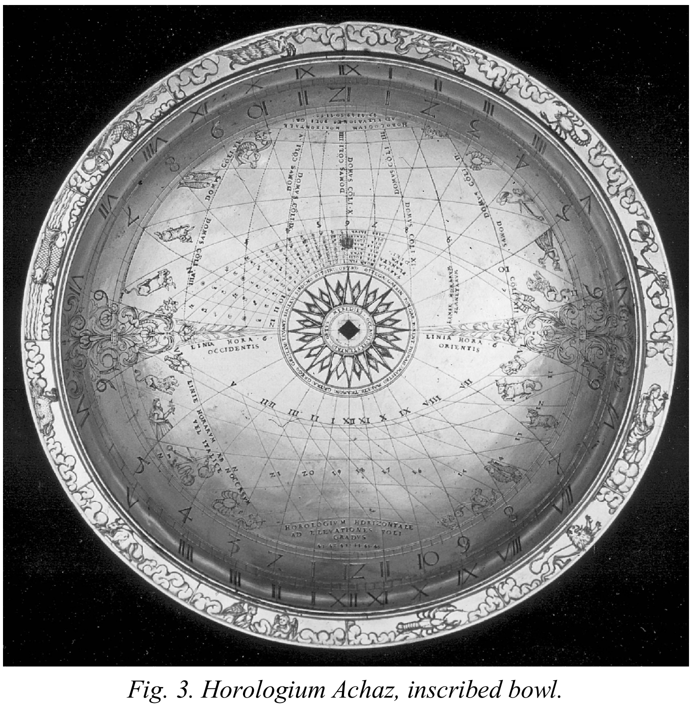

Fig. 3. Horologium Achaz, inscribed bowl.

the outset was A.P. Herbert. In his delightful book *Sundials Old and New: or Fun with the Sun*,[3] he proved experimentally to his own satisfaction that refraction could have played no part in the apparent miracle.

If in fact no miracle did take place, how might Isaiah have interfered with the Dial of Ahaz so as to simulate one? The clue to one possibility is contained in Miss Earle's description of Schissler's replica, already quoted, as follows: "The upper plate is the sun-dial proper….with flat *moveable* rim an inch wide" (italics mine). If the hour lines on the Dial of Ahaz were inscribed on the rim, instead of just below it as inscribed by Schissler, then it would have been comparatively easy to move the rim surreptitiously, when his audience's attention was distracted, by ten degrees, at the beginning of Isaiah's demonstration. In like manner the rim could be restored to its former position when the demonstration was concluded. However, for my own part, I do not believe that Isaiah would have been guilty of such bare-faced deceit. Until such time as a rational and plausible explanation is advanced, I am inclined to believe that the 'miracle of Ahaz' really did take place.

ACKNOWLEDGEMENT

I am grateful to the American Philosophical Society, Philadelphia, for permission to publish Figs. 1,2 & 3, which are their copyright.

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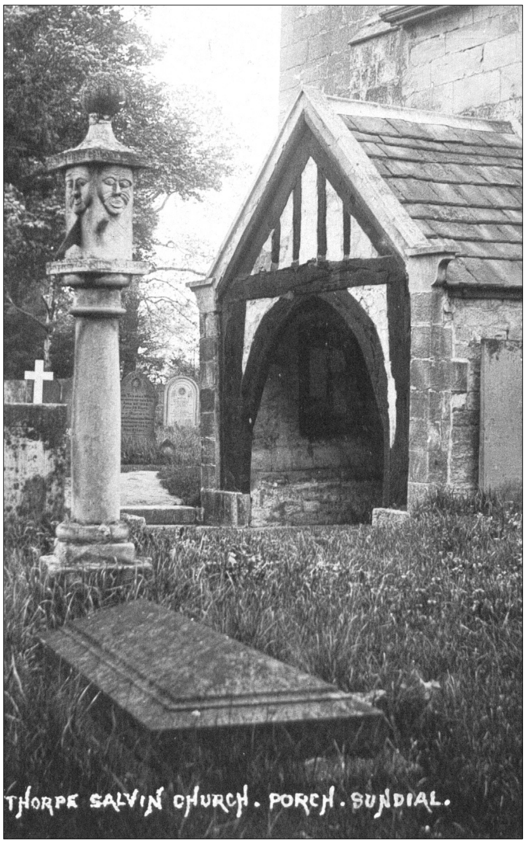
Postcard Potpourri 5 – Thorpe Salvin Church

Peter Ransom

This undated postcard intrigued me by the sun faces that can be seen. Scanning and enlarging the image shows that there are south and east vertical dials with a presumed west dial. Closer inspection shows lines on the ball at the top so I suspect that this is a spherical dial. No trace of a movable gnomon can be seen.

St Peter's Church at Thorpe Salvin is located at grid reference SK520811. Thorpe Salvin is in the West Riding of Yorkshire, 4 miles W. of Worksop. The church is remarkable for its handsome Saxon Doorway and the tower and major structures are 12th century. A picture of the dial can be seen at http://www.j31.co.uk/thorchu.htm and the gnomons are no longer present, though it does confirm a west vertical dial! Details of the dial can be found in the Sundial Register in Yorkshire (S) where it was last recorded by Tony Wood in 2001.



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