The British Sundial Society

BULLETIN

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BULLETIN

OF THE BRITISH SUNDIAL SOCIETY

EDITORIAL

Our authors have, as ever, written on a wide range of topics. There are dials to delight the eye in the photos of 'Dial Dealings', and graphs to provoke thought in the sine-curves for the EOT. There is history in Isaac Newton and Samuel Foster, and painstaking craftsmanship at Towneley Hall. There are challenges to cardboard-dial-makers in Horary Quadrants and in Calendar Dials. It is good to know too that this extensive list of interests and skills is at least as great as envisaged by the founders of the British Sundial Society. David Young's entertaining article about our foundation tells of the questionnaire sent to people vaguely 'interested' and Anne Somerville's summary of the answers, and of their suggestions for bulletin topics, all those years ago.

Are we in danger of taking our subject too seriously? Should the Bulletin publish more Poetry? Fiction? Jokes? You might not think that sundial study lends itself to fiction, but we recall reading, in the pages of our learned contemporary 'Compendium', the adventures of the fictitious Nicole, the young woman who introduces Fred Sawyer's gnomonic Quiz questions. There may be some among our membership who, alongside their knowledge and skills of hand and mind, can add the gift of imagination.

René R J Rohr
(1905-2000)
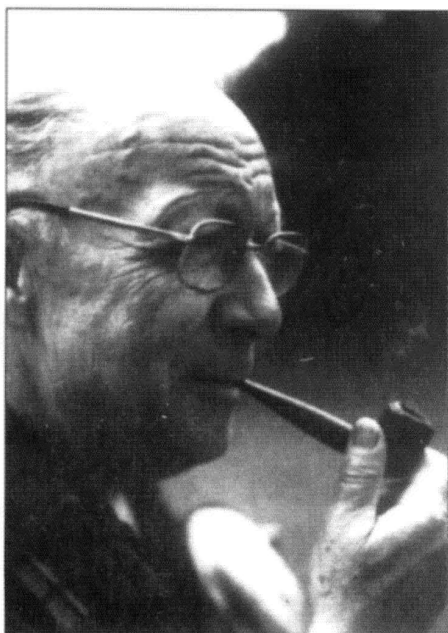
Over a year ago, on 13 December 2000, Captain René Rohr died, just two months after his 95th birthday.

René R J Rohr was born on 20 October 1905 in Strasbourg in the province of Alsace (Elsass). In 1923, at the age of 18, he left home for a career at sea, which is perhaps not surprising since Strasbourg is one of the chief inland ports of France. René was fortunate in that, during his early years at sea, he was encouraged in furthering his studies and his career in the Merchant Navy.

In due course, he evidently qualified as a Master Mariner and, at the outbreak of World War II, transferred into the French Navy, being given command of a mine-hunter class of warship. During this time, he attained the rank of Captain, before his post-war return to sea in the Merchant Service. Having widely travelled the oceans of the world, he gave up the sea and spent some years working in a bank in Strasbourg, before taking retirement.

During his time at sea, René Rohr had studied and practised Navigation, a subject closely related to the science of Gnomonics or the Art of Dialling. Nevertheless, it was not until after his retirement from the sea that he became interested in sundials and in their construction. He studied the subject with enthusiasm and in 1965 his first book on sundials was published in French, under the title *Les Cadrans Solaires* by Gauthier-Villars. It was soon translated into English (and other languages) and published by the University of Toronto Press in 1970. It was a refreshing addition to the limited sundial literature then available to the aspiring student of the subject, and, indeed, it became a standard work of reference. It is still considered as such, having been augmented and updated in more recent French and German editions.

René Rohr's contribution to the study of sundials was not limited to his works on their history and construction. He produced a beautiful volume devoted to the sundials of his native Alsace in 1982 and wrote many articles concerning all matters on dialling, as well as designing and constructing sundials himself. He was already a well-known and respected authority on the subject when the British Sundial Society was founded in 1989. He had met Andrew and Anne Somerville a few years earlier and they had become firm friends. Consequently, it was a natural choice to elect René Rohr as one of the first Vice-Presidents of the Society when it was formed.

Although, sadly, René Rohr never managed to attend any of the BSS annual conferences, members will all have known his name and may have had some affection for him through the medium of his popular work *Sundials – History, Theory, and Practice*. I never had the pleasure of meeting him and only knew him through occasional correspondence. Nevertheless, his name stands out as an authority on sundials and he will be remembered for his lasting contributions in this field.

It is unfortunate that the news of René Rohr's death did not reach the British Sundial Society until the autumn of the year 2001, and it is with regret that we pay tribute to him so belatedly. He died after a long illness, in his native Strasbourg. The British Sundial Society is privileged and honoured to have had René R J Rohr as one of its most distinguished Vice-Presidents.

Christopher St J Daniel
Chairman
8 January 2002

AN ISAAC NEWTON SUNDIAL

JOHN DAVIS

While travelling to a BSS mass dial meeting in 1999, I made a pilgrimage to Woolsthorpe Manor in Lincolnshire. Now in the hands of the National Trust, Woolsthorpe was the birthplace and home of Britain's greatest scientist, Sir Isaac Newton. It was here, in the *annus mirabulis* of 1665/6, that Newton performed his famous experiments with light, producing his theory of the formation of the rainbow by differential refraction of white light. This experiment with a prism is currently reconstructed in one of the upstairs rooms of the Manor. He also formulated his theory of universal gravitation here, the basis for the sudden explosion in mathematical astronomy and allowing, for example, Flamsteed[1] to calculate the Equation of Time so precisely. Continuing my journey, I drove through a heavy rainstorm on the A606 and saw, stretched out across the Vale of Belvoir, the compete arc of a rainbow and including the secondary bow. I felt that the old man must be up there watching me, and resolved that the experience should be celebrated in a tangible form.

Newton has a strong connection to dialling, not just through his theoretical work[2]. Woolsthorpe once had two dials (Figure 1) inscribed on its stone walls, and these are strongly ascribed to Newton's own boyish hand. One of these now resides inside the nearby church of Colsterworth[6] (upside down!) and the other is preserved under glass in the library of the Royal Society. What better memorial than a
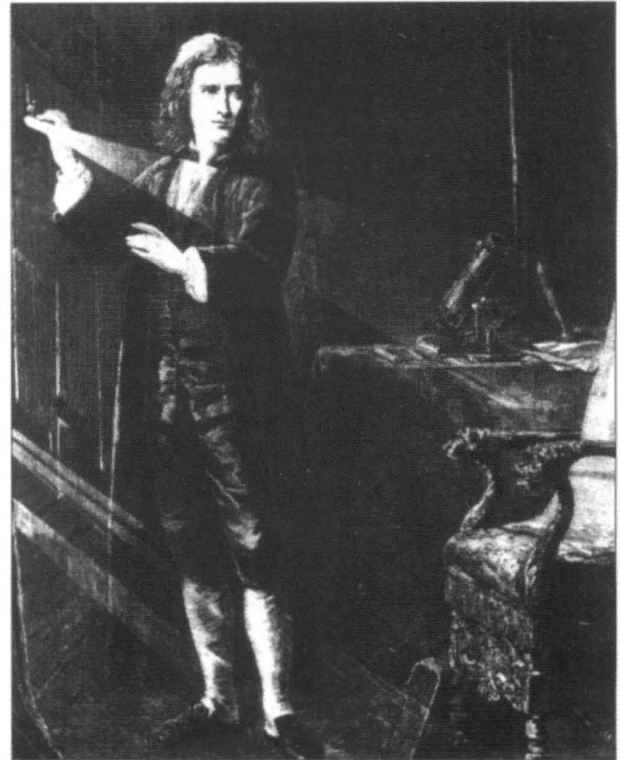

Fig.2. An engraving based on John Adam Houston's imaginative 1870 reconstruction of Newton conducting his prism experiment in the study at Woolsthorpe.

sundial to record my experience? A famous painting of Newton holding a prism (Figure 2) by John Adam Houston, was my inspiration - Newton should actually be part of the dial! My other inspiration was the famous Dolphin Sundial[5] at the National Maritime Museum, where a ray of light passing between the tips of the tails of two dolphins falls onto a hemi-cylindrical dial plate with a polar axis. By combining these two ideas, and using some artistic license, I came up with the basic design. In one hand, Newton would hold a brass triangle representing the prism, with a central hole producing a single ray of sunlight. With the other arm, he would hold a curved screen carrying the dial plate.

The basic idea then waited nearly two years until I found a sculptor capable of making the bust that was needed. Vanessa Stollery normally models animals and figures, but had made some busts of scientific figures. She was intrigued by the idea and we agreed on making a mould for a prototype Newton sundial. The first item produced was a mock-up of the working parts of the sundial, with the nodus-plate "prism" firmly attached to the centre of the dial plate and the whole structure on a stand, holding it at the correct angle for the latitude (52° 5' N). For practical

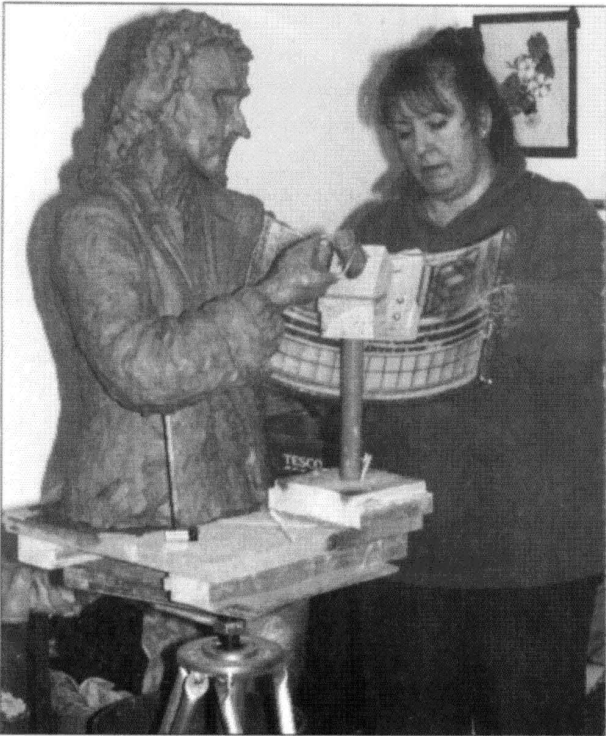*Fig.1. Woolsthorpe Manor with a man on a ladder examining Newton's sundials. From a painting by J.C. Barrow, 1797. (Grantham Museum).*

Fig.3. The sculptor Vanessa Stollery producing the clay model of Newton, with the mock-up dial on a stand.

Fig.4. The completed dial.

Fig.5. The shadow on the dial face at 10:38 GMT on 6 May. The (temporary) nodus is a 3mm sphere in a 5.5mm aperture. Inset: close-up of the spot.

reasons, the part-cylinder was reduced to a 97.5° sector, allowing the dial to show times from 9 a.m. to 3 p.m. throughout the year. The actual size was set by my ability to make A3-sized brass plates, and this fitted well with a nearly life-sized figure. The hard work was then undertaken by Vanessa, who built up the clay model of Newton on a metal framework, set around the dummy dial (Figure 3). The modelling was done from various portraits of Newton, concentrating on those of him as the young man which he was when he performed his optical experiments. When completed, the clay model was covered with a silicone layer and backed-up by a fibreglass shell. From this mould, a cold-cast bronze model was made, incorporating the backing plate of the dial. The figure was finally fixed to a green stone base, after careful adjustments to the bottom of the casting to ensure that the dial axis was in the proper polar direction. The finished dial can be seen in Figure 4.

The dial plates themselves were made by photolithography and chemical etching of thin (0.5 mm) brass sheets which would readily conform to the backing sheet. As in the Dolphin Dial, two interchangeable plates are used to cover the full analemma, allowing the dial to show Greenwich Mean Time in the winter and British Summer Time in the summer. Unfortunately, the dates when the clocks are officially changed do not correspond to the extremes of the analemma, leaving short periods when an hour has to be mentally added or subtracted. The plates are delineated for the longitude of Flowton (1° 3' E), although plates for other longitudes could easily be produced. Also, with minor adjustments to the cast figure, other latitudes in England could be accommodated. The dial plates carry a simple motto as well as Newton's name and dates, and other gnomonic data. It reads

.....And all was light

being taken from Alexander Pope's famous epigram[3]. The brass "prism" has a circular cavity so that it can take

interchangeable aperture plates. The radius of the dial plate is 240.4 mm, so that an aperture of 2 mm gives a spot of light with an apparent diameter of 5-6 mm at noon, reducing to 3 mm at 9am or 3pm. Experiments with a shadow sharpener[4] have also been made and are shown in Figure 5. This took the form of a 3 mm phosphor bronze sphere suspended in the centre of a 5.5 mm aperture punched in a piece of brass shim. At noon, the device gave a fine spot shadow with an apparent diameter of around 2 mm, surrounded by a bright annulus. However, the central shadow tended to merge with the outer ring with the 45° illumination at 9am and 3pm and so this device is not normally installed.

The prototype dial now lives in my garden, and we are looking for sites, preferably with a Newton connection, where copies can be installed.

Authors' address:
Dr J R Davis
Orchard View, Tye Lane
Flowton
Ipswich   IP8 4LD
*email: john.davis@btinternet.com*

REFERENCES AND NOTES

1. J. Flamsteed: *De Aequatione Dierum* (1672). See www.burnley.gov.uk/townley/tryall/jftable.htm.

2. A.A. Mills "Isaac Newton's Sundials" *Antiquarian Horology*, pp 126-139, Summer 1992

3. Nature, and Nature's laws lay hid from sight: God said, Let Newton be! and all was light.
   Alexander Pope (1688-1744). Epitaphs.

4. See Letters, NASS Compendium, 7 (3) September 2000 for a full discussion.

5. The Dolphin Dial is illustrated in the BSS Sundial Register 2000 and is Serial No. 2157.

6. The Colsterworth dial is in the BSS Sundial Register 2000 and is Serial No. 0620.

A NEWTON SUNDIAL -ADDENDUM

Although the basic structure of the Newton statue can be adjusted for various latitudes in England, Murphy's Law dictated that the first order for a duplicate came from a professor and Newton admirer at UCLA. The latitude of Los Angeles is around 34° North so it would have looked ridiculous to tilt the figure by 18° to maintain the dial in the equatorial plane. However, the cost of remaking the model was prohibitive. As the primary requirement was for a statue and the sundial was a bonus, it was decided to use the existing structure with the dialplate cylinder set for 52° and simply to calculate where the sunray from the nodus would fall. Clearly, this results in the spot falling on the dialplate only in the winter months, when the declination of the sun is towards its minimum values.
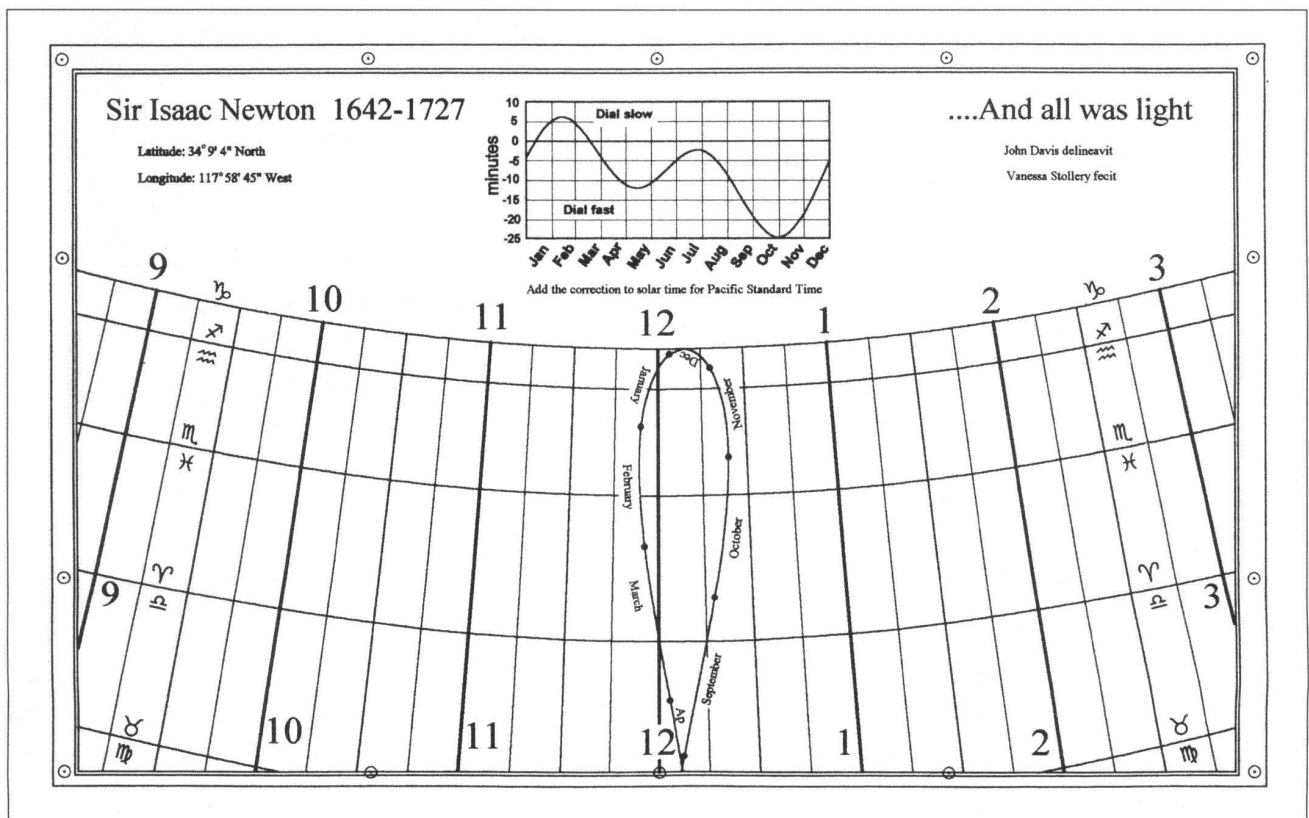
A computer aided design (CAD) drawing of the Los Angeles dialplate, unwrapped as a flat sheet.

The calculations were done in three steps. Firstly, the altitude and azimuth of the sun at the required location were found for each hourline on every day of the year when the spot was likely to be on the dial face. These values were in the normal cartesian coordinates with axes running E-W, N-S and vertically. The equation of the sunray through the nodus plate was then transformed into the tilted cartesian coordinates aligned with the dialplate. This allowed the x,y,z coordinates of the intersection of the ray with the plate to be solved. Finally, this point was transformed into the polar coordinates of the dial cylinder, allowing the plate to be 'unwrapped'; and thus the 2-D coordinates required for plotting on a flat sheet of brass could be obtained.

It was decided to dispense with the interchangeable plates showing mean time directly, and simply to use a fixed plate showing solar time. As there was much unused space at the top of the plate, a graph was inserted showing the combined Equation of Time and longitude correction to convert to Pacific Standard Time. Additionally, a noon analemma was plotted together with the declination lines for the entry of the sun into the constellations. The overall result can be seen in the figure.

THE FOSTER-POINT SUNDIAL: TIME IN A PERFECT ROUND

FRED SAWYER

(This article gives the substance of a lecture delivered by Fred Sawyer at the BSS Annual Conference at York, May 2001. It is published at the suggestion of the Chairman in order that the material may become more widely available-Ed)

In *Posthuma Fosteri: The Description Of A Ruler....*, the first of his works to be published following his untimely death in 1652, Samuel Foster introduces a new scale which he identifies simply as the Θ scale. With this innovation serving as a radius, he is able, as I have shown in *The Further Evolution of Samuel Foster's Dialing Scales*, to lay out a horizontal sundial beginning with a circle evenly divided into twelve hours.

This is as far as Foster takes his scale. He is interested in a graphical technique for laying out sundials. I, on the other hand, would be very intrigued to find a novel 'way to design a dial that uses an equiangular array of hour-points to indicate the time. It would seem that 'we should be able to accomplish this feat by modifying the technique that Foster developed. In fact, we can do exactly that.

We do so by reversing Foster's process. He uses what is essentially a clockface to lay out the hourlines. I propose using the gnomon shadows, reflected through a Foster-point, to get a dial with equiangular hour points, thus effectively adapting a clock face to serve as the face of a horizontal sundial.

Begin with a horizontal clock face, with noon at the south point and 6 at the north. Construct a gnomon that is parallel to the celestial axis, as usual. However, the gnomon should not actually touch the dial face, since the face will need to be rotated to make time adjustments. Instead, the gnomon should be supported or anchored from another point off the
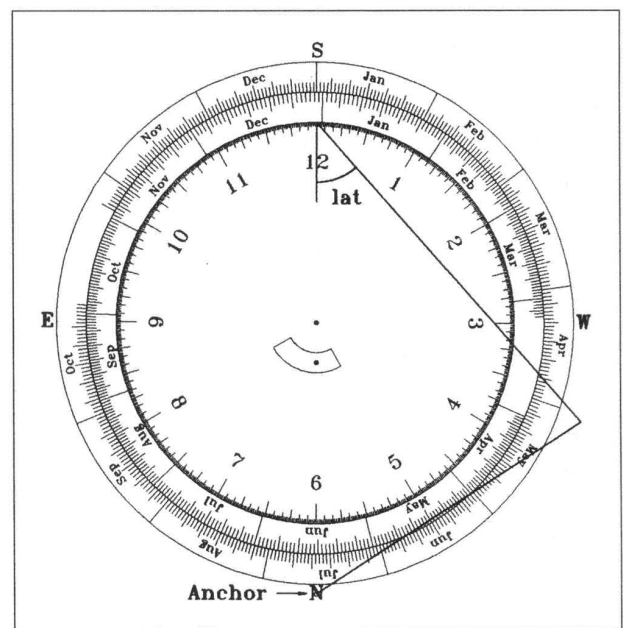
Fig.1.

face of the dial, as indicated in the Figure 1. In this 'way, the gnomon can be suspended above the dial, just barely touching it at the dial centre, 'which is at the south end of the meridian diameter of the dock face. (See Figure 7).

The clock face and a circumscribed scale (to be described below) must rotate together as a unit around the centre. About the circumference of these two, there is another round scale that remains stationary. These additional scales will allow us to correct for the equation of time.

A sweep index or rotating pointer is installed with its pivot at the Foster-point for the dial's latitude. The Foster-point occurs on the radius between the centre and the northern point. Its distance from the circumference of the clock face circle is 2·*radius·sin(latitude) / (1 + sin(latitude))*. If you were to lay a copy of Foster's Θ scale 'with the same length as the radius along this ray with 0° at the circumference and 90° at the centre, the Foster-point 'would be at the mark corresponding to the dial's latitude. Note that there is a slot around the Foster-point; since the pivot must remain stationary 'while the dock face is free to rotate.
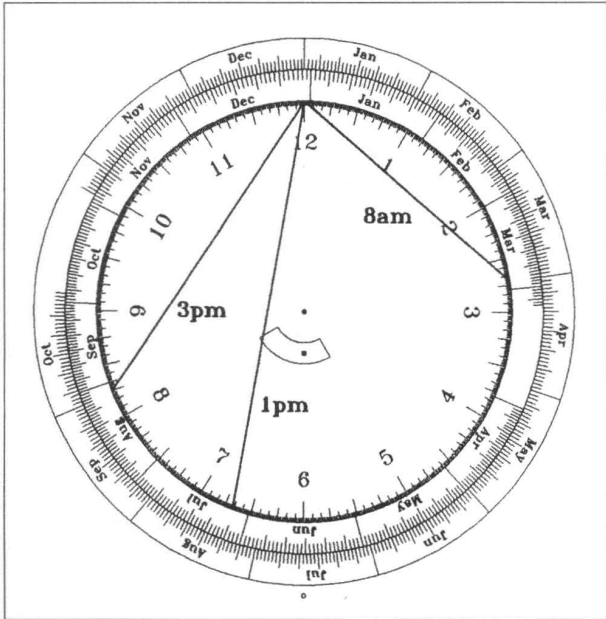

Fig.2.

Now with this arrangement, it would seem at first that the shadows of the gnomon at various times of day have very little to do 'with the hour points on the dial face. Consider the two examples in Figure 2. The shadows do not even
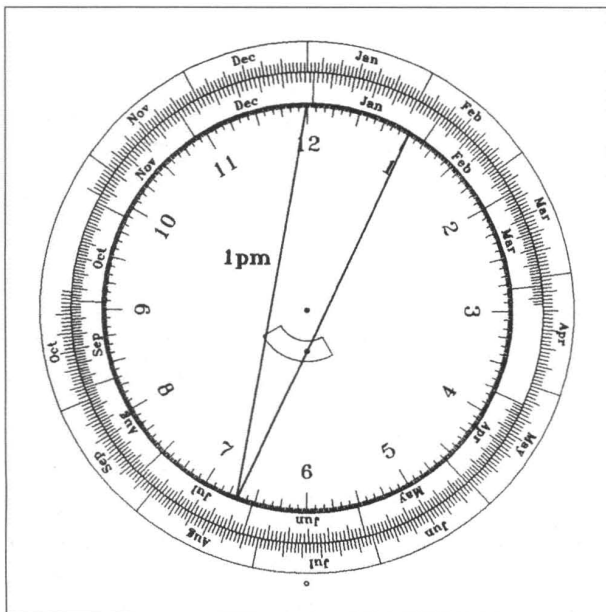

Fig.3.

come dose to registering the correct time. However, if 'we use the sweep index to reflect the point where the shadow hits the hour circle back through the Foster-point to the other side of the circle, 'we find that the time is now indicated perfectly (see Figures 3 and 4).
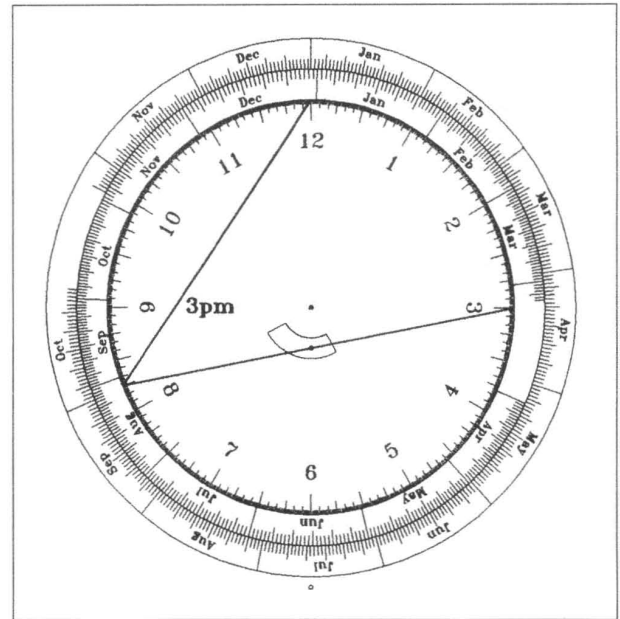
Fig.4.

So, by providing the dial with a sweep index rotating around the Foster-point, we have a working sundial.

But 'what of the scales on the circumference? How do 'we use them to adjust for the equation of time and longitude corrections? The technique they embody is essentially the method patented (US Pat.#1,044,238) on Nov.12, 1912 by William Renard Pilkington (of Pilkington-Gibbs fame) for his heliometer design.

The outer scale is simply equispaced markings for each day of the year - spread out over 330 degrees. The inner scale is similar, but with an additional angle for the equation of time added for each day (1° for each 2 minutes of time correction - since with a clock face each hour is 30° instead of 15°).

To adjust for, say November 1, simply align the markings for that day on both scales. The appropriate time 11:44 will be on the meridian. (Figure 5)

To adjust for longitude, simply draw the inner scale rotated an appropriate additional number of degrees away from the 12:00 point (2° clockwise for every 1° 'west of the central meridian of the time zone).

Note the 30° (i.e. 1 hour on the clock face) spaces on the inner and outer scales. I have added them to account for Daylight Saving Time.

Fig.5.

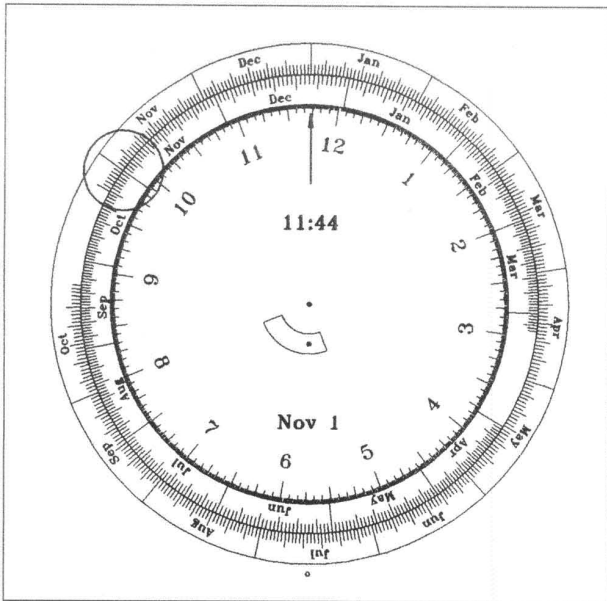The inner ring leaps ahead in spring, but the outer ring catches up in the fall. So, e.g. on May 1, with Daylight Saving Time in effect, matching the two May 1 lines puts 12:57 on the meridian. (Figure 6)
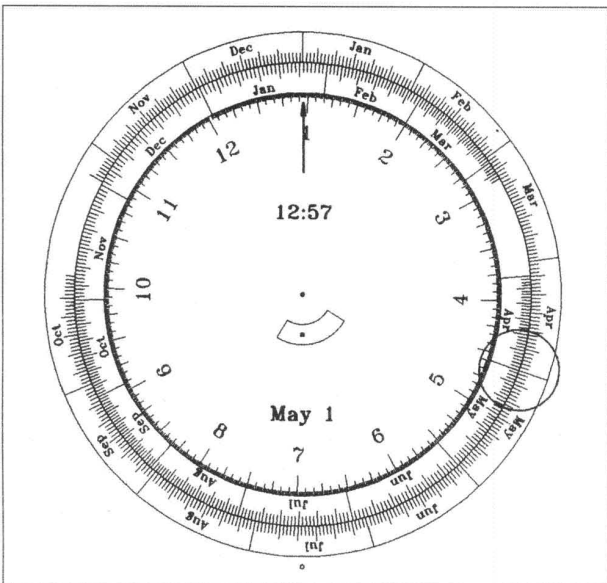

Fig.6.

The sundial thus easily adjusts for the equation of time, longitude corrections, and Daylight Saving Time. Finally, note that here in the northern hemisphere, I have constructed a horizontal sundial.

This technique can actually be used on any plane - but you have to be careful in selecting your plane, since it is possible to wind up with a clock face whose hours run backwards. Just as a normal vertical direct south dial will have hours that run counterclockwise in the northern hemisphere, so we would get a similar result with a Foster-point dial parallel to a horizontal plane somewhere in the southern hemisphere.
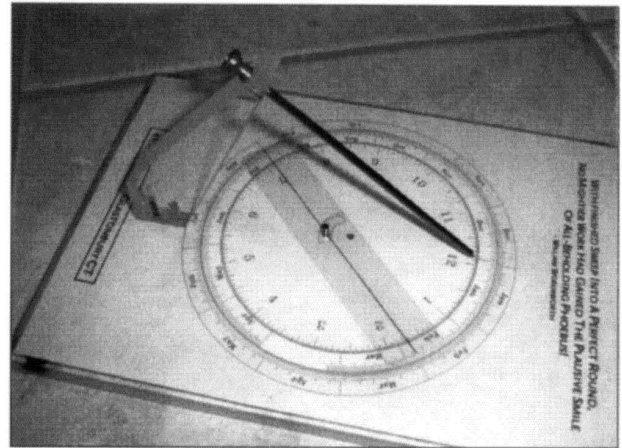
Fig.7. A Foster-point sundial constructed for me by Mac Oglesby

If someone south of the equator wants a basic dial with hours that run clockwise, he or she should start with a vertical direct north dial.
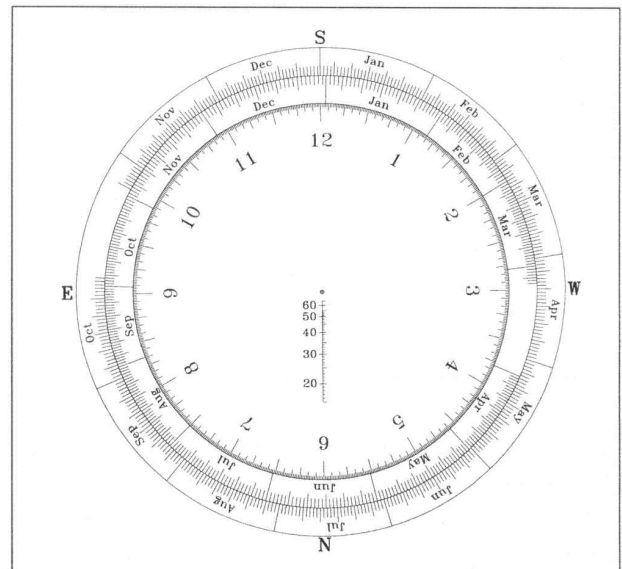
Fig.8. Foster-point sundial face with latitude scale

In general, to determine which face to use, we can solve the following equation for the latitude at which a plane with the given inclination and declination will be parallel to the horizon on the equator: *tan lat = tan inc. cos dec.* To assure a clockwise face in the northern hemisphere, be sure to be at a latitude north of this point.

In closing, allow me to cite the motto I have chosen for the first Foster-point dial. I think these lines from William Wordsworth (though taken out of context) are particularly appropriate for this dial.

With finished sweep into a perfect round, No mightier work had gained the plausive smile, of all-beholding Phoebus!

8 Sachem Drive, Glastonbury CT 06033
fwsawyer@aya.yale.edu

DIAL DEALINGS

MIKE COWHAM

In this edition of Dial Dealings I am reviewing sundials on offer for the whole of 2001. It was not a year of any spectacular auctions but there were a few exceptional dials. I will take the sales generally in chronological order and comment on the highlights of each, and will pick out any dials that I found particularly interesting.

CHRISTIE'S SOUTH KENSINGTON - 5 APRIL

In this sale were two dials of particular rarity and high value. The first was a lacquered copper polyhedral dial by *Erasmus Habermel* dated 1590. It exceeded its top estimate of £60,000 making £91,750. (Fig. 1.) This dial with seven faces records Equinoctial, Bohemian and Planetary hours with scales for sunrise and sunset. The second, a standing ring dial, 15" high, by *Tho Heath, London*, (Fig. 2.), tripled its top estimate making £75,250. Standing ring dials are quite rare, but in recent years several have come onto the market. They always fetch high prices being precision instruments. They achieve their accuracy by being fully adjustable for all latitudes, both North and South, with a large compass and screw feet for perfect leveling with the aid of built-in spirit levels.

Fig. 2. Standing Ring Dial by Thomas Heath.

Fig. 1. Polyhedral Dial by Erasmus Habermel - 1590.

An unusual type of inclining dial, early 18th Century unsigned but French, (Fig. 3.), made just £2820. Its unusual feature is the latitude arc that passes through the centre of the inclining plate. These arcs are normally fitted at one side. Note that the dial was made for an unusually wide range of latitudes, ranging from 5°S to 82°N.

Fig. 3. Unusual French Inclining Dial.

CHRISTIES SOUTH KENSINGTON – 7 JUNE

This sale had a large number of dials but many of lesser quality. Consequently many were unsold. A most unusual dial offered was a mechanical equinoctial dial signed simply *I F H*. Unfortunately its condition was not good and it had parts missing. This was one of the unsold items but it appeared again in October at Christie's Los Angeles and
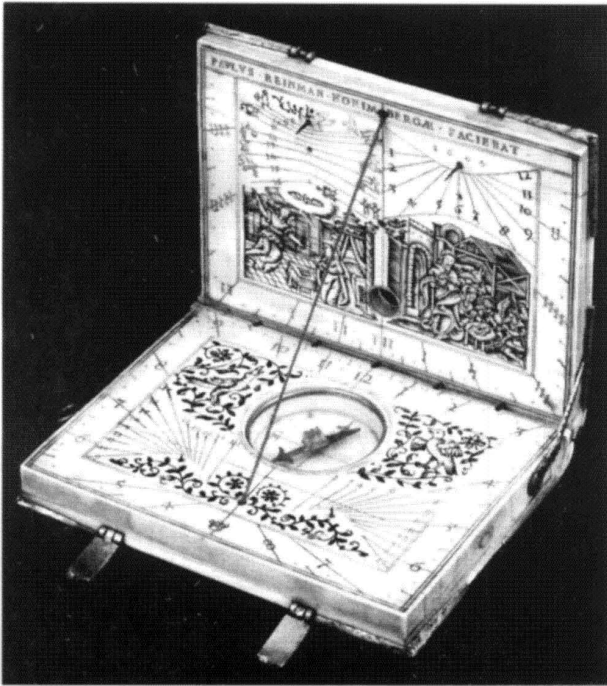
Fig. 4. Ivory Diptych Dial by Pavlvs Reinman - 1604.

later at South Kensington in December, and was still unsold. Also in this sale was a most attractive ivory diptych dial. (Fig. 4.), by *Pavlvs Reinman, Norimbergæ*, dated 1604. It was of the rarer book form carrying several horizontal and vertical dials in the Nuremberg tradition. The 'covers' of the book had additional scales for Perpetual Calendar, Moon dial conversions and a Wind Rose. It sold for £14,100.

SOTHEBY'S OLYMPIA – 20 SEPTEMBER

This was the first instrument sale from Sotheby's new premises in Olympia. This sale included several good dials. Among them were four 'Butterfield' types, two of the silver ones making around £900, one was unsold and the brass one made £646. An exceptionally large (14" diameter) ring dial, by *J. Evans* was sold for £5875. A French gilt brass pocket nocturnal, unsigned but dated 1597, (Fig. 5.), was a very attractive item and nearly doubled its top estimate making £19,975. A German pocket compendium from 16th Century made £6462. The real star of the sale was also a compendium. It was made by the famous London instrument maker *Elias Allen* around 1615. (Fig. 6.) With a diameter of only 2¼" it was little larger than a pocket watch. This compendium sold for £47,000.

CHEFFINS, CAMBRIDGE – 6 DECEMBER

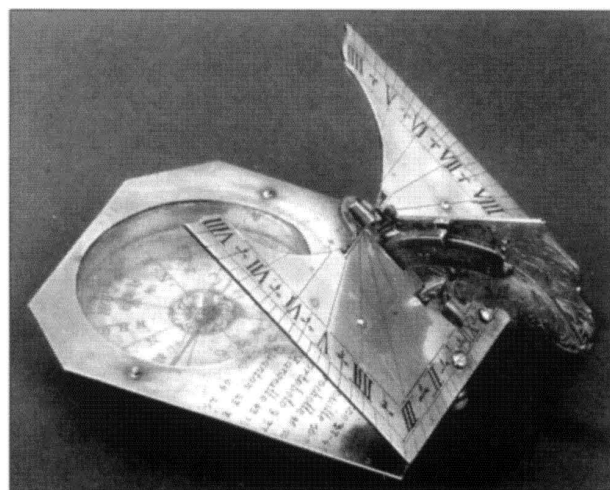This was one of my local sales and therefore worth a visit. There were no dials, but amongst a large quantity of books I came across a copy of 'Sundials' by Eden & Lloyd (the famous Gatty 4ed.). It was in excellent condition and I intended to buy it to replace my somewhat tired and overworked copy. I was the under-bidder at £150 against a
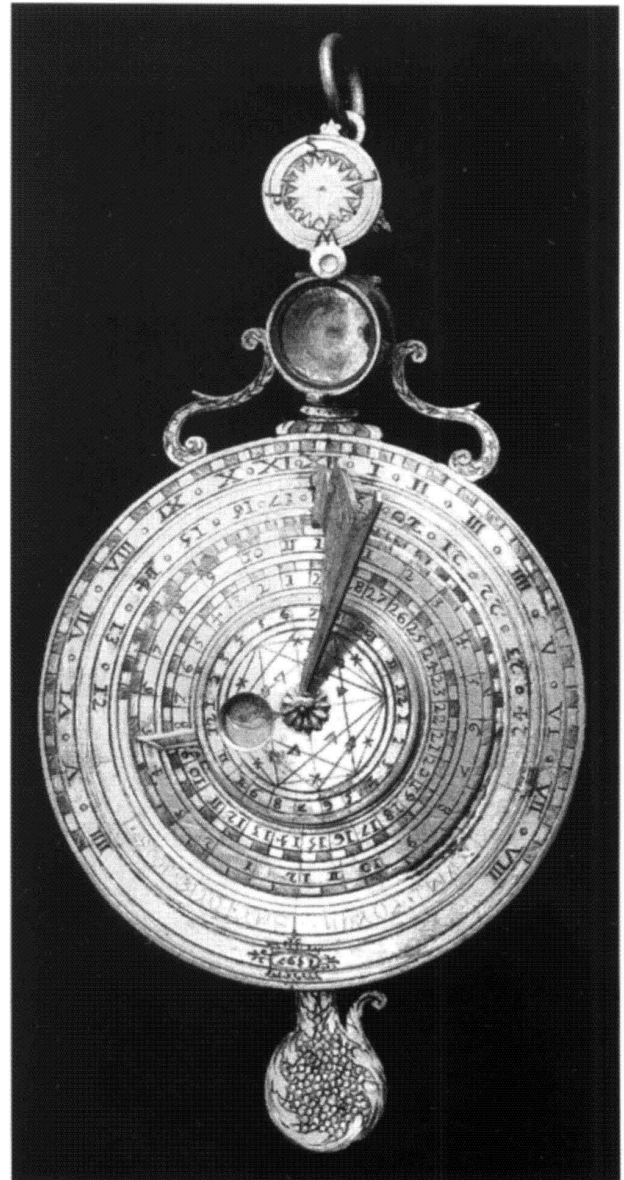
Fig. 5. French Gilt Brass Nocturnal - 1597.

dealer who acquired it at £160 plus premium. This meant that he paid around £188 for it. With a reasonable mark-up his selling price will have to be well over £200. If you already have a copy, then hold on to it, if not, buy one soon before the price rises even higher.

CHRISTIE'S SOUTH KENSINGTON – 13 DECEMBER

This was perhaps the best sale of the year having several rare and interesting dials. A very attractive 16th Century French gilt brass astronomical compendium, unsigned but attributed to *Philippe Danfrie*, was sold for £157,750, well above its top estimate of £120,000. (Fig. 7.) This compendium carries the English Tudor Royal Arms and is complete with its tooled leather case.

There was one 'Butterfield' type dial that was, for me at least, by a previously unrecorded maker, *Bizot AParis*.
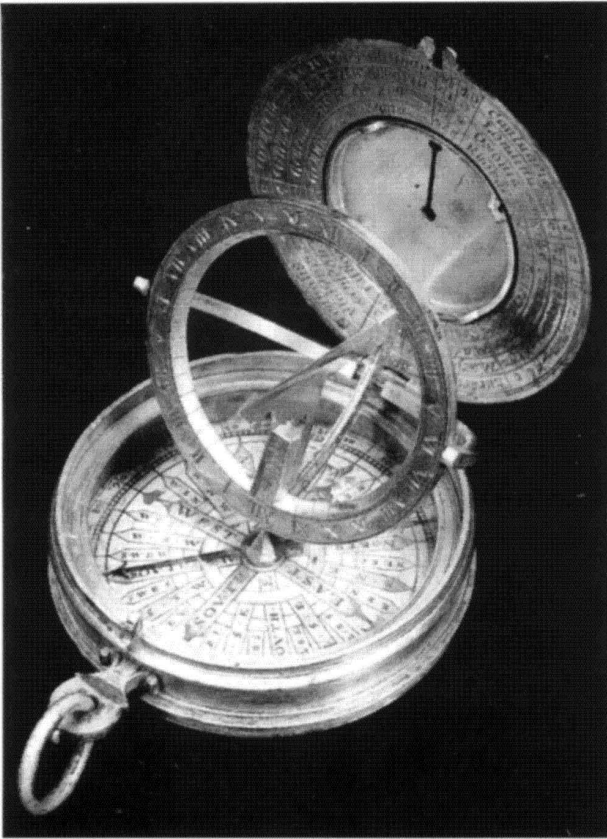
Fig. 6. Astronomical Compendium by Elias Allen.

Fig. 8. 'Butterfield' Dial by Bizot.

Fig. 9. Small Poke Dial.

Fig. 7. Astronomical Compendium by Philippe Danfrie.

(Fig. 8.) It sold for £2820. A particularly interesting feature on this silver dial was a gilt gnomon support in the shape of lion, another first I believe. These are normally in the form of a bird using its beak as the pointer.

A small 'poke' or pocket ring dial, only 1¼" diameter, signed simply *MS*, was sold for £352. (Fig. 9.) It is of the less common type that has its hour scale marked on a separate strip of brass inserted such that its effective diameter is reduced. Although not adding to its accuracy

this design probably makes calibration easier. A multiple wooden Chinese dial was offered. (Fig. 10.) This had four similar equinoctial dials set around its central compass on an octagonal base. Chinese dials of this type do occasionally come onto the market and are quite interesting at a relatively low price. It sold for just £235.

PHILIPS – 18 DECEMBER

Philips have now joined up with Bonham's making 'the world's third largest auction house' – their words. With this merger we can expect to see an increasing number of interesting items coming under their hammer. They obviously hope to take away some clients from Christie's and Sotheby's. It will be interesting to see how they fare in the coming year or two.
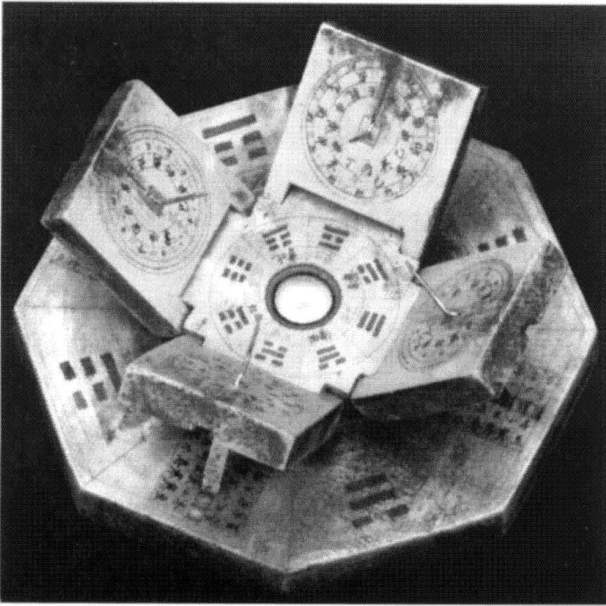
Fig. 10. Chinese Multiple Dial.

Sales at Philips have traditionally carried only a few dials, mostly of the 'garden' type. In this sale there was one by *Mellor, West Malling*. They also had a good quality ring dial by *Butterfield*. (Fig. 11.) Dials by him other than 'Butterfield' type dials are relatively uncommon and, like all of his instruments, always of exceptional quality. Many people forget that he was a top-class instrument maker and associate his work mainly with the ubiquitous 'Butterfield' dial. This ring dial sold for £4200 reflecting its fine standard of workmanship.

Fig. 11. Equinoctial Ring Dial by Butterfield.

During October I made a trip to Crakow in Poland. In an antique shop there I found a modern 'Heliochron Taschen Sonnenuhr' dial signed *Muster Gesetzl Gesw*. It was not of any great value. I paid the princely sum equivalent to £8 for it. It shows that there are still a few bargains out there to be found. Good hunting for 2002.

FORTHCOMING SALES FOR 2002

These are the dates set at the time of writing but some have still to be determined*. Please check to confirm before travelling to view any sale.

Christie's South Kensington	Tom Newth – 020 7321 3147 11 April, 2 July, 4 December
Sotheby's	Catherine Southon – 020 7293 5209 (now at Olympia, Hammersmith Road, London) April/May 2001 On-line sales at <sothebys.com> 30th May, November*
Bonhams (incorporating Philips)	James Stratton – 020 7468 8364 Alexander Crum-Ewing – 020 7393 3950 28 May, 3 December
Scientific Instrument Fair Radisson SAS Portman Hotel,London.	Stuart Talbot - 020 8969 7011 28 April 2002, 27 October 2002

ACKNOWLEDGEMENTS

BOOK REVIEW

La Gnomonique, by Denis Savoie, Les Belles Lettres, Paris, 2001. 453 pages, 135 line diagrams.

This new work by the president of the Commission des Cadrans Solaires of the Société Astronomique de France will make an important contribution to sundial-construction.

In this first volume there are no illustrations or descriptions of elegant and ornamental sundials from the past. The author intends to produce a historical survey in due course, together with a few topics which he has so far omitted, such as the design of reflected sundials and the various altitude dials.

Instead of making a historical approach he has produced a practical guide for the present-day maker of sundials. First he explains all the factors which decide what the dial can do and how such factors are to be determined. Wherever possible one is advised to consult published maps and ephemeris tables. Then on the basis of these geographical and local measurements a highly mathematical formula is developed that defines the lay-out of the dial and the form and position of the gnomon. A strong preference is shown for laying out lines by plotting rectangular co-ordinates for the calculated positions of the shadow. Anyone who has attempted with a simple protractor and straight-edge to draw straight lines or curves on a full-scale working drawing or directly upon an irregular surface will appreciate this approach!

The carefully constructed equations can be rather daunting. For instance it is rather difficult to trace the hour-lines on a flat surface which is inclining from the horizontal and also facing obliquely away from the meridian-line. Nevertheless the process demonstrated here to fix just one of those lines is particularly complicated. Five relevant angles are involved and appear in a series of calculations in more than forty combinations of their trigonometrical functions! However even that is manageable with a modern computer, which can be programmed to print out values for the whole design.

It is true that such an abstract approach to design problems may not be attractive to everyone. I know that some designers who have a strong visual sense prefer to make exact drawings from which they can take their measurements. However the analytical method can provide an array of lines and key points with great precision. In fact there is a sensible caution in the book against over-estimating the possible accuracy of a shadow-line on a sundial.

Step by step, through twenty-eight chapters, the reader is guided through the mysteries that discourage one from tackling unusual designs. Azimuth and analemmatic dials and the projection of hour-lines upon the internal surface of hemispheres and upon cylindrical surfaces such as architectural columns are all explained, together with unusual innovations such as Gordon Taylor's equiangular sundial for the Herstmonceux Observatory, and the bifilar sundial described for us by Fred Sawyer. More elaborate dial furniture such as Italian and Babylonian hour-lines and the construction of diurnal curves are all explained. We are shown how to determine the number of hours during which any particular dial is illuminated by the sun, the most reasonable length for the gnomon, and how to predict local problems such as the shadow cast by an overhanging roof.

All this and much, much more! One feature of the book which I particularly liked was that plenty of numerical examples are given throughout, where one can test one's grasp of the different calculations involved. It gives one confidence in the method if the correct result can be reached from the data provided.

However it must be emphasised that this is not an introduction to sundials for the complete novice. For instance, it is not until page 131 that one meets a simple description of the horizontal sundial and even then the treatment is rather mathematical.

This book is a hoard of good things. It seems presumptuous to draw attention to one rogue page among so many, but the logic of an interesting development on page 349 seems to falter due to three misprints and an error.

For many readers the book will offer a new challenge by encouraging them to venture further into the art of dialling. However, one looks forward to a future edition translated into the English language so as to make its guidance simpler for us all.

Walter Wells

JOURNAL REVIEW

Compendium, Journal of NASS. Vol.8 No.1 (March 2001)

The 'Sightings' section of Compendium usually supplies something of interest, and in this issue a spectacular 'Sightings' photograph is reproduced on the cover. It is a 16-foot-high vertical dial on the side of a red wooden barn, visible from the road (Route 30) in Vermont. The barn wall declines 17° west of south The numerals 8 am to 5 pm and the hour lines are painted white wood, and the gnomon is white metal. The description of this striking dial is headed 'A Gift to Vermonters'.

The issue contains several notes on the use of the rainbow as an altitude or an azimuth dial, including an account by John Moir of his device for sighting the summit of the rainbow's arc and reading the hour by plumb-bob and nomogram lines.

Some of the most interesting 'Compendium' items are to be found among the snippets headed 'Letters, Notes, e-mail'. Somebody proposes making a 'Sundial calendar for the year 2002' with 365 items, photos, pictures, and posting it on the internet for enthusiasts to download, and print-off and staple Somebody has made a backyard mini-stonehenge, circular and with equally-spaced stones, as a sun clock with human gnomon. Somebody describes a plan for a huge 'Heritage Sundial' being made of old railway . lines and granite blocks, as a tourist attraction to restore the fortunes of the ex-company town of Pinawa, Manitoba.

Compendium, Journal of NASS. Vol.6 No.2 (June 2001)

This issue sees the start of a series of articles by Claude Hartman called 'Back to Basics'. It is written 'by a novice for novices' and is intended for readers with 'little math' and who are put-off by the formulae, equations, plane and spherical trigonometry often seen in the pages of Compendium. The author starts (wisely) with the construction of an equatorial dial, a design easy to make accurately with few tools. We will watch the 'Back to Basics' series with interest.

Two articles in this issue refer to the sundials of the medieval Islamic world. An article by Berggren, of Burnaby, B.C. Canada, tells of the use of the length of the shadow of a vertical gnomon in identifying prayer times. It touches on the skills of Muslim mathematicians in projecting spherical figures onto plane surfaces. An article by Ferrari of Modena, Italy, describes a particular type of universal sundial and suggests a possible method for its design.

René Vinck presents us with a neat straightforward design for a latitude-independent portable sundial. It has only two parts: a quadrant-shape dial plate drawn on millimetre graph paper, and a transparent cursor (acrylic sheet strip) with vertical pin gnomon at one end. The other end is pivoted at the right-angle point where the straight sides of the quadrant meet. The design is so simple and the method of use so clearly explained that many readers will be encouraged to 'have a go' at this one.

Fred Sawyer announces that NASS is holding a year-long celebration of the 350th anniversary of the death of Samuel Foster, Professor of Astronomy at Gresham College London, one of Fred Sawyer's heroes.

Compendium, Journal of NASS. Vol. 8, No.3 (September 2001)

Samuel Foster the brilliant 17th Century mathematician is celebrated in three articles in this issue. René Vinck writes about Foster's 'Circle', the basis of his dialling scales. Fred Sawyer writes more about the dialling scales and also writes about the 'Foster-Point Sundial'.

The 'Back to Basics' series continues with some sensible advice about the placing of your first sundial; will tree-shadows hide it? Will it be in sunlight throughout the year? There are useful notes on finding your latitude and longitude and your north-south line-really basic material.

There was an enthusiastic report from Bethanie Sawyer, a participant in a student-group's visit to an excavation (under a house in present-day Rome), of the 'Sundial of Augustus'. Only a small section of the pavement and its bronze markings have been exposed by the excavation started 20 years ago, but even from this fragment the size and impressiveness of the original could be surmised.

From this 2000-year-old Augustus Dial, our attention is turned to an ultra-modern Sundial Bridge at Turtle Bay Museum in Redding, California. This footbridge spans the Sacramento Rive to connect the north and south sections of the Museum Park. It is made of translucent non-skid glass decking, suspended from cables attached *at one end only*, to a gnomon-shaped pylon sloping due north. This will become the gnomon of a large horizontal dial to be laid out on a plaza at the north end of the bridge. The front cover of this issue of Compendium shows a photo of this spectacular Sundial Bridge.

Compendium, Journal of NASS. Vol 8 No.4 (December 2001)

This issue opens with two articles on bifilar sundials. First comes a short description by Fer de Vries of his bifilar dial with parallel date-lines, an ingenious design involving a straight N-S edge and a double-curved E-W edge. The author provides a photo of an actual example set up in a park in the Netherlands.

Then comes an interesting account by Claude Hartman of the dials of a Spanish/Majorcan engineer/designer, Rafael Soler Gayá. He has developed the bifilar design to intersection of shadows not merely of two straight edges but of one straight and one curved edge. This extension of the 'bifilar' idea gives rise to many aesthetically pleasing possibilities, several of which are shown in photographs and diagrams in the article. Two of the designs had been prepared for the Genk Sundial Park in Belgium. In one, the curved edge, a parabola, is provided by a jet of water from a fountain, reaching a height of precisely 1m and crossing a straight horizontal fence whose top is 1m above the dial face. Another curve is a catenary: a chain suspended from pillars at each end; the chain's shadow crosses that of a vertical pillar below. Perhaps after all there is something more to bifilar design than the mere exhibition of mathematical acrobatics.

This year's annual 'Sawyer Dialing Prize' went to Robert Adzema, for the design of a large equatorial/horizontal dial placed outside the Free Library of Suffern, New York. The two dials (equatorial standing on horizontal plinth) have a common gnomon, a stainless steel rod. A nodus, a disc with pinhole aperture, throws a light-spot onto an analemma which marks the noon-line of the equatorial dial, so the analemma becomes a solar calendar. A good series of photos in the 'Sightings' section shows this prize-winning dial.

This issue includes an account of the 7th annual NASS conference, held in Montreal, Canada. It had been arranged months ago for the weekend of 15 September, but 'emotional turmoil and disrupted travel schedules' after the 11th September Attack meant that there were fewer participants than usual Those who came obviously made a success of the occasion, and the account includes photographs of some of the many good sundials in and around Montreal.

M.S.

READERS' LETTER

LIME MORTAR

Andrew James' fascinating article about a render for sundial panels encourages me to write once again about lime mortar. Once before I wrote to the BSS explaining the technical difference between lime and cement, yet still there have been many cases of repairs to historic sundials, cited in the journal, using cement.

Cement could probably NEVER be use in a mortar mix because it will prove to be stronger than the surrounding materials. What this means is that the cement mortar will erode more slowly than the adjacent materials (perhaps a precious carved limestone sundial) and in fact cause increased erosion to the softer material.

Lime mortar should be used in all cases. Cement might be appropriate in concrete buildings, but not in any building where the movement of water vapour is part of its nature.

Anybody who cannot find people locally to advise them on he use of lime should contact the Society for the Protection of Ancient Buildings, technical enquiries; or I can help.

Peter Ayley
Fondation_Barguillere@compuserve.com
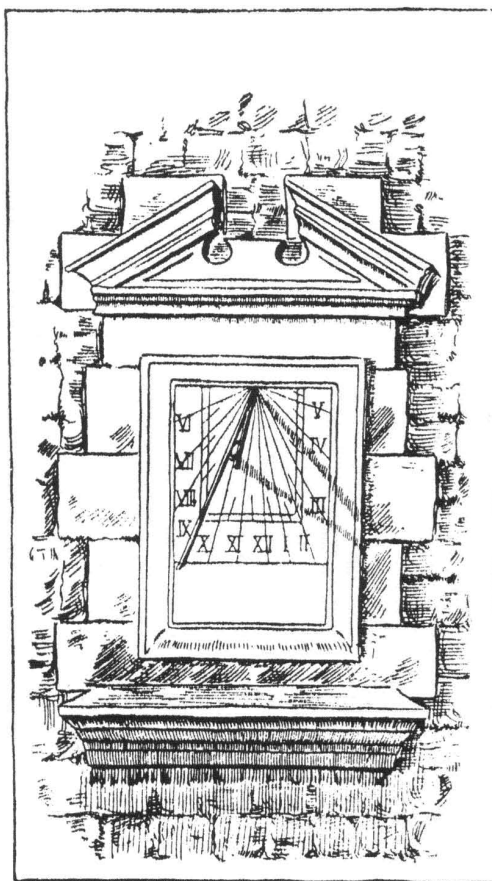
A DERIVATION OF THE EQUATION OF TIME

JOHN FOAD

I was delighted, a few years ago, to discover that the 'errors' of a sundial were well known and documented, and that by allowing for them we could get accurate 'clock' time from a dial. In my ignorance I was even more surprised to find that the deviations were the same every year, depending only on the date. I found that dial time runs ahead of the clock by over a quarter of an hour at Hallowe'en. By St Valentine's it lags by almost as much, and then continues to vary, in a regular pattern, through the rest of the year. As I started to acquire back numbers of the Bulletin, I found that the reasons had been documented in many articles. Especially clear and full explanations were given by Mr C P Adams in June 1993, Mr D W Hughes in the following issue, and Mr A Mills in February 1994.[3]

The extent of the variation, I found, can be expressed as the sum of two sine curves. (Diagrams in ref.3). One, due to the elliptic orbit of the Earth, has a period of twelve months, and is at a minimum at perigee, when the Earth is closest to the Sun, and at apogee, the opposite extreme of the orbit. The other sine curve, with a period of six months, arises from the tilt of the Earth's axis, and has its minimum effect at the solstices and the equinoxes.

The equations for the two curves are approximately.

$E1 = 8 \times \operatorname{Sin} A\{D - 2\}$ and

$E2 = 10 \times \operatorname{Sin} (2 \times A\{D - 80\})$

where $A\{D\}$ represents the angular position of the Earth relative to the Sun on day D (D running from 1 to 365). $A\{D\}$ can be expressed in degrees as $(360 / 365.25) \times D$.

The term $\{D - 2\}$ relates to the fact that E1 is zero at the perigee, as mentioned above, on or about January 2 (D = 2). The term $\{D - 80\}$ appears because E2 is zero at the Vernal Equinox about March 21 (D = 80). The factors 8 and 10 (and also more accurate approximations usually given as about 7.6 and 9.8), I have always had to take on trust.

I recently came across a way of finding these factors from first principles, using the eccentricity of the Earth's elliptical orbit (about 1 : 60), and the magnitude of the tilt of the Earth's axis (23.44°). This is published in the book Practical Astronomy by H Robert Mills[1], which I can strongly recommend to anyone with an interest in sundials or astronomy. It has a very practical 'hands-on' approach, and includes a good section on sundials. It is clear,

thorough, and entertaining. The author contributed several articles to the Bulletin between 1992 and 1997, but as far as I know he never wrote up for the Bulletin his work on the derivation of the Equation of Time. The rest of the present article is a summary, in my own words, of Mr Mills' argument. It does not follow his method in every detail, and any errors are entirely my responsibility.

THE EFFECT OF THE EARTH'S ELLIPTIC ORBIT

Taking for simplicity the Earth-centred view, the Sun (which I shall call the 'True Sun') appears to travel at a variable speed in an elliptic orbit ABA'B' around the Earth E at one focus of the ellipse (see Figure 1), completing one circuit in one year. Meanwhile the Mean Sun, a theoretical concept on which our clock time is based, travels in a circular orbit at constant speed, starting and finishing at the same time as the True Sun. The True Sun is sometimes ahead of the Mean Sun, and sometimes behind. The difference in the angle reached by the True Sun and the Mean Sun at any point around the circuit (ie at any calendar date) gives a measure of the correction needed at that date to make sundial time agree with clock time. This correction is known as the Equation of Time.

Fig. 1.

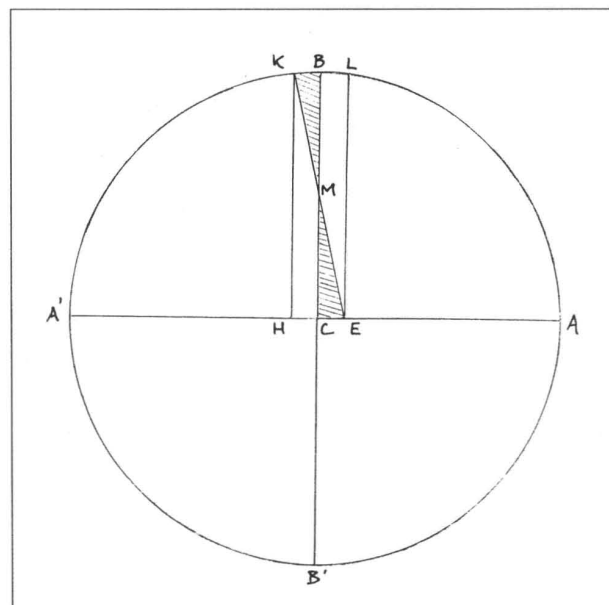The eccentricity of the ellipse is given by the ratio CE : CA and is about 1 : 60. It is exaggerated in the diagram for clarity. At A, the perigee, the Mean Sun and the True Sun are together. The speed of the True Sun is determined by Kepler's Second Law, which says that the line from the focus to the Sun sweeps out equal areas in equal times. At the apogee A' the True Sun has swept out one half of the

area of the ellipse, and the Mean Sun is also half way round, so again they are together. The greatest difference can therefore be expected to be at one quarter of the way round, and again at three quarters.

Let us consider the situation some three months after perigee, where the Mean Sun is at L (angle AEL = 90°), and the True Sun has raced ahead and reached K. Because the Sun sweeps out equal areas in equal times, it follows that the area AKEA is one quarter of the area of the ellipse ABA'B'. But the segment ABC is also one quarter of the area of the ellipse. Therefore the two shaded areas, MBK and MCE, are equal, and HC is very nearly equal to CE. Also, because the eccentricity is small, EL is very nearly equal to CA. Thus the tangent of the angle LEK is approximately HE / EL, or about 2 x CE / CA = 2 / 60.

Tan LEK = 2 / 60 = 0.0333, from which we find that angle LEK = 1°.908. This is the angular difference between the True and the Mean Sun at this point in the orbit. The True Sun is 1°.908 ahead of the Mean Sun, or 1.908 x 4 minutes, which is 7.63 minutes of time.

Now we have seen that the True and the Mean Suns are together again at apogee (A'), so if the True Sun runs ahead in the first half of the year it must fall back through the second, reaching its maximum difference at about three months after apogee, at B'. It is reasonable to assume therefore that the difference in position varies sinusoidally as the Sun moves from 0° at A, through B (90°), A' (180°), B' (270°) and back to A. A is the perigee, taken as 2 January, which leads to the formula for this part of the Equation of Time:

E1 = 7.63 x Sin A{D-2}

where D is the day number (1 January = 1), which can be written out in full as:

E1 = 7.63 x Sin {(360 / 365.25) x (D - 2)}

THE EFFECT OF THE TILT OF THE EARTH'S` AXIS

The second component of the Equation of Time arises from the inclination of the Earth's axis.

Fig 2 is an Earth-centred view of the Solar System. The Earth is at E, spinning at one revolution a day about its axis, which is vertical, through the Pole at P. The inclined curve CTC'T' is *not* the daily path of the Sun through the sky. It is the slow path of the Sun around the Earth in the course of a full year. Thus it shows the Sun at C, and at C', the Equinoxes, lying on the Ecliptic. At T, the Summer

Solstice, it shows the Sun 23½° above the Ecliptic, and at the Winter Solstice T', it is 23½° below. As the Earth turns once, the Sun moves 1/365 part of the way along the Ecliptic CTC'T'.
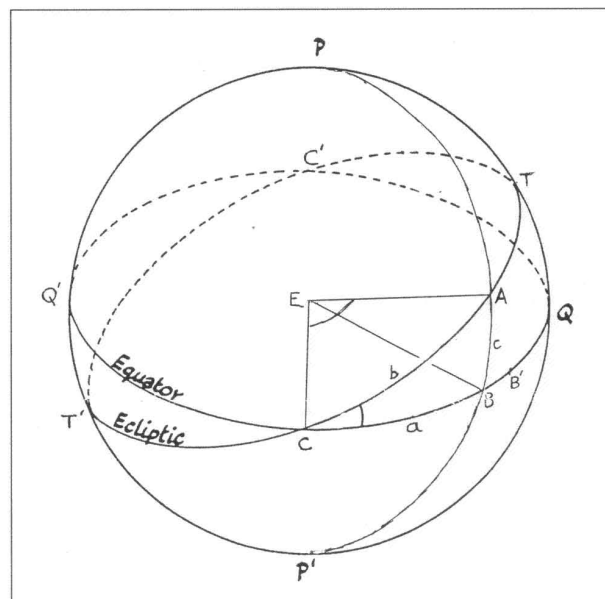
Fig. 2.

I now need to introduce the idea of the 'True Sun on the Equator' (TSE). Like the Mean Sun, it has no actual existence, but is a useful concept. If the True Sun is at A, for example, we draw the Great Circle through the Pole P and down through A, meeting the Equator at B. The point B is what I call the TSE.

Now the shadow of a sundial is cast of course by the True Sun, say at A, which is in the same vertical (and 'shadow-casting') plane as the TSE at B. A clock measures time by the position of the Mean Sun. So the difference in the times shown by a sundial and a clock is governed by the difference in the positions of the TSE and the Mean Sun.

We can now begin to see how they differ. Take the situation at the Vernal Equinox. In the course of one day the Mean Sun travels 1/365 of the way around the Equator from C towards Q. At the same time the True Sun moves 1/365 of the way along the Ecliptic towards T, and the TSE moves along the Equator by a shorter distance. Because the True Sun is climbing (at about 23°) the TSE lags behind the Mean Sun. However, the situation is different by the time of the Summer Solstice. At that point the True Sun has reached T and its daily movement is horizontal, parallel to that of the Mean Sun at Q. The True Sun is on an 'inside track' as they race around the Pole, and the TSE actually moves round the Equator faster than does the Mean Sun.

So, we have the TSE losing against the Mean Sun at the Equinoxes, and gaining at the Solstices. Midway between,

the two conceptual suns will be moving at the same speed. From C to the point B (if the angle CEA is 45°) the TSE lags behind the Mean Sun. After B it starts to catch up again. The accumulated difference will reach a peak at B.

While the TSE moves from C to B, the Mean Sun moves from C to B', where CEB' is also 45°. We need to know, therefore, the difference between CB and CB', which will give us the maximum difference between Sun Time and Mean Time. To find CB we need a little spherical trigonometry. Consider the spherical triangle ABC. Arcs like CB are treated as angles, and are measured as the angle subtended at the centre of the sphere. They are usually denoted by the lower case letter of the opposite corner. Thus for example the side CA is known as 'b' and has a magnitude of 45°. The angles of a spherical triangle are measured on the surface of the sphere at the point of the angle, so that for example the angle B is 90°, and C is 23°.44, as we might expect.

One of the standard formulae for spherical triangles is known as the Four Part Formula. It tells us that in such a triangle,

$$\text{Cos } a \times \text{Cos } C = \text{Sin } a \times \text{Cot } b - \text{Sin } C \times \text{Cot } B$$

Relating this to our triangle, we have

$$\text{Cos } a \times \text{Cos } 23°.44 = \text{Sin } a \times \text{Cot } b - \text{Sin } 23°.44 \times \text{Cot } 90°$$

Now Cot 90° = 0, so the last term disappears. The angle b is 45°, so Cot b is 1. Dividing both sides then by Cos a, we get

$$\text{Tan } a = \text{Cos } 23°.44 = 0.9175, \text{ so that } a = 42°.536$$

The difference between the arcs moved by the TSE and the Mean Sun is thus 42°.536 - 45° = -2°.464

The maximum value of this component of the Equation of Time (again, at 4 minutes per degree) is thus 4 x (-2.464) = -9.856 minutes of time. Again it can be assumed to vary sinusoidally, but this time it reverts to zero at four points (C, T, C', and T'). We therefore have two full cycles per year, so that over the year the component varies as the sine of twice the angular position of the Sun. So now we have

$$E2 = -9.86 \times \text{Sin } (2 \times A\{D - 80\})$$

taking the angle from the Vernal Equinox (21 March, day number 80) which can be written in full as:

$$\mathbf{E2 = -9.86 \times Sin \{2 \times (360 / 365.25) \times (D - 80)\}}$$

In order to understand why this factor is negative, it helps to picture the True Sun and the Mean Sun moving across the sky during the course of a day, one behind the other. If the Mean Sun is ahead in the sense of Fig 2, then as they pass overhead from East to West, the True Sun will arrive first. When the True Sun has reached the noon meridian, clocks still show some minutes before noon. It is therefore necessary to subtract this component from Sundial time to get Clock time.

THE FULL EQUATION OF TIME

This now leads us directly to our full formula for the Equation of Time in terms of the Day Number:

$$\mathbf{E = E1 + E2 = 7.63 \times Sin \{0.986 \times (D - 2)\} - 9.86 \times Sin \{1.971 \times (D - 80)\}}$$

This gives values close to those tabulated for example by Cousins[2]. The error is largest towards the end of September, where it reaches 69 seconds. The accuracy can be increased by tweaking the values of 2 and 80 (which are only approximate, and vary from year to year). However I feel that the formula as given is adequate for any practical purposes to an amateur like myself, and it has the very real attraction that I can now understand how the parameters are developed from the physical characteristics of our Solar System.

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1. H Robert Mills: *Practical Astronomy, A User-friendly Handbook for Sky-Watchers.* Albion Publishing (now Horwood Publishing), Chichester, 1994
2. Frank Cousins: *Sundials: a Simplified Approach.* John Baker, London, 1969
3. A.A. Mills: *Bull.BSS* 94i 30 (1994)

Author's address:
Greenfields
Crumps Lane
Ulcombe
Kent, ME17 1EY

THE MAKING OF THE TOWNELEY HALL SUNDIAL

A New Sundial commemorating the life of Richard Towneley of Burnley, Lancashire

ALAN SMITH

The name Richard Towneley will not be new to readers of this Bulletin, for Tony Kitto gave a good sketch of his life and contributions to science in the article he wrote entitled *Richard Towneley and the Equation of Natural Days* in the June 2001 issue, pp.60-65. At the beginning of August 1999 an exhibition was organised at Towneley Hall, Burnley, called *The Towneley Time Trials*, which lasted for almost a year, and which contained much material relating to Richard Towneley's life and work, particularly in the field of astronomy and timekeeping, and his friendship for and relations with England's first Astronomer Royal, John Flamsteed. At the close of the exhibition there was much discussion about the possibility of creating some sort of permanent memorial to this important and relatively neglected 17th century scientist, and the decision was made to mount a sundial in his memory, on the wall of Towneley Hall.

Having been much involved with the *Towneley Time Trials* exhibition I was commissioned in the summer of 2000 by the Towneley Hall Society, in collaboration with the

Fig. 1. The completed dial mounted on a buttress at Towneley Hall, Burnley.

Borough Council of Burnley, to design and make a suitable dial. A series of designs was initially made; these were put before the Borough Council and English Heritage, since special permission was required because Towneley Hall is a Grade I listed building. This process took some months, but by the beginning of 2001 authority to proceed had been granted, and work on the dial began.

After deciding that the dial would be vertical, south-facing and made of slate, it was agreed that certain features would be incorporated, and these are listed below (see Fig. 1):

1. TOP LEFT
A diagrammatic representation of the escapement which Richard Towneley designed in 1676 for the 'great clocks' at the then new Greenwich Observatory, made by Thomas Tompion for Flamsteed's use, and provided by Sir Jonas Moore.

2. TOP CENTRE
The Towneley Coat of Arms

3. TOP RIGHT
The letters "MM" for the Millennium, in Roman numerals

4. ABOVE DIAL
Details of Latitude and Longitude

5. CROSS
On the noon line to show the allegiance of the Towneley family to the Roman Catholic faith

6. NAME
Richard Towneley's name and dates

7. NODUS
A nodus on the gnomon to mark the solstices and equinox

8. DIVISIONS
The dial to be divided into quarter hours

The dial was designed to fit on the exactly south facing surface of a corner buttress at the hall, and decisions on its height from the ground and its overall size were determined by trying variously sized pieces of hardboard held up at the
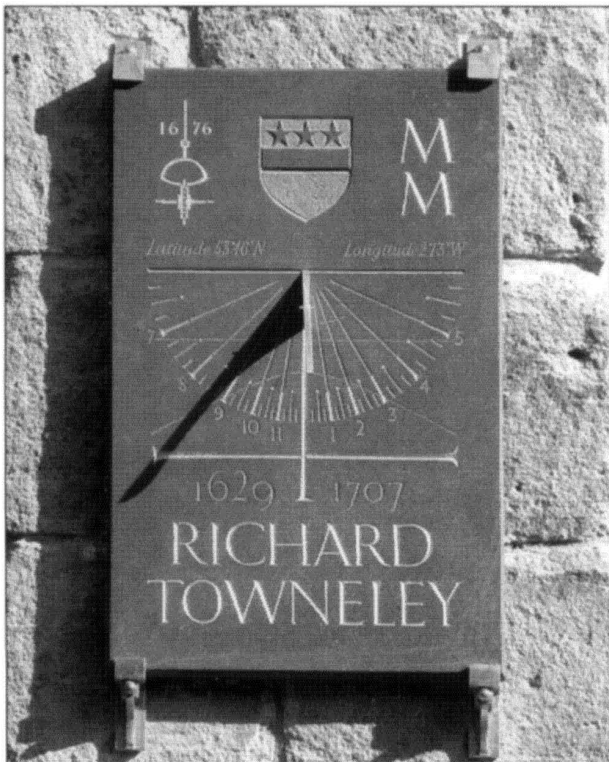
site. These tests resulted in the positioning of the bottom edge of the dial at about 11 feet above the ground, over the first buttress off-set, and a dial size of 36 inches high, 23 inches wide and 1.75 inches thick.

CONSTRUCTION OF THE DIAL

Normally newly made dials are presented in publications in their *finished* state, but for this article I thought it might be useful to give some indication of the actual work involved in designing and making a dial of this sort. At a rough estimate the work, including the initial design process, occupied about 600 hours, starting early in January 2001, with completion by the beginning of April. Transport to Towneley Hall from my workshop and mounting took one full day.

Source of the slate The slate was ordered from Inigo Jones Slate Works at Groeslon, near Caernarfon, Gwynedd, N.Wales. It was ground to precise dimensions with a bevelled front edge and delivered to my premises some weeks later. The weight is slightly less than 200lbs. (about 90kgs.)

Workshop support The first job on receipt of the slate was to construct a large timber framework to support it. In my restricted workspace I leaned this support against a heavy pottery kiln and secured it at the base to prevent slipping. A tool tray was also a necessary adjunct. (Sec Figs. 2, 3 & 4)
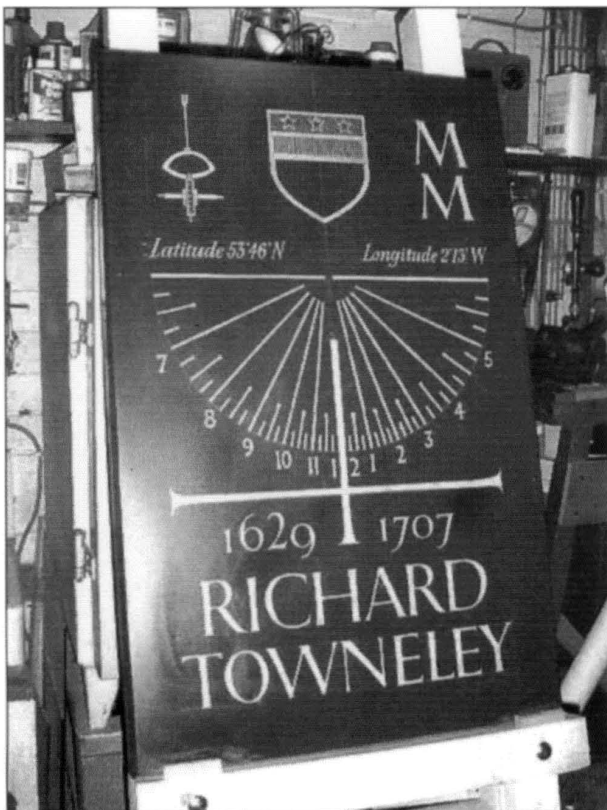
Fig. 2. The painted dial on its easel in the workshop.
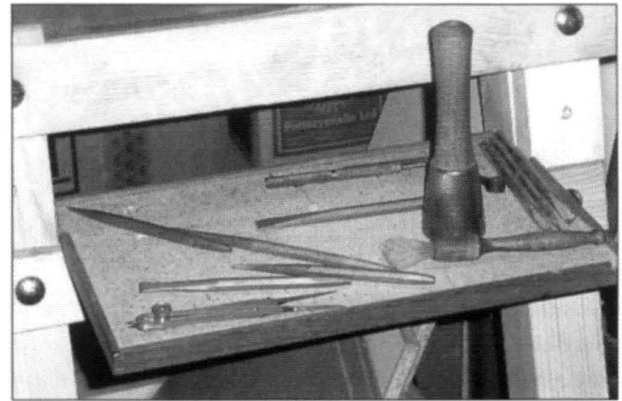
Fig. 3. Carving tools; various steel chisels, dummy mallet, brush and compasses of proportion (front left).

Fig.4. Work in progress with tool tray mounted on the easel.
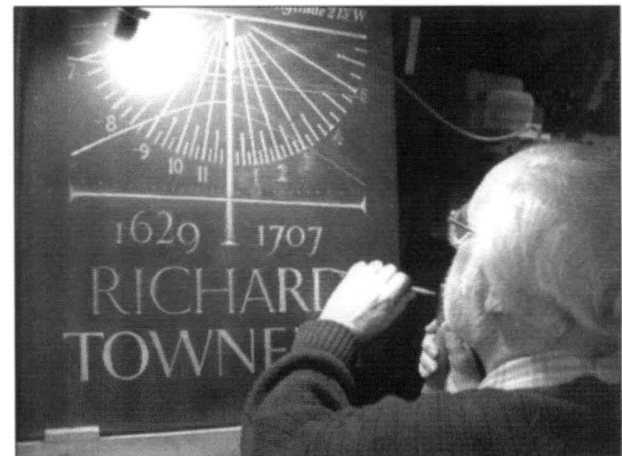
Fig.5. Carving the lettering, the dummy used 'overhand'.

Setting out the design Before any cutting can take place the small-scale chosen design must be enlarged on the slate, and for this the use of proportional compasses was a great help. At the same time the calibration of the dial itself had to be done with great accuracy, so I calculated the angles first geometrically, then mathematically, as a 'belt and braces' approach. As a final check Graham Aldred very kindly supplied me with precise co-ordinates from his computer programme to compare with my results, and in

this way highly accurate measurements were achieved. He also checked the solstice and equinox lines which I had produced by the 'Trigon' method, and also calculated the exact position of the nodus. I am most gratefull to Graham for his interest and assistance. The drawing of the dial and accompanying lettering and other furniture was done with a fine water soluble crayon, helpful in making corrections.

Painting the design As a guide to later cutting the best procedure is to paint the whole design on the slate with water-based colour - grey for the plainly cut parts and yellow ochre for the parts to be gilded. In this way the design can be judged, any alterations easily made, and the client can see how the finished dial will appear. At this stage a few important decisions were made when Susan Bourne (the Curator at Towneley) and Tony Kitto viewed the work. Painting before cutting is an ideal method (it was done by the Romans) and the work at this stage can be seen in Fig.2.

Cutting No words can adequately describe the process of cutting lines and lettering in stone, for this is a technique which can be acquired only by years of practice. The

Fig.8. Escapement design and almost completed coat of arms.

design, drawing and spacing of the lettering is also a discipline which inevitably needs some years of experience. The actual tools used - steel chisels, dummy mallet, brush, compasses and dividers - can be seen in Figs.3 and 4, and some idea of the way in which they are handled is shown in Figs. 5 and 6. A fine groove is first cut along the line to be followed, then the full form is cut on each side, maintaining a constant slope, sometimes striking the chisel with the dummy 'overhand' as in Fig.5, or 'underhand' as in Fig.6, sometimes heavily to remove large pieces and sometimes with great delicacy. Fig.7 shows something of this stage of the work, and it must be emphasised that no mechanical tool is employed since all the cutting is done by hand and eye. Working in slate is highly demanding - only the smallest of mistakes can be corrected, so sharp tools and steady judgement are required. Fig.8 shows the almost complete cutting of the Towneley coat of arms with its rough textured ground, and includes the clock escapement symbol. During the cutting the seating for the gnomon was also done (see Fig.9). To avoid unsightly fastenings the 10mm thick gnomon (see below) was inserted into a slot cut to receive it, with a single hole
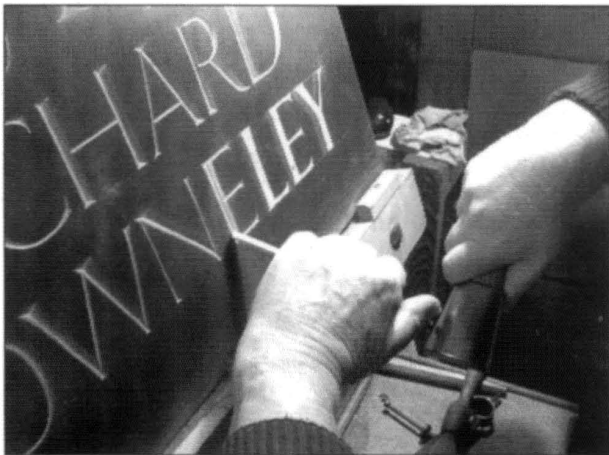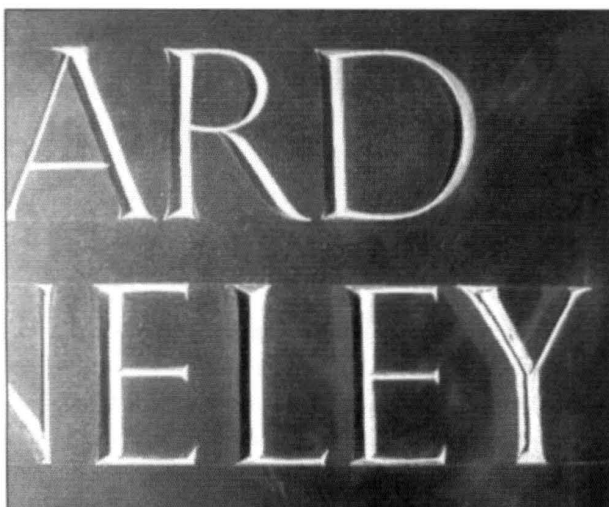

Fig.6. Carving the lettering, the dummy used 'underhand'.

Fig.7. Detail of partially finished carved lettering, the 'Y' incomplete with its centre line started.
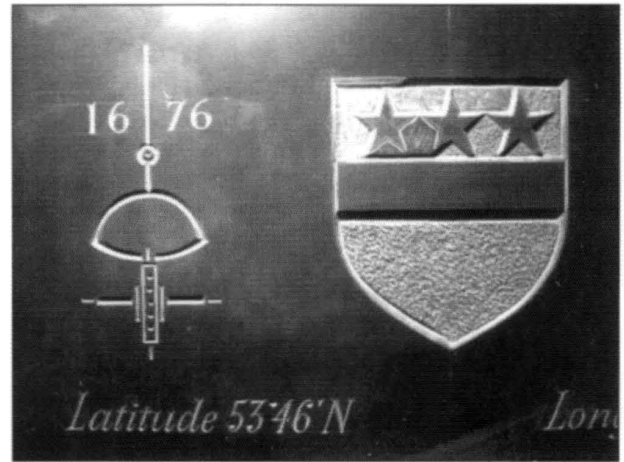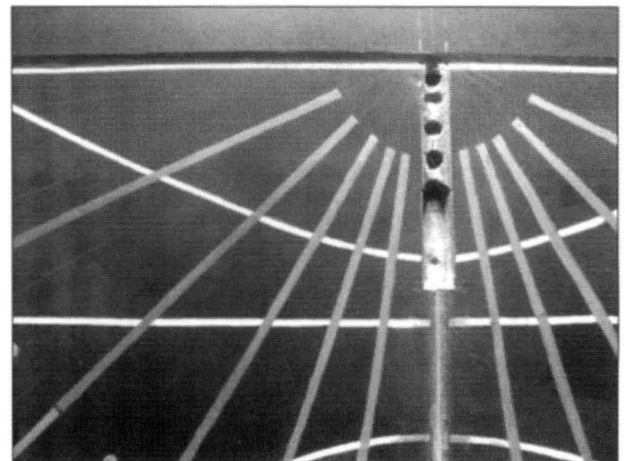

Fig.9. Detail of carved dial top line, painted hour lines and partially completed slot for the foot of the gnomon.

cut through the centre so that it could be fastened with a bolt from the back.

Gilding With the cutting complete the next stage was the gilding of parts of the design. Only certain parts were gilded, in particular the principal dial marks, the name of Richard Towneley, the 'MM' and so forth, the rest left plain to be seen by light and shadow in the sunshine. For outside work loose gold leaf is the best, and for the exposed position of this dial I used a heavy quality leaf, known in the trade as 'extra'. The parts to be gilded were first coated with red-coloured oil paint, then later with gold size. The size dries very slowly to the point where it is just right for applying the gold (e.g. 12 hour, 16 hour, 24 hour etc.) and at this stage the gold leaf was transferred to the work. Gold leaf is extremely flimsy and blows about all too easily! The tools used (see Fig.10) consist of a gilder's cushion with its protective parchment screen to avoid draughts, a knife for cutting the leaf, a gilder's 'tip' for transferring the gold to the work and a soft brush for easing the gold to the size. The illustration also shows a piece of leaf on the cushion and the open 'book' (containing 24 leaves held between sheets of tissue) as purchased from the material dealer. When applying the red paint and the gold size the edges of the work were overlapped (see Fig. 11) so that when everything was thoroughly dry the whole surface could be rubbed down, leaving the edges of the lettering etc. clean and sharp (see Fig.12).

Fig.10. Gilder's tools; the draught-screened cushion with a portion of gold leaf on it ready for cutting, cutting knife, gilder's tip, book of gold leaf and soft brush.

The gnomon Various materials may be used for making a gnomon, but in this case I chose aluminium. Years ago this would have been inappropriate in the polluted atmosphere of industrial Lancashire, but with the clean air legislation today this metal remains clear and bright. The form of the gnomon was cut from a 10mm sheet of aluminium, with a 10mm deep foot to fit into the recess mentioned above (Fig.9). I made an aluminium threaded bolt to fit into a tapped hole to hold the gnomon in place; it was important
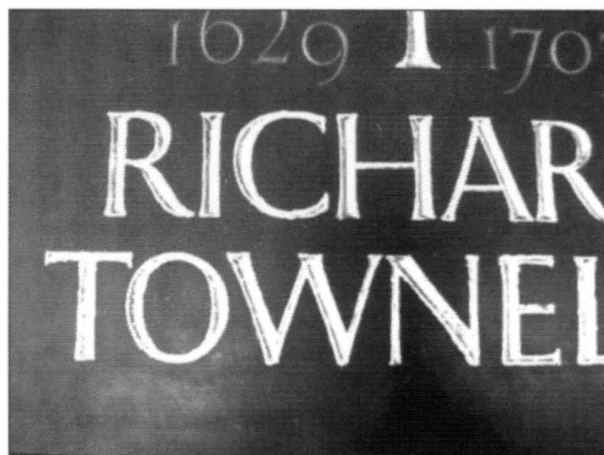
Fig.11. Gilded lettering before rubbing down.
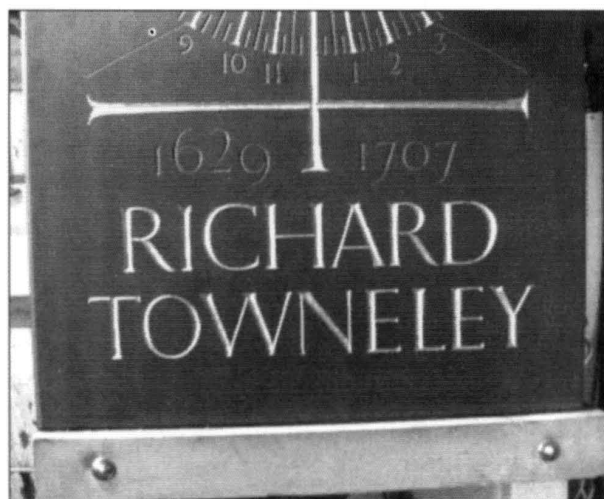
Fig.12. Finished gilded lettering, after rubbing down.

to use the same metal to avoid interaction of different metals producing corrosion. For the nodus I chose to use the bar type. This is far better for a south-facing dial than a notch since the shadow of the nodus can clearly be seen right up to the noon line.

Mounting the dial Once completed the dial remained in my garden until it was convenient to take it to Towneley Hall. Philip Irvine of Southport took responsibility for this final stage, and Fig. 13 shows him easing the dial into its supporting brackets. These brackets were designed and made by Philip in phosphor-bronze, held in the wall with stainless steel bolts embedded in an epoxy-resin seating. To lift this considerable weight he used a long ladder with a block and tackle suspended from an upper rung. The Richard Towneley dial began its working life on 5 September 2001 in the pouring rain, but a visit some days later showed it happily doing its work under a brilliant sun. It is intended that a post-card or leaflet about the dial will be available to the public in due course, to explain its various features.

Author's address:
21, Parr Fold Avenue, Worsley, Manchester
M28 7HD

Fig.13. Philip Irvine mounting the dial.

SUNRISE AND SUNSET: AN OBSERVATION

PETER RANSOM

Having been involved with using graphing calculators at school I wondered about using one (a Texas Instruments TI-83 Plus) to plot the length of daylight against the time of local noon around the British Isles. As the length of day, sunrise and sunset are all of importance to diallers, something of significance should appear.

The time at which the sun rises (and sets) depends on the longitude of the observer. If the sun rises at 6 a.m. at Greenwich, it rises 4 minutes later at Portsmouth, which is 1° West of Greenwich. This is because the Earth spins through 360° in 24 hours corresponding to 15° each hour, or 1° every 4 minutes.
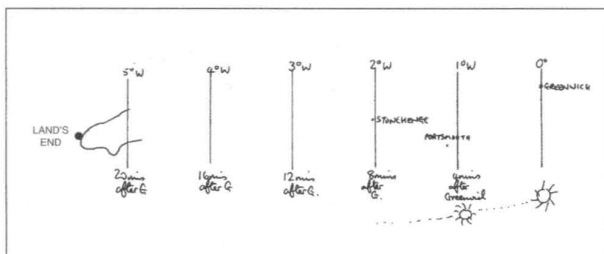
Fig.1. Longitude of coastal points.

Calculating sunset - sunrise gives us the length of daylight. During the winter months the sun rises later in the north, and sets earlier. In fact on the winter solstice, the sun is 23.5° below the celestial equator, so anywhere above 66.5° north will be in darkness all that day. Finding then the length of day should give us some indication of the latitude, with a longer day the further south you go. Think about what happens during the summer months!

The places I used are located around the coast of the UK, starting with Land's End, then Southampton, London, Dover, Lowestoft, Hull, Newcastle upon Tyne, Edinburgh, Aberdeen, John O'Groats, Cape Wrath, Oban, Carlisle, Liverpool, and Swansea. In this order we can trace round mainland Britain.

I found the latitude and longitude of the places from a gazetteer, then used the website at

http://www.abdn.acuk/student_societies/lairig/weather/sunrise/

to give me the sunrise and sunset times on 1 March, 21 March and 22 June. It was on March 1 that I started thinking about the situation. I used 21 March as it is the vernal equinox, and at that time the sun is in the plane of the equator. This should mean that the length of day is the same for all locations. On March 1 I expect the day to be shorter in the north than in the south. The twenty-second of June is about the time of the summer solstice, or longest day, so I thought it would be interesting to see what happens then.

So if we plot local noon time horizontally, and length of day vertically, on March 1 Land's End should be plotted near the top of the scatter graph, as it enjoys the most daylight as it is the furthest south of the places mentioned. It will also be to the right of the graph as local noon there occurs after the rest of the British Isles.

I expect that for March 21, the places will lie on a straight line, as the length of day will be the same. After March 21, the days get longer, and anything above 66.5° north gets midnight sun for a period of time. Thus I expect to get a reflected British Isles.

Having done the thinking, I now wished to see what happens. Of course the times are given in the form hhmm, so 0706 represents 6 minutes past 7 in the morning.

L1	L2	L3	3
706	1805	▄▄▄▄	
650	1747		
645	1741		
639	1736		
639	1739		
649	1739		
656	1743		

L3(1)=

The first step is to convert the times from hours and minutes into hours. This can be done quickly by using a list operation. (Full details can be obtained from the author.)

L1	L2	L3	1
7.1	18.083	12.592	
6.8333	17.783	12.300	
6.75	17.683	12.217	
6.65	17.6	12.125	
6.65	17.65	12.15	
6.0167	17.65	12.233	
6.9333	17.717	12.325	

L1 ={7.1,6.83333...

Now the plotting function has been used to plot the length of daylight (L4) against the time of local noon (L3). Adjusting the scales slightly, the upside down map appears!

You can use the trace function and cursor to move around the main island now, identifying the places. The cursor here is on the 13th place, i.e. Carlisle. We can see from the co-

ordinates that on 1 March local noon is at l2.41 hours, and the length of daylight is 10.78 hours

P1:L3,L4

X=12.41   Y=10.78
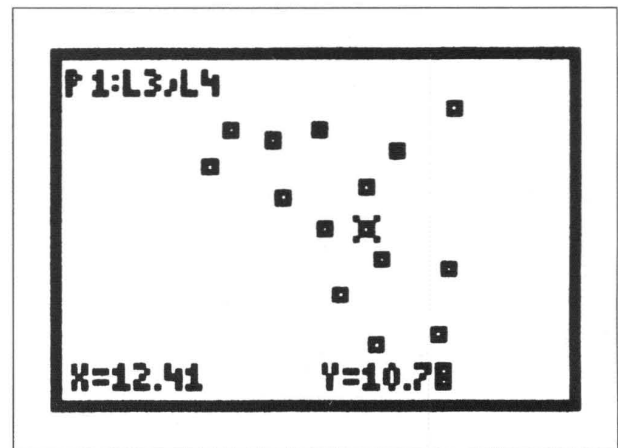
On 21 March the times of local noon are within 3 minutes of each other, all about 12 hours and 12 minutes. Not the 12 hours I expected, but wait! Perhaps the daylight is longer since it will begin when the sun's light starts to show, i.e. just before half the sun is over the eastern horizon, and ends not when the sun has sunk half over the western horizon, but when its light stops showing. Here's the scatter graph, after scaling. With a stretch of the imagination is a reflection of the UK in a vertical axis!

P1:L3,L4

X=12.016667 Y=12.2
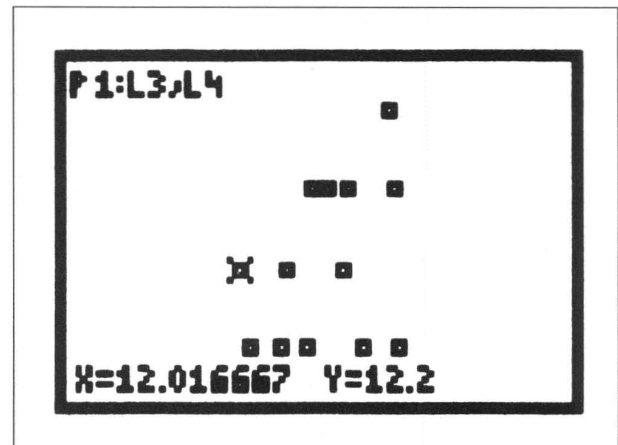
Here the trace has been used to arrive at the 5th place - Lowestoft. This is the furthest place east, so with the reflection one expects it to be on the left side.

Let's think this out now. Places to the east of the UK will have their noon earlier than places to the west, as the sun appears to travel from east to west. Hence easterly places will always be plotted on the left-hand side, and westerly places on the right-hand side. As the summer months approach the days get longer, and the further north you go, the longer the days, so that's why the plot has flipped over a horizontal line, putting the northerly places at the top of the graph. It just remains to plot the summer solstice.

Here are the lists after the sunrise and sunset times have been entered. Notice that as the places get further north, the length of daylight (L4) increases.
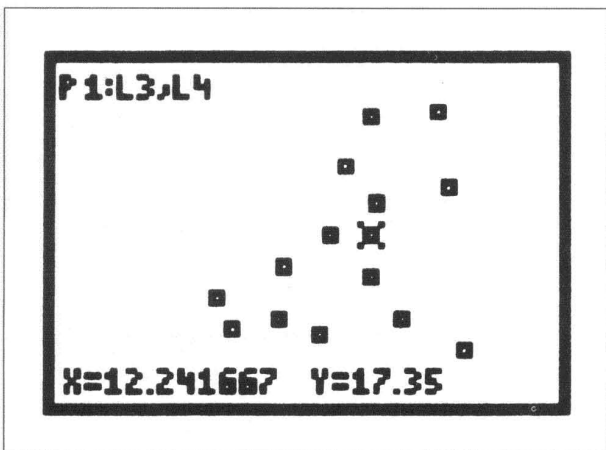
Of course there is little difference in the three plots shown so far since the scales have been made to fit the window. Plotting each of the three sets of data on the same axes might show some interesting developments! I did this by hand, and obtained the following.
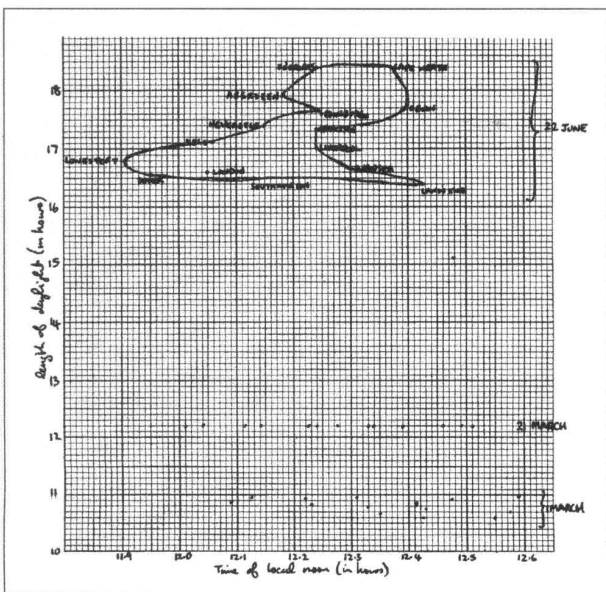
Fig.8. Graph for 3 dates.

Very interesting! It appears that the 'map' shows a sort of reflection in the 'lines' representing the time of daylight at the equinoxes. Using a scale of 4 cm to represent 1 hour would make the upper map look more like the UK. I leave it to readers to explore this phenomenon for themselves.

Fig.9. Sunset at Southampton.

REFERENCE
IMA Bulletin Vol 20 Numbers 1/2 January/February 1984 p12.

29 Rufus Close,
Rownhams
Southampton
S016 8LR
p_ransom@hotmail.com

SMALL MYSTERY IN YORK

A. O. WOOD

In the entrance lobby of the York City Art Gallery is a mounted stained glass dial by Henry Gyles dating from about 1670 and is reckoned to be one of his earliest dials. Originally at Nun Appleton Hall in Yorkshire, it was donated, via the York Glaziers Trust, to the Gallery in 1986. Although described as 'stained glass' it is in fact, probably painted. (1 - 4)

As a glass window dial it was meant to be read from inside and so the hour numerals appear to go in the opposite direction from an ordinary vertical dial.

The centre panel is a depiction of an earnest cherub holding a suitably dated conventional vertical dial. There are other allusions to the passage of time, the hare and hound, the arrow and an hourglass and a motto 'qui non est hodie' (literally 'who is not today'); all are intended to present a moral - that mortality is with us.

The centre panel picture is thought to be by Gyles himself and is based on a Venetian painting of a child holding a tambourine. At one time the picture was attributed to Titian but in all probability is by Francesco Vecellio and painted in about 1530. It is likely that an engraving by Teniers of 1660 was available for copying (5).

As drawn, the vertical dial has the numerals going the same way round as the stained glass viewed from inside and is therefore wrong for a normal vertical dial mounted on an external wall.

The mystery is of course 'how did this come about?'. If the picture had been 'sub-contracted out' it may have been explicable through ignorance. A professional diallist however would presumably have made the delineation deliberately. Perhaps he thought to avoid questions from his client; perhaps he thought nobody would notice!

Picture of the complete dial © C St J H Daniel

Picture of the centre panel © York City Art Gallery

Thanks to Allison Sharpe of York City Art Gallery, Tessa Molloy and Christopher Daniel for their information and assistance.

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4. Daniel, Christopher St J H. 'Sundials in Stained-Glass in England and Wales', *Clocks*, Vol. 10/ 10, (April, 1988), pp. 30-37. Nun Appleton Hall sundial depicted in colour on front cover.

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Author's address:
5 Leacey Court
Churchdon
Gloucester GL3 1LA

A BRIEF HISTORY OF THE BRITISH SUNDIAL SOCIETY

PART 2

DAVID YOUNG

WE GET STARTED

Part 1 of this history dealt with the initial thoughts about setting up a society and the arrangements for the first meeting of the founders. The date was Friday 5th May 1989. Andrew and Anne Somerville stayed with us the night before and on the appointed day we met Charles Aked for the first time. Unfortunately Christopher Daniel was at the last moment unable to come but was consulted on the telephone. Andrew told us that by this time he had received 50 positive replies to his letter so we unanimously decided to go ahead with the formation of a society.

The minutes of that meeting make interesting reading:
- Resolved that the sundial society should be formed independent of any other organisation.......the name to be "The British Sundial Society"
- It was resolved that the subscription should be £7.50 for single membership or £10 for Family membership
- AS to send out application forms to all interested people. DY agreed to act as treasurer and to have membership cards prepared to be sent out to subscribers and to open an account with the Town and Country Building Society in the amount of £10.
- Original contributions would be invited for a bulletin to be issued in advance of an inaugural meeting, (CA to edit)

Andrew had divided the work out amongst the three of us on the basis that we were retired and therefore had plenty of time (theoretically!) to make an early start. We all thought it important that we find out the particular interests of members by means of a questionnaire so that we could develop the Society in the most appropriate way. As well as contacting all those who had expressed interest he was to make the arrangements for a members meeting in the following spring with Oxford as a possible venue.

MEMBERSHIP MATTERS

It was just as well we did have time over the next few months as it was a particularly busy period. Andrew Somerville was busy with the arrangements for an Oxford meeting and with much correspondence with potential members - and some others not so welcome... In a letter to me he wrote " I had an interesting letter the other day, it starts off 'Lofty spiritual beings work on the sun' and goes on about life ether streaming through the cosmos etc. - but no sub for the society - Some mothers do have them!" In the same letter he also told me that he had made a definite booking at Exeter College Oxford for 24/25th March - the only weekend they had free for a year... how lucky we were.

I had membership cards printed, prepared a welcome letter and designed a comprehensive questionnaire, all to be sent to those who had returned the enrolment forms to me. Cheques soon came rolling in at every post so that at last we had money in the bank that was not our own! Every new member was given a number and after allocating 001 - 004
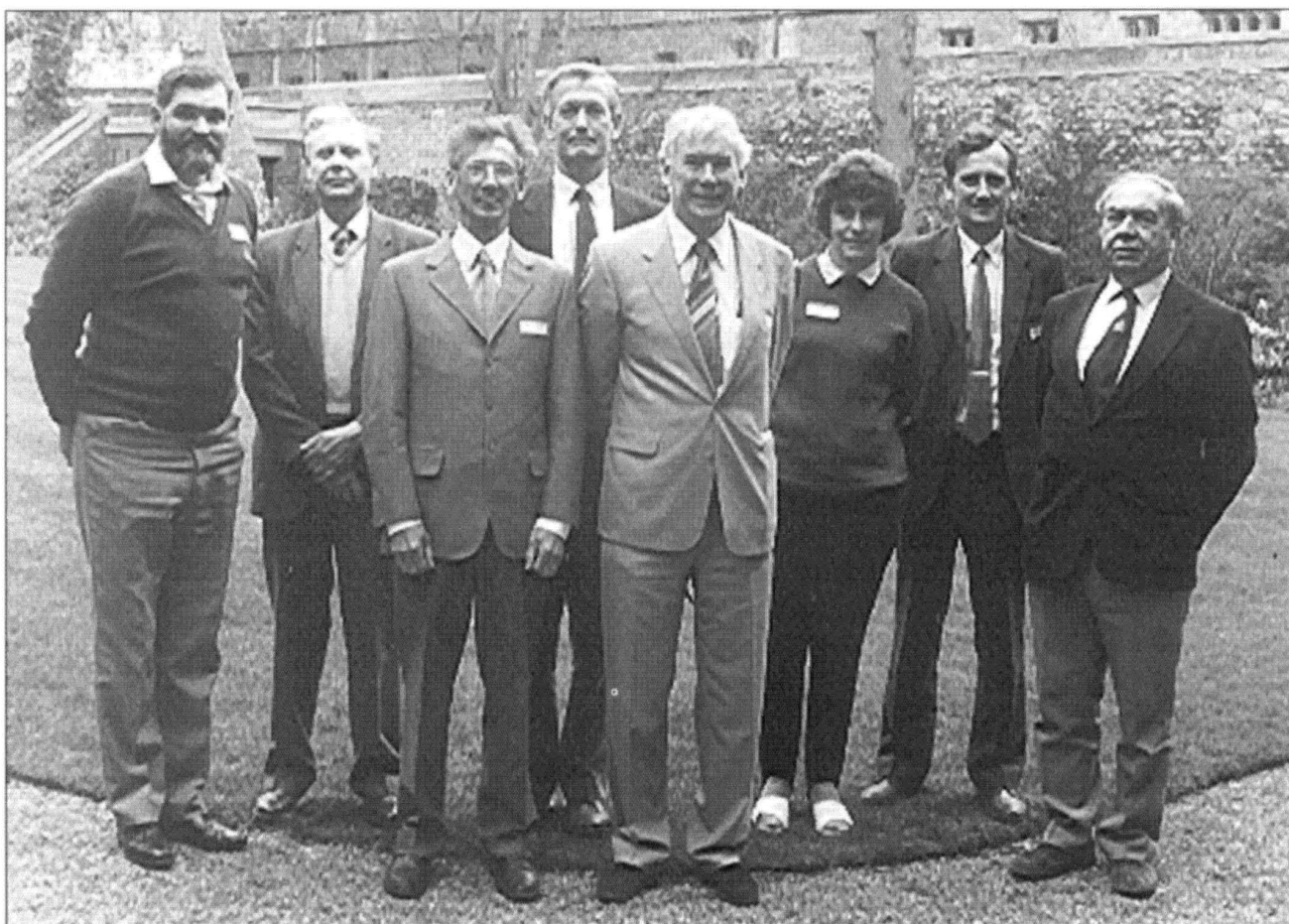
First Council (from the left) Richard Thorne, David Young, Gordon Taylor, Christopher Daniel, Andrew Somerville, Jane Walker, Michael Cowham and Charles Aked

to us four they were given in strict order of receipt of application. It is interesting that so many of those early applications were from many that are still active in the society today. David Pawley of "Newbury" fame was 006 and Dr Allan Mills from Leicester University was 010. 007 was given to our oldest member George Higgs who was then 'only' 89, he was inordinately proud of his number - although only after the James Bond connection was explained to him!

THE BULLETIN

Charles was anxious to get a journal sent out but initially had to write a lot of it himself, (not that he was ever averse to that). In addition there were contributions from Andrew with a historical bias and from Rene Rohr with a distinctly mathematical approach, a somewhat esoteric article by Peter Drinkwater and a piece by myself on the formation of a National Recording scheme. Financial restraints meant that this would have to be a simple photocopied publication of about two dozen pages. Charles made several suggestions for the name of the journal, "The Sciagrapher" for one (look up your dictionary!). Many members may wonder why, in the end our journal should have been given the rather unimaginative title "The Bulletin". It had been

originally conceived as a newsletter but after Charles had sent us a draft copy, Andrew wrote to me on 27th June with some minor criticisms "I think it should be called a bulletin, which covers both news and articles" so without further ado that is what it became and has remained ever since. It is widely respected among diallists all over the world and I personally hope that some future PR orientated member will not want to change it. Once the title had been established the problem was that neither Charles nor I had the facilities on our Amstrad word processors to print letters larger than 12 point for the title page. I got over this by stencilling the letters, choosing yellow paper to make the 100 copies we required. Yellow, of course still remains the colour for the cover of our Bulletins. These, with large envelopes, membership address lists and hurriedly produced enrolment leaflets were taken to West Drayton one day in early July for Charles to make up and despatch the completed bulletins. In his letter of the 19th July he told me they had all been dispatched but he complained about the extra heavy envelopes I had supplied as he had to stagger to the post office with his parcel of letters and then spend an hour licking stamps! The job as editor was no joke.

The first B.S.S. Bulletin 1989

OUR SECOND MEETING

(1989) By August membership had passed the 100 mark, quite beyond our expectations so extra copies of the Bulletin were needed for the newer applicants. As costs had to be kept down these were made at home as and when required. Andrew Somerville arranged a meeting at The Museum of the History of Science at Oxford in September where we were able to see the facilities at nearby Exeter College for the inauguration of the Society and talk to Tony Simcock about a visit to the museum on the first day. We were relieved that Christopher Daniel could come.

We had now had several hundred pounds in hand and I estimated that we have enough to produce two more Bulletins plus initial expenses for the Conference - but not much else. The shape of the conference was worked out in some detail bearing in mind that the number expected was anyone's guess - somewhere between 30 and 50 we thought. Luckily the college seemed fairly relaxed about exact numbers at that time. Andrew had done most of the planning on the basis of a serious conference conducted in a light hearted manner - an ethic which has continued to be our guidelines ever since. He had also written a draft constitution to be submitted to members. This had previously had much agonising discussion, but finally agreed by all four of us at this meeting. Christopher Daniel had been working on a possible logo for the society and presented a draft design made on the basis of a portable equatorial dial. It was agreed that a final decision would be made at our next meeting in the New Year.

Anne Somerville gave us a very comprehensive analysis of the 85 Questionnaires returned up to that time and as nothing like it has been done since, it is worth recording here some of the results

MEMBERS INTERESTS IN SUNDIALS

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We found it interesting to see that dial construction came top of the list of interests which bore out our decision not to become a section of the AHS. Surprising that scratch dials became bottom.

CONSOLIDATION

The second bulletin was now being prepared by the Editor, this time with 32 pages and double the print run making many more trips to the post office for him as well as extra work for his stapling machine! Included with this issue

Sundial wine, the dial can be seen on the hillside

were details of the meeting in March and a list of members from my register. I was also able to produce address labels to help on this second issue. In the meantime, Andrew had been interviewed on a radio programme and was thus able to publicise the society in a way that brought very many responses. In a letter he sent me 28th November he said he was still getting replies, some positive but many like "where is the best place for my sundial in the garden?" and of course "I have a sundial, how much is it worth?". He goes on to say "I hope the flow stops soon, it is taking up too much time.....I can see that we shall need to set up a structure for dealing with enquiries; an education officer, an advisor on construction, an antiquarian and a writer of tactful letters to little old ladies!

DIAL RECORDING

While all these things were going on I had been anxious to do something about dial recording and in fact Andrew had encouraged me to do so. We had revised the trial form I had shown in the first bulletin with the help of suggestions received from members and an examination of those used by the Dutch and German Societies. We had by October some 70 members interested in recording so I wanted to get forms out as soon as possible, the limitation being that printed pads of forms would be too expensive. I had drawn out a form on a sheet of A4 paper managing to get 3000 photocopies made at a very modest price. Making up the pads was a tiresome process involving painting the top edges of the sheets with two coats of PVA adhesive while being squeezed by a heavy book. As it was necessary to leave these to harden off it took about three weeks to finish some 80 pads. However within a month all were sent off with a covering letter, guidelines and a sheet of carbon paper for copies to be kept by the recorder.

It was exciting to see the first forms returned and by the end of the year I had several hundred completed, a large proportion from just three members Neville Rodber and Richard Thorne from the south-west and Robert Sylvester from Cumbria. At this time too, membership forms were

still coming in steadily and we were approaching a total of 200. At no time did we pay for advertising. Various newspapers and magazines were happy to announce our formation as a news item and many journalists were intrigued and contacted us afterwards for further information to write articles for publication. However some, even those in the "quality press" were of dubious scientific accuracy! (That tendency has not changed much since).

PREPARATIONS FOR OXFORD

With the advent of 1990 and only a short while to go before Oxford we had a meeting, at the home of Christopher Daniel. He had prepared diagrams of two possible symbols for the Society, which were put for consideration with others on the table. This caused a marked division of opinion, Christopher and Andrew opting for the one that we now have, and I opted for the more traditional one. As Charles was not present it was decided to delay a decision until after he was consulted. In the event Charles agreed with me and in a letter made that absolutely clear (there was little compromise as far as Charles was concerned) However this meant a 2 - 2 tie and eventually, as it was necessary to make a positive decision, the Chairman used his prerogative and the present design was chosen. In hindsight it was probably a good decision and it is an uncluttered and distinctive design, the chief trouble is trying to explain to the general public (and quite a few members) what it is meant to represent in a just a few words. The meeting also discussed detailed arrangements for Oxford where I was to provide the information packs, with pen, name labels etc and Christopher, Andrew and Allan Mills would give the key lectures. By this time I had received applications from over 40 members so we knew that our initial target had been met. Our member Michael Cowham offered help and also recommended that we should leave plenty of time for members to see the displays and talk to each other and this was readily agreed by Andrew who revised the program so that coffee would be served in the room with the displays and the whole of the Friday evening would be free.

As can be imagined there were very frequent letters and telephone calls between us in the run up to Oxford with the amazing final number 73 participants, while the overall membership had reached 240. I had told Andrew earlier in January that I was finding it increasingly difficult to do three jobs with such a rapidly expanding society and would want some relief at the AGM. He did his best to help and after some research had approached Richard Thorne who had agreed to be nominated as Treasurer and Gordon Taylor who had agreed to be nominated as "Registrar". This theoretically left me with the post as Membership Secretary
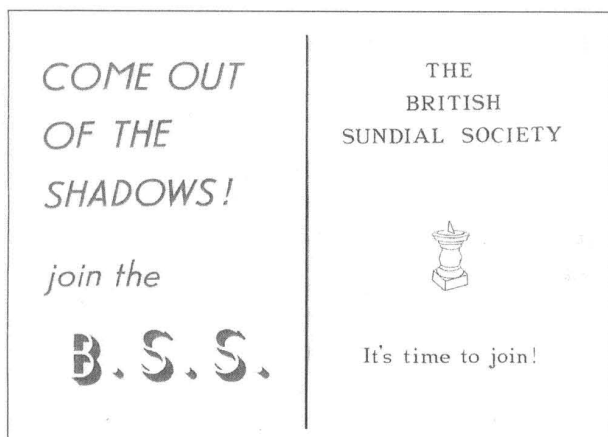
Two covers of an early leaflet

but it turned out that Richard's wife was prepared to do this job and I had to agree that it made sense for both jobs to be combined as indeed was my own experience. So quite suddenly I had talked myself out of three jobs to find that I would have none after the AGM! Our very last meeting, a week or so before the conference was held at my house where Andrew tied up some loose ends. While on holiday in Germany he had passed a vineyard with a huge vertical sundial standing on the hillside and had somehow persuaded the owner to send us a crate of his 1983 "Sonnenuhr" Reisling for the conference without charge. This would be served at dinner. Unfortunately carriage and duty had to be paid which took a little gilt of the gingerbread!

THE INAUGURATION, EXETER COLLEGE, OXFORD (March 1990)

The conference was considered by all a great success, we were fortunate in attracting a number of visitors from abroad, Mr Marinus Hagen from Holland, Mr Karl Schwarzinger from Austria and Dr and Mrs Holland from the United States. A message from our Patron The Earl of Perth was read out. The business part of the meeting was conducted with little problem; there was inevitable discussion about the constitution, which could have continued all day except for the firm hand of the Chairman. It was agreed that the annual subscription should be raised to £12.50 per person in the hope that a better standard of printing for the journal could be obtained. Dr Philip Pattenden gave us a conducted guide of some Oxford sundials. The dinner in the great Hall was considered excellent and the sundial wine was consumed with much pleasure. After lectures and a visit to the History of Science Museum the elections took place, apart from the four founders, Richard Thorne, Gordon Taylor, Jane Walker and Michael Cowham were elected to the new governing body, the origin of our Council today.

The reader may conclude from the above that Christopher Daniel played a comparatively minor role in this first year but this is only partly true, his help with advice and balanced judgement on a variety of problems was readily given at our meetings and numerous phone calls. Little did he realise that his part would dramatically change in the coming year.

Author's address:
Brook Cottage
112 Whitehall Road
Chingford
London E4 6DW

KAREN'S HAND SUNDIAL
A 'DIGITAL UNIVERSAL RING DIAL'

KAREN DEAL ROBINSON

Many years ago, I made a beautiful portable dial of brass and rosewood. It had a horizontal dial and an analemmatic dial on the same plate, so that it could be oriented without the use of a compass. After spending days making it, I had it stolen from my backpack. Since then, I have searched for the perfect impromptu portable sundial, something easily constructed that I could always have with me. It should be easy to use, and not require me to have a compass or other means of finding north apart from the dial. It should also be usable at various latitudes.

In their article "Digital Sundials--Time At Your Fingertips" (Compendium, Vol.7 No.3, September 2000), Fred Sawyer and Mario Arnaldi describe traditional methods for using the hand as a sundial. If the stick that's used for a gnomon is held at an angle to the palm equal to the latitude, these methods can be fairly accurate. However, they rely on a dubious technique for aligning the hand with north, using the length of the shadow of the heel of the hand. I tried the technique with limited success. After reading the article, it occurred to me to try to invent a sundial which would be made of the human hand, and which would be more accurate and reliable than the traditional hand dials. I decided to base it on the universal ring dial.

THE UNIVERSAL RING DIAL

The universal ring dial has always been my favourite portable sundial. I have a lovely one made of brass by my husband Terl. I like to use it on hikes because it doubles as a compass. The universal ring dial is a form of equatorial dial.

The shadow of a central gnomon is cast on an outer ring whose plane is perpendicular to the gnomon. A movable marker on the gnomon is adjusted to reflect the sun's declination at different dates. It is traditional for the marker to be a pinhole, but on my brass dial, Terl used a tiny rubber washer that slides up and down the gnomon and is much easier to make. The dial is turned until the shadow of the marker falls on the ring to show the time. When this happens, the gnomon automatically points to the celestial north pole. Actually, there will be two places the shadow of the marker will fall on the ring, one showing a time in the morning and one showing a time in the afternoon. Only one will give the correct alignment and time, so you have to know whether it is morning or afternoon.

I decided to invent a way to use the hands to form a universal ring dial. The result is a method that gives me the correct time to within about half an hour. My brass dial is much more accurate, but I don't always have it with me, and my hands are always available. I like the fact that I can find north using nothing but the sun and my own two hands, provided I know the month, the approximate latitude, and whether it is morning or afternoon.

HOW TO MAKE THE DIAL

The hand dial uses the forefinger of one hand to form the gnomon. I will call that finger the gnomon finger. It uses the forefinger of the other hand to form a quarter of the ring where the hours are marked. I will call that finger the dial finger, and that hand the dial hand. In the morning the dial finger will be the right forefinger, and in the afternoon it will be the left forefinger. The reverse will be true of the gnomon finger.

Form the dial hand into a fist, palm up, with the thumb inside. Stretch the first finger out into a hook. (See figure 1.)
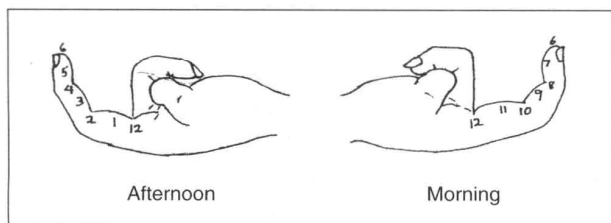

Afternoon   Morning

Fig.1.

Curve the finger to approximate a quarter circle. The creases of the finger form the even hour lines, as marked in figure 1.

The first finger of the other hand forms the gnomon. Lay it across the knuckles of the dial hand. (See figure2.) At the summer solstice, the tip of the gnomon finger should line up with the outside edge of the dial finger. At the equinox, the tip of the gnomon finger should line up with the centre of the dial finger. At the winter solstice, the tip of the gnomon finger should line up with the inside edge of the dial finger. These positions are shown in figure2. At other times of the year, approximate the position between the given positions. Adjust the dial finger slightly so that the gnomon finger passes through the centre of the circle. (See figure 3.)

Winter Solstice   Equinox   Morning Solstice
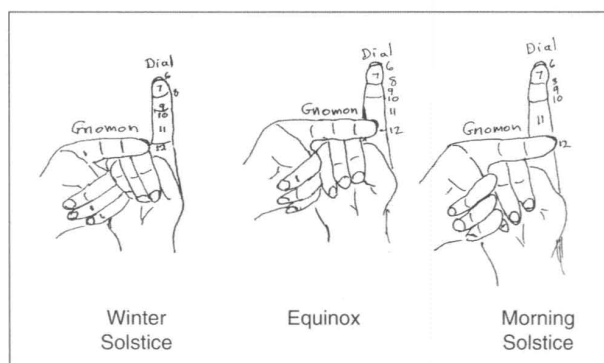
Fig.2. View from above, before tilting.
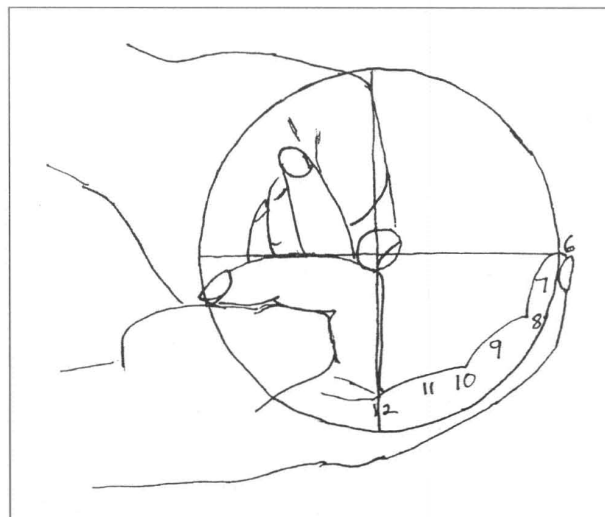
Fig.3. View from North Pole.

Tilt the hands so that the gnomon finger forms an angle with the horizontal approximately equal to the latitude. (See figure 4.) At the middle latitudes, this is a natural and comfortable position for the two hands. The plane of the quarter circle of the dial hand will still be perpendicular to the gnomon. At the equinox, the tips of the two forefingers should lie on a horizontal line. This won't quite be true at other times of the year, but the position of the dial hand should remain the same. The noon mark should lie at the bottom of the arc.
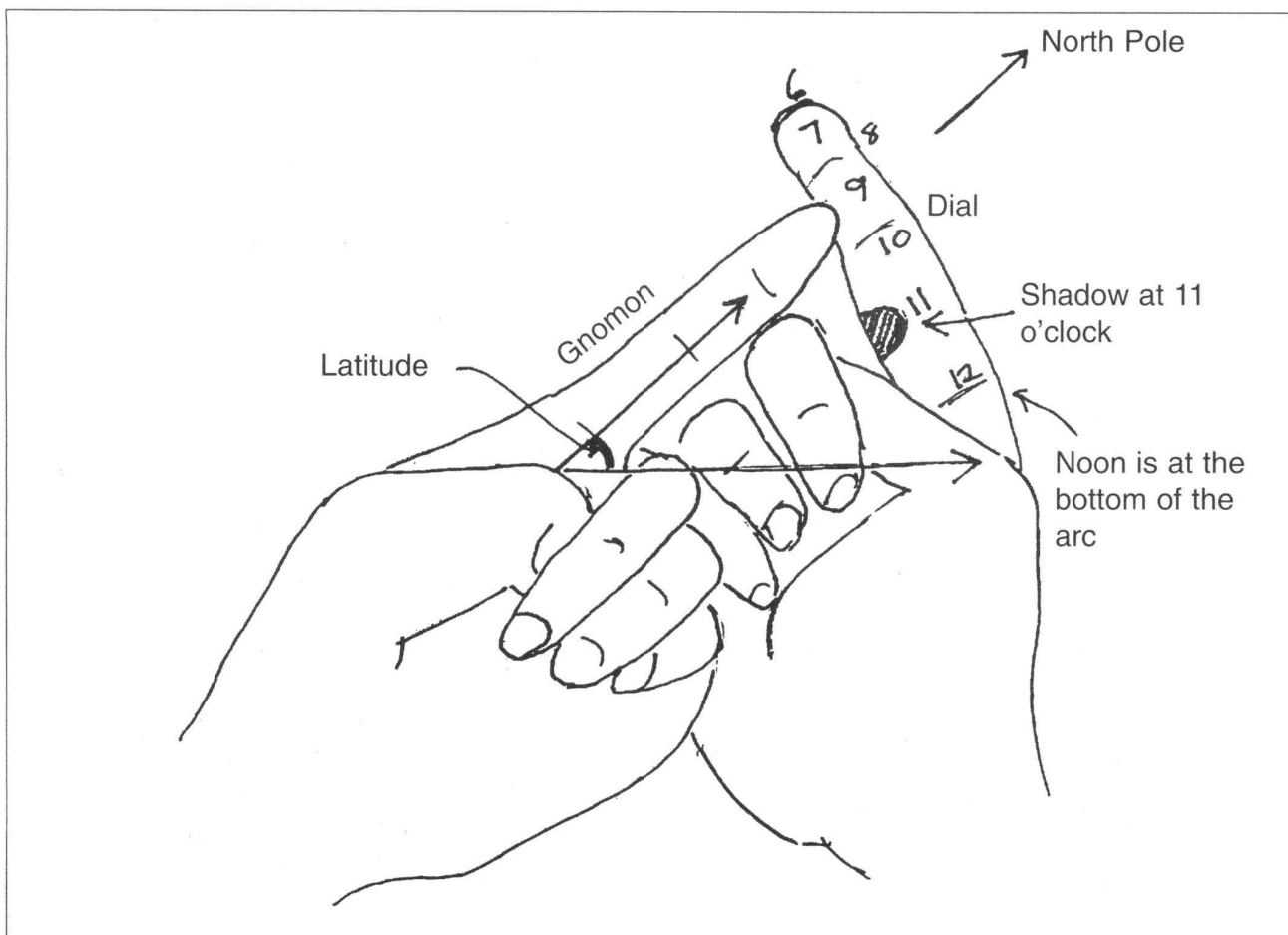
Fig.4. View from the side

Turn your body so that the shadow of the tip of the gnomon finger falls halfway between the two edges of the dial finger. (See figure 4.) The gnomon finger will now be pointing approximately toward the celestial north pole. From the position of the shadow, read the time, using the numbers given in the figures. Make the appropriate adjustments for daylight savings time, longitude, and the equation of time. If you want a finer shadow, a stick or pencil could be used in place of the gnomon finger. However, the hand dial is crude enough that a finer shadow probably won't increase accuracy.

This dial only gives the hours between 6 am and 6 pm. If you want to use it in the early morning or late afternoon in the summer, you can turn the whole thing upside down to get those hours. It's awkward, and you have to hold your hands a little above your head, but it can be done. You still have to make sure that the gnomon finger forms an angle with the horizontal equal to the latitude. The 12 o'clock mark now represents midnight and is at the top of the arc. You also have to switch hands when you turn the dial upside down.

CONCLUSION

I love the brass universal ring dial that Teri made for me, and I enjoy taking it on hikes. But it's rather big to carry absolutely everywhere, and if I did I would worry about losing it or having it stolen. With any luck, I will always have my hands with me. I believe that the "digital" universal ring dial is exactly the impromptu dial I have been looking for all these years.

ADDENDUM

Since writing this article, I found that an inexpensive equatorial dial can be made from a small embroidery hoop, available at most craft stores for under a dollar. Use small bolts to fasten the two hoops together, and a dowel through the centre as a gnomon. A small rubber washer on the dowel is adjusted to give the date.

Author's address:
Karen Robinson
cliffordrobinson@.earthlink.net

THE HORARY QUADRANT

MIKE COWHAM

"**QUADRANT**, *quadrans*, in geometry, an arch of a circle, containing 90°, or the fourth part of the entire periphery."

"**QUADRANT** also denotes a mathematical instrument, of great use in astronomy and navigation, for taking the altitudes of the sun and stars, as also for taking angles in surveying, &c."

This is how an 18C Encyclopaedia[1] describes the quadrant. It then goes on to list the principal and most useful quadrants: -

"Common surveying quadrant, astronomical quadrant, Adams's quadrant, Cole's quadrant, Davis's quadrant, Gunter's quadrant, Hadley's quadrant, horodictical quadrant, Sutton's or Collins's quadrant, sinecal quadrant &c."

In this article I am limiting my studies to those quadrants principally used for time measurement, either from the sun's position in the sky by day or the stars by night. These types have been underlined in the above list.

Some important points should be noted when working with quadrants.

1. Each quadrant is made for a specific latitude and is not designed for use at other latitudes. However, it is often possible to use many quadrants at other latitudes by correcting any altitude reading to the figure that it would be if the observation had been made at its original latitude. For example, many quadrants were produced for London at 51° 32' N, but for use in York at 53° 55' N, (a difference of 2° 23'), add this difference to the sun's elevation when taking a reading.

2. A quadrant is an altitude-measuring device; therefore it is possible to confuse morning and afternoon readings, especially around noon. If unsure, then two consecutive readings some minutes apart should show whether the sun is still rising or is falling.

3. All altitude measuring devices become difficult to read as the sun approaches noon. At this time there is little change in the sun's altitude and any errors in setting or reading may cause large errors in time measurement. Results are most exact around mid morning or mid afternoon.

4. Many of the old quadrants were made before 1752, therefore those made in Britain will most likely be made for the older Julian calendar. It is therefore necessary to deduct 10 or 11 days from the calendar reading when setting the Bead. (Although the calendar correction was 11 days in 1752 the error was only 10 days prior to 1700.)

5. Equation of Time and Longitude difference corrections apply to quadrants exactly the same as for other forms of sundial.

GUNTER'S QUADRANT

This is the type of quadrant most commonly seen and it was made from the mid 17C until the 19C. Refer to Fig. 1.[2] for details. This type of quadrant is sometimes referred to as a 'horary quadrant'. Gunter's quadrants were made in a variety of materials such as wood, ivory and brass, and in a range of sizes. A typical Gunter's quadrant will be made from boxwood and have a radius of around 120mm.

The Limb is divided into 90° and may be further sub-divided if size allows. Its main scale is a stereographic projection of the sphere on the plane of the equinoctial. To save space the entire 360° expanse of the sky has been effectively folded four times to fit onto one quarter of a circle. Usually this projection will have certain major stars placed on it. Those most commonly seen are **PW** (Pegasus Wing or Markab), **Arc** (Arcturus), **Lh** (Lion's Heart or Regulus), **Be** (Bull's Eye or Aldebaran) and **Vh** (Vulture's Heart or Altair). These are often listed inside the shadow square with their Right Ascension figures. (Fig. 5.) Details of the use of the shadow square or quadrat are given later.

The Gunter's quadrant is therefore an important astronomical instrument but its main use is for time telling. A few examples of typical observations that can be made are given below.

To find the sun's meridian altitude for any given day, lay the Thread so that it crosses the required Date. The reading of degrees where it cuts the Limb is the sun's meridian altitude.

To find the hour of the day, set the sliding Bead to the sun's place in the Ecliptic. This dotted line crosses the quadrant diagonally and is marked with zodiac signs and degrees. Observe the sun's altitude through the two Sight Vanes clamping the Thread in this position with finger or thumb.

GUNTER'S QUADRANT

SIGHT VANE

SHADOW SQUARE OR QUADRAT

THREAD

EQUATOR (EQUINOCTIAL)

AZIMUTH LINES

DECLINATION SCALE

BACK SHADE

DIRECT SHADE

TROPICS

SIGHT VANE

HORIZON

LIMB

HOUR LINES

BEAD

ECLIPTIC

PLUMMET

DATE

Fig.1.

HORODICTICAL QUADRANT

UPPER BEAD

SIGHT VANE

ENEQUAL HOUR LINES

CALENDAR SCALE

EQUINOCTIAL HOUR LINES

SIGHT VANE

THREAD

LOWER BEAD

LIMB

PLUMMET
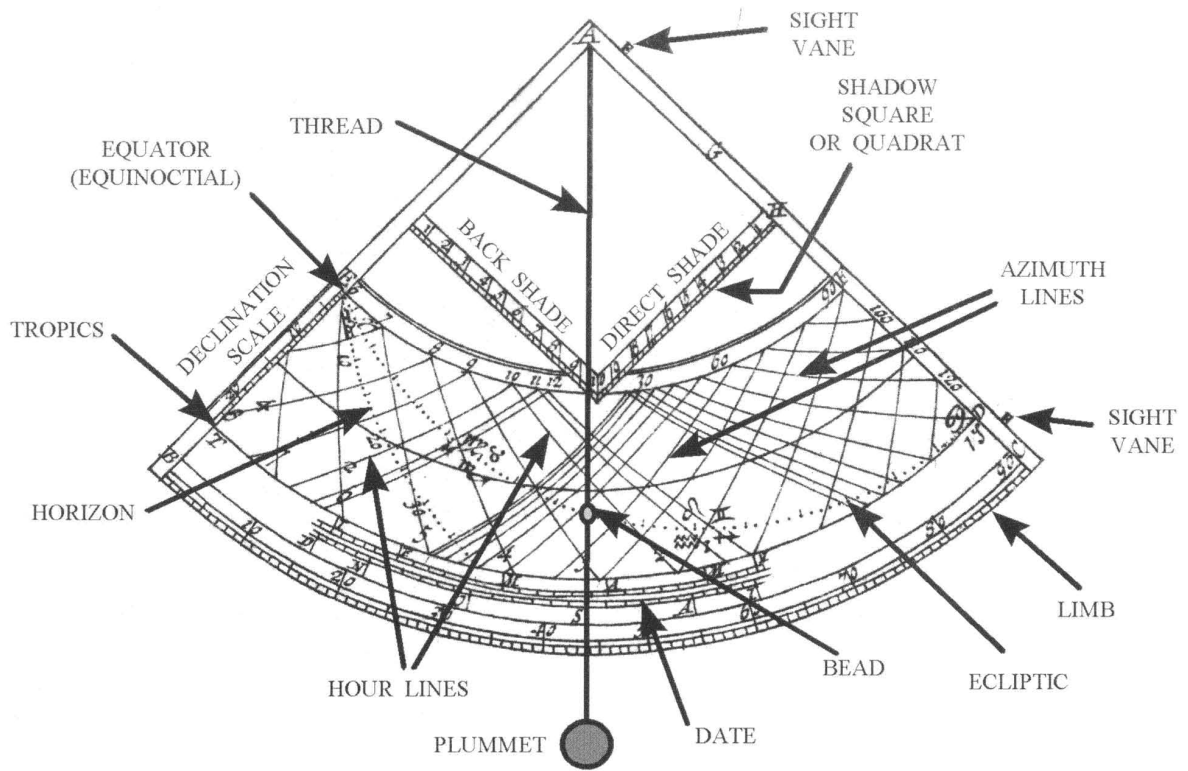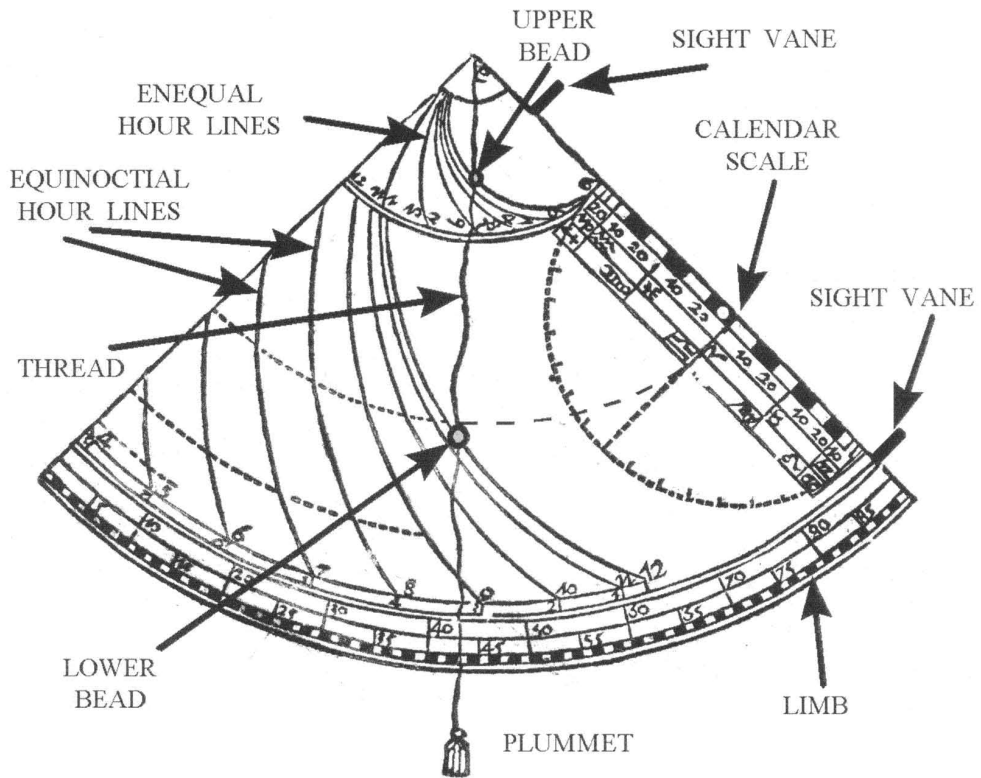
Fig.2.

The Bead will now show the time directly on the Hour Lines.

An alternative method for setting the Bead is to position the Thread to cross the correct date on the Date scale, adjusting the Bead to where the Thread crosses the **XII** line. Then take the sun's altitude as before.

When taking these sun sightings **never** look directly at the sun as it will blind you. Hold the quadrant from above and let the sun's rays pass through the Sight Vane near to apex in such a way that a small spot of light falls centrally on the lower Sight Vane.

To find the sun's declination, set the Bead to the sun's place in the Ecliptic, then move the Thread to the Declination Scale and read the figure from the position of the Bead.

To find the Right Ascension (RA) of the sun, lay the Thread on the sun's place in the Ecliptic and read the angle from the Limb. Remember that the quadrant represents the full 360° and has been folded by four so, if necessary, deduct the reading found from 180° etc., working from the first point of Aries = 10 March (Julian) or 21 March (Gregorian).

To find the hour at night from the position of a marked star, place the Bead over the star to be observed. Find how many hours this star is from the meridian. This may be marked already on the quadrant. (Fig. 5.) Subtract the sun's RA from this figure and note the difference. Add this difference to the observed hour. Note that RA may be expressed in hours & minutes or in degrees from the first point of Aries, remembering that 15° is equal to one hour. EOT correction will not be required for readings from stars.

HORODICTICAL QUADRANT

This type of quadrant is relatively uncommon but is very simple to use. See Fig. 2.[3] for typical layout details. The shape of the Equinoctial Hour Lines depends on how the Calendar Scale has been drawn. It is normally as shown but sometimes a linear version is preferred to avoid the cramping around the solstices. When the Calendar Scale is linear the main curves become 'S' shaped rather than circular. On some quadrants the zodiac divisions are extended as arcs right across the face to cross the Hour Lines. There is no reason why the Calendar Scale should have any particular linearity as the Equinoctial Hour Lines can be modified to suit.

In use, the Lower Bead is set to the correct date on the Calendar Scale and the altitude of the sun is observed through the Sight Vanes as with the Gunter's Quadrant.

The time may now be read from the position of the Bead from the Equinoctial Hour Lines. The times of sunrise and sunset are simply found by moving the Thread to the left-hand edge and by reading from the Lower Bead.

Fig.3. Horodictical Quadrant on the Reverse of a Nocturnal.

In some cases Unequal Hour Lines are also marked on the quadrant. The time in Unequal Hours may be obtained as follows: - Set the Lower Bead to the correct date and hold it on the 12 hour Equinoctial Line. Move the Upper Bead so that it lies exactly over the 6 hour or noon line, (the right hand curve). This arrangement is as shown in Fig. 2. Take a reading as normal and the Upper Bead will simultaneously record Unequal Hours and the Lower Bead Equinoctial Hours. Note that in this example, dawn and dusk on this Unequal Hour scale are labelled as 12 hours and noon as 6 hours.

An example of an early horodictical quadrant on the reverse of a Nocturnal is to be seen in Fig. 3.

SUTTON'S QUADRANT

The Sutton's Quadrant is a stereographic projection of one quarter of the sphere between the tropics on the plane of the ecliptic. See Fig. 4. 1 The lines originating from its right edge are Parallels of Altitude. The lines crossing them at right angles are Azimuths. The smaller circle of radius at the top represents the Tropic of Capricorn and the larger circle around the Limb, the Tropic of Cancer. Two Ecliptic arcs are drawn, one each for summer and winter seasons. The two Horizons also originate from this same point. The Limb is divided into 90° for angular measurement. It has a further scale calibrated each 15° marked with Hours. Each Hour is usually subdivided into individual minutes for accurate time recording.

Time telling by this quadrant is a little more complex than the others, but once mastered is capable of giving accurate

SUTTON'S QUADRANT

DATE

TROPIC OF CAPRICORN

THREAD

TROPIC OF CANCER

BEAD

AZIMUTH LINES

HORIZON   ECLIPTIC
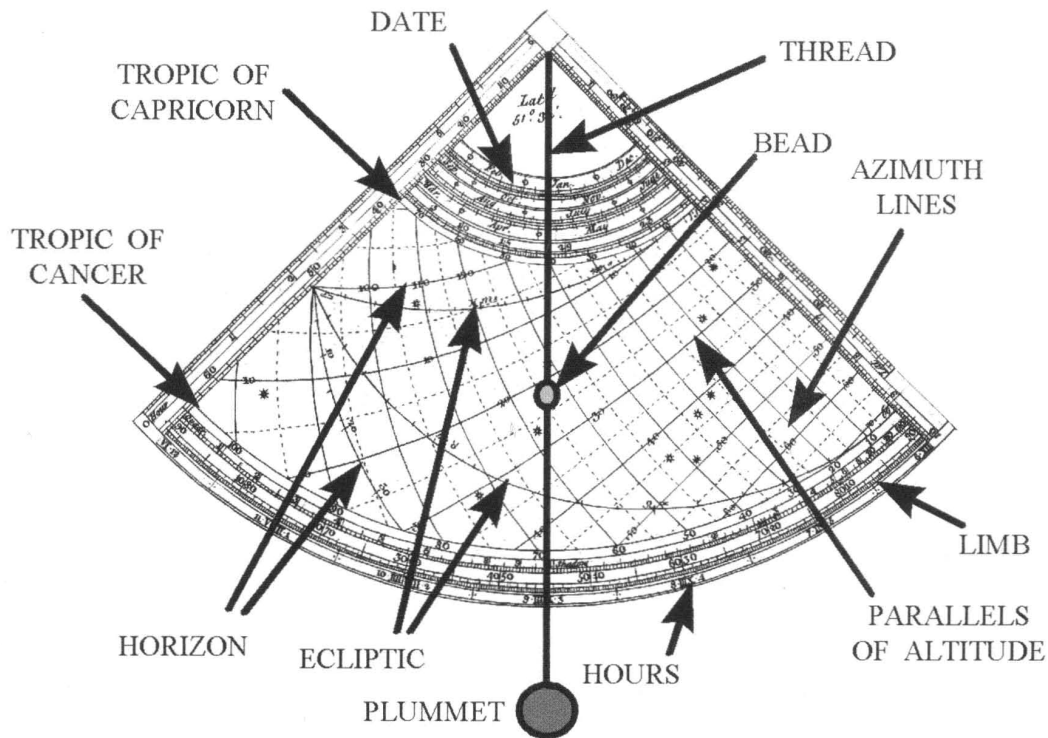
LIMB

PARALLELS OF ALTITUDE

HOURS

PLUMMET

Fig.4.

results. The first step is to set the Thread so that it crosses the current Date. Then adjust the Bead so that it lies exactly on the appropriate Ecliptic line, (summer = lower or winter = upper). If the degrees of Zodiac are already known, then the Bead may be set directly to that figure in the Ecliptic scale. Once set, the sun's altitude reading may be obtained as before. Then move the Thread so that the Bead now lies on the Parallel of Altitude corresponding to the reading taken and read the time from where the Thread now crosses the Hour scale on the Limb.

Henry Sutton (working 1649, died 1665)[4] was a well known and respected Instrument Maker from London. He produced quantities of these 10" quadrants around 1658. To enable him to make the quantity required he engraved a printing plate producing the quadrants on paper, which were then pasted onto oak bases. Most of those extant are dated, showing that he was continually updating his printing plates. On the reverse side are often seen other scales including sines, arcsines, tangents etc. Due to their cheap and relatively fragile method of construction very few of these have survived.

SHADOW SQUARE OR QUADRAT

"**QUADRAT**, *quadratum*, a mathematical instrument, called also a geometrical square, and line of shadows, it is frequently an additional member on the face of the common quadrant...."[1]

The Quadrat is also known as a Shadow Square and it will be found on many instruments as well as quadrants. It is extremely simple to use employing proportions to solve trigonometrical problems and a way of avoiding what seemed to most people to be complex trigonometry.

Fig. 5. shows a typical quadrat. Shadow squares will also be seen in Figs. 1 and 3. The number of divisions along each face, Direct Shade or Back Shade can be of any number as long as both scales are identical. Twelve divisions are commonly used but numbers up to 100 sub-divided to 1000 are known. The shadow square may not immediately be recognised because on occasion it will be placed around the curve of the Limb giving uneven divisions, but these will be derived from an equivalent square. Fig. 3. is a good example of this where the quadrat scale is marked **VMBRA VERSA & RECTA**.

The shadow square is primarily used for surveying. A typical use would be to determine the height of a building, tree, mountain, or even the depth of a well. The feature of interest will be observed through the Sight Vanes. The point at which the thread crosses the shadow square is noted. A measurement to the foot of the building is made and simple proportions used to find the height of the building. This is in essence a Tangent scale.
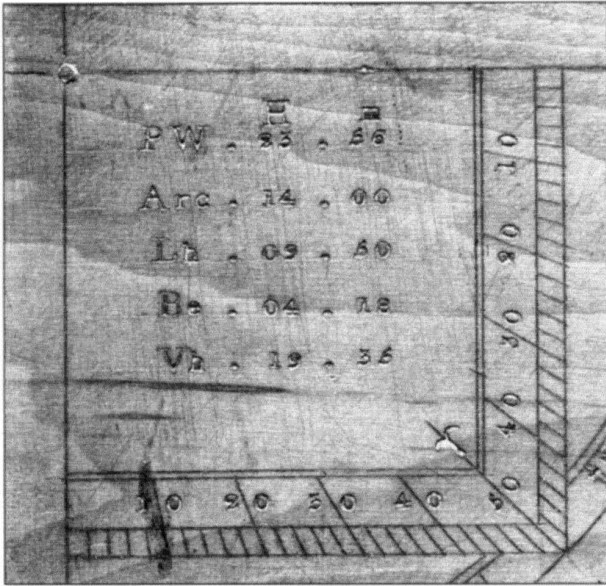
Fig.5. Shadow Square or Quadrat on Boxwood Quadrant, c1755.

To take an example, if the observer is 100 feet from a tall building and he wishes to know its height, he lifts the quadrant to his eye to sight the top of the building and finds that number 8 (Direct Shade) is crossed by the Thread on a scale of 12 divisions. Therefore the ratio of height of the building is in proportion 8:12 or 66.7 feet above the observer. It is then necessary to add the height of the observer's eye to this figure, perhaps 5 feet, making a total height of 71.7 feet. If the observer had been further away from the building such that the other limb of the shadow square (Back Shade) were crossed by the Thread then the figure would have been 12:8 x 100, or 150 feet plus his eye height making 155 feet. The shadow square can also be used horizontally or at any other angle for surveying.

The Sutton's Quadrant uses a slightly different arrangement by adding a standard Tangent scale around the Limb. It is then only necessary to multiply the horizontal distance by the reading taken from this scale.

The best way to learn how to tell the time by these intriguing devices is to acquire or make them and put them to the test. I have tried each of these types and with a minimal amount of skill have found that it is possible to read the time to within a few minutes, especially at low sun altitudes.

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CALENDAR DIALS

ALLAN A. MILLS

In the equal-hour sundial, a shadow casting element (the stile) is fixed to point upwards at the celestial pole. It is therefore parallel to the Earth's spin axis and, being so distant from the Sun, may be treated as coincident with that axis. Therefore the rotation of the Earth giving rise to the apparent daily motion of the Sun across the sky produces a plane of shadow in a direction that is controlled only by the Sun's position around the horizon (azimuth) characterising the time of day. In particular, the direction of the shadow plane is independent of the Sun's altitude. Therefore interception of this shadow by dials arranged either coaxially or in various planes (commonly vertical or horizontal) produces a pattern of straight hour lines that is unaffected by the time of year. This is illustrated most easily by a well-known equatorial dial.[1] For practical reasons the stile is rarely represented by a taut wire in working sundials: it is usual to mark it by the sharp upper edge or corners of a rigid triangular gnomon.

Now consider the situation where a ring-like annulus completely surrounds a gnomon, being held at a constant radial distance from its stile. Rather than acting as the shadow-receiving surface, let the annulus cast its own shadow upon the gnomon. At the equinoxes a band of shadow will cross the gnomon perpendicularly to the stile, and its point of interception will remain fixed throughout the day. In other words, by inverting the usual situation and casting the shadow upon the gnomon, we obtain an index that is independent of the time of day!

It is, however, sensitive to the apparent height (altitude) of the Sun as it varies in the course of the year: this inverse dial indicates time of year, so might be termed a calendar dial. This behaviour is a direct result of the changing declination of the Sun produced by the 23.5° inclination of the ecliptic to the celestial equator. As a practical result, the upper edge of the shadow band falls at 23.5° above its equinoctial position at the winter solstice, and the lower edge reaches 23.5° below it at the summer solstice.

Intermediate positions may be calculated from a table of solar declination versus date.[1] Note that these intercepts refer to positions along the stile: shadows of the edges of the ring upon the flanks of the gnomon will appear as varying hyperbolic curves.
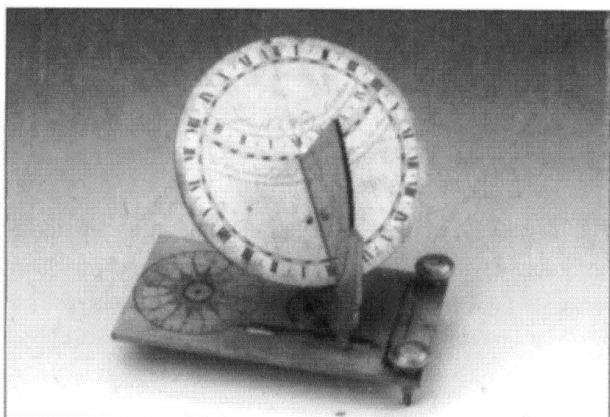

Fig.1.Calendar dial by Heath and Wing, 1758. Museum of the History of Science, Oxford; inventory no. 45528, image no. 150417. (Copyright reserved by the Museum; published by permission.)

In modern times, attention was drawn to the above phenomenon by Chris Lusby-Taylor[2], and an ingenious paper version was subsequently designed by John Moir.[3] However, the calendar dial is represented by two instruments in the collection of the Museum of the History of Science, Oxford. That which most clearly demonstrates the principle is shown in Fig.1. (Lewis Evans Collection, inventory no. 45528, image no. 150417.) Signed Heath and Wing, London, it is inscribed 'The Universal Dial and Dialling Instrut.' upon a circle 105 mm in diameter. According to a catalogue entry at the museum, the makers published a description of the device and its use in 1758.[4]

The principle appears well-adapted to the construction of an unusual monumental dial (Fig.2). Here, the stile forms the edge of a gnomon of tapering triangular section. Of course, such a stile still shows the hour of the day if its shadow is registered within the annulus (equatorial dial) or upon the ground (horizontal dial). Unfortunately, the important noon position is obscured on both. A tall structure will always throw a diffuse shadow due to the finite diameter of the Sun, and a 'shadow sharpener' (a filing card pierced with a pinhole) may be required to facilitate accurate reading.[5,6]

Author's address:
Dept. of Physics and Astronomy
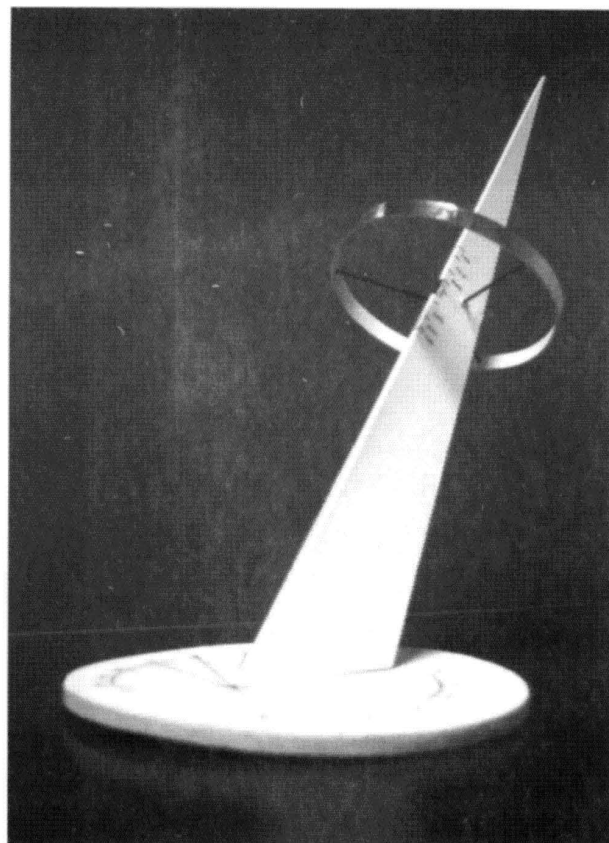*The University*
Leicester LE1 7RH

Fig.2. Working model of a monumental calendar dial for latitude 52.5°N.

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EXTENDING THE USEFUL RANGE OF A SUNDIAL

MIKE COWHAM

We have a horizontal sundial in the garden that we use to tell the time when gardening. For much of the day it is more than adequate for our needs - as long as the sun is shining. However, towards evening, especially during our long summer days, the shadow gets very difficult to read.

The dial was new, bright and shiny in 1986 but since then it has withstood the worst that the weather can throw at it, not to mention atmospheric pollution . And why is it the favourite perch for our friendly robin? His 'presents' don't help a lot.

Therefore it seems that a sundial, especially at low sun angles, does not show much contrast between the shadow and background illumination. Going back to elementary science, we recall that the amount of light falling on a horizontal plate is roughly proportional to the cosine of its angle. At noon in summer, the sun will stand at around $61.5°$ from the horizon here in Cambridge, making it about $28.5°$ from overhead. This then gives (Cos 28.5°) or 88% maximum illumination power. However, as the sun approaches nightfall (or around dawn - but who will be out at that time in the morning?) at, say, 1 hour from sunset, the angle of the sun will be less than 15 giving only 25% as much light. Also the light from the sun at this low angle has to struggle through a much thicker layer of our polluted atmosphere. Another factor that affects the contrast of the shadow is the background illumination from the blue sky and the clouds, but this is more difficult to quantify. Throughout much of the day the sky remains at much the same brightness due to scattering of light, making the low sun angle reading even more difficult.

I walk over to the dial and peer intently trying to find out where the shadow is lying - is it time for dinner? I hold up my hand along the eastern edge, and immediately I can see the shadow of the gnomon quite clearly in my palm. With care, this position can then be transposed onto the dial plate. The reason is that I have now eliminated the 25% sun intensity on the plate (i.e., hand) and restored it to near 100%. Also my paler hand gives more contrast than my robin-decorated dial.

Conclusion - what I need is a vertical dial for low sun angles. A good idea, but I have no where to put it. Then I think about modifying my original dial with two small (say $^1/_4$ " high) fences around it. This new addition seems to overcome many of the problems associated with low sun angles. The horizontal markings can be extended to climb
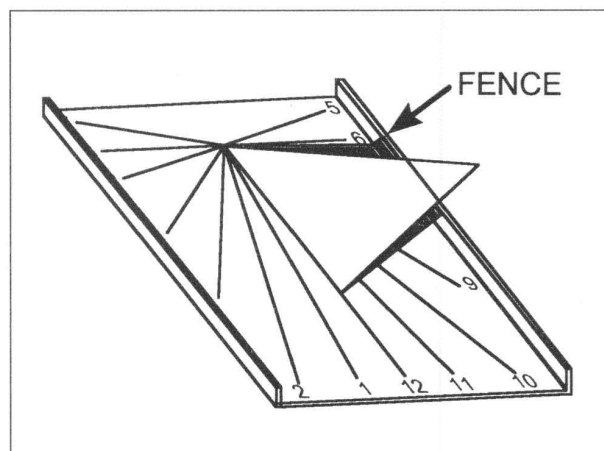
the fences. Yes, the fences will tend to prevent low shadows from illuminating the dial plate, but this does not matter any more. It is a bit like an armilliary sphere, but without its inherent problems where one edge of the arc can occasionally get in the way of the reading.

Then I started to think about how to make such a dial. If it is engraved or etched, this would be a very difficult process as the surface is no longer flat. Most other processes will be made more difficult by the addition of these fences. Could they be bent after the marking has been completed? Yes - possible, but I would not like to try it. My solution therefore is to add the fences at a later stage. This means that some form of bracket will be needed but this is not an impossible solution A further thought is that solid fences will reduce the dial's drainage properties. This is not a good idea. Certainly the fence must not go right around the dial, effectively making it into a bowl, unless large drainage holes can be added. The simplest way is to make the fences stand slightly above the dial so that water can simply run underneath. Hopefully such a solution will not restrict too much the removal of our dear robin's 'presents'.

Since working on this idea, I have been informed that this sort of thing has been done to dials before. Who was it who said that '*there is nothing new in dialling*'?

P.O.Box 970
Haslingfield,
Cambs, CB3 7FL

MORE RAILWAY SUNDIALS

GERALD STANCEY

The town of Locarno, in the south east corner of Switzerland, and Domodossios, in northern Italy, are connected by a most scenic metre-gauge railway called the Centrovalli Line. Some years ago, on a rail touring holiday down this line, I had tantalising glimpses of some interesting sundials on churches in Italy. However the real gems were on the station at Re. I vowed to return, and last year I found myself with a free afternoon in Locarno and a train timetable that showed that a two-hour visit was possible.

At Re the line runs roughly east—west, and the station buildings are on the north side of the line. The railway is single-line, and to the south of the station there is open country. There are no dials on the south facing wall of the station buildings On the east and west walls of the station are declining dials with analemmatic hour lines and aperture gnomons. The east wall also carries an analemmatic noon mark. The markings are formed from what looks like ¼ inch diameter black tubing and are clearly visible against the white walls of the station building. They are obviously the work of a craftsman but who was he? Nobody at the station knew anything about them.The town was closed for the afternoon and my poor knowledge of Italian did not help. Who was the master diallist? And did he also make the other dials that I glimpsed from the train?

If you go to Re, allow time to visit the massive modern church. It really is an amazing building for such a small town.

While not carrying sundials, some stations on the meter-gauge line from Chur to Arosa bear old Swiss sayings that
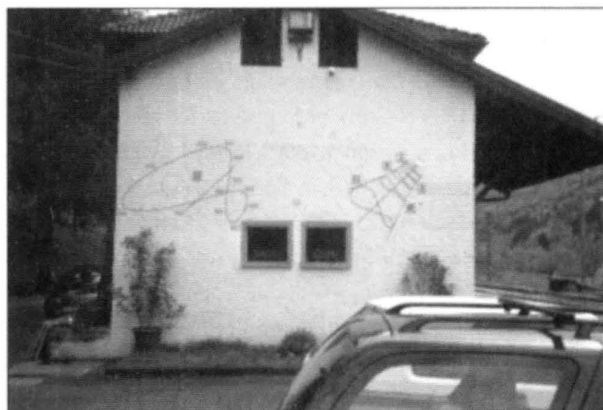

Fig.1. View of west dial, Re station

Fig.2. View of east dial and noon marks

would not be out of place on a sundial. Roughly translated, we have at Peist: 'Time flies, Mankind, be prepared'; and at Langweis: 'Time levels high and low, but it hurries. Understand it and be busy'.

Author's address:
22 Peterborough Avenue
Oakham, Rutland,LE15 6EB

'EIGHT BELLS AND TOPMASTS' BY CHRISTOPHER LEE, PUBLISHED BY HEADLINE BOOK PUBLISHING

This extract was received from our member John Moir. It is printed below by kind permission of the Publishers.

23 JUNE 1958

Yesterday the stars. Today I now know about time. At least, I think I do. I thought that time was nothing more than that. Twenty-four hours a day. It is, but it isn't. Apparently there are two types of time. One is called solar time - that's what everyone knows about, or is supposed to - and the other is sidereal time - that's about stars.

This evening the Mate started talking about solar time. He says it's the ordinary twenty-four-hour thing which everyone understands. It comes from what the sun does every day. Or really what the sun appears to do, because it doesn't do what we think it does - like rise and set. According to the Mate, solar time is all about working out if the sun reaches a fixed point at the same time everyday

(which it doesn't) and, if not, where is it (late or early)? That I could see immediately, but then he said it was to do with what he call the obliquity of the ecliptic and the eccentricity of the earth's orbit. He says the obliquity of the ecliptic is the angle between the ecliptic and the equinoctial. What, I said, is the ecliptic? There was a big pause.

'Don't they teach you anything at school these days, Chuck?'

I said I must have left before we got round to ecliptics. He didn't think that was very funny.

He said, 'Maybe they thought that you were too thick to take it on board.'

Maybe. But what is it? An ecliptic I mean. Dead simple, he said, it's the apparent path of the sun. Why apparent? why not just say what it does? Another big sigh. Because, he said, we think, it rises in the east and sets in the west, but it doesn't because we're actually doing the going round. Like Galileo, I said. Sigh Number Three. I must remember it doesn't pay to be smart. Write this down, he said: The apparent motion of the sun is that it rises in the east and sets in the west once a day and each year completes one revolution of its orbit - that's the ecliptic.

I think that all this means is this: if I'm standing in the back garden in Belvedere at midday with the sun overhead and then I wait until it comes round again the next day, then the time for the sun to be overhead again will be different. As it's going from east to west, the gap between being overhead the first time and overhead the second time must be the only way in which we can measure what he calls real time. That means a sundial at home is always the right time - as long as you can see the rotten sun, of course.

He said, More or less. He says more or less quite often, which, I think, means I don't always get it right. So I drew a big circle and put a mark right at the top at noon, then pretended to wait for the sun to come round again, exactly twenty-four hours later. According to my drawing, the sun wouldn't be at the same point (that's the thing about ecliptics and the rest). Therefore (I think) the point between that mark and where the sun actually was twenty-four hours later is the only accurate measurement we have of time. So it doesn't matter where you stand on earth, the distance between the two marks on the circle is how you can measure time. The Mate said it was more or less right and that the arc is called the Westerly Hour Angle.

I was feeling quite pleased with myself and then spoiled it.

I said it all sounded very convenient. Just because we say the sun comes up and goes down, why can't we think of it as going down first and coming up later. If we did that, we would reverse what we think is time. And why should we always think of time as going forwards? It might be going backwards. Maybe it doesn't exist. Maybe we're just making it up. He looked at me for about as long as it takes to smoke half a cigarette and then he said, Listen, Chuck, this is a navigation lesson, not a frigging seminar in metaphysics. Metaphysics? I must get a dictionary.

*Wolfson College Cambridge, Armillary Sphere.*
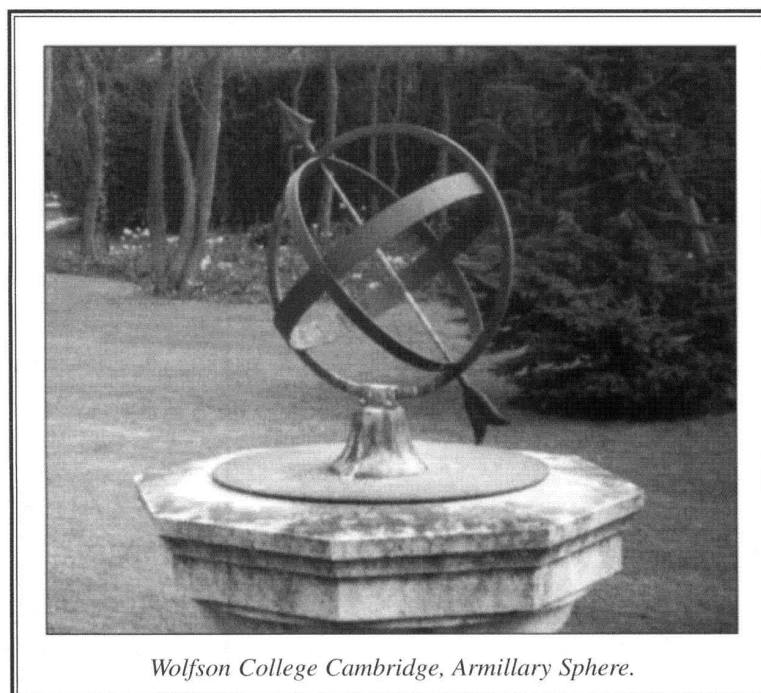
'WHEEL OF TIME'

Noon marks traditionally employed a small hole to image the midday sun upon a straight vertical or horizontal line. Modern timekeeping necessitates replacing the line by a figure-8 shaped analemma

Incising the latter on a surface that is part of a circle makes it possible to replace the aperture with a convex lens. If the lens has a focal length equal to the radius of the circle, and is fixed at the centre of the circle, it will throw a small, bright, well-defined solar image.

This construction makes it possible to consider large sculptural features, where an image produced by an aperture would be too dim and ill-defined. The illustration is merely a model!

Allan Mills
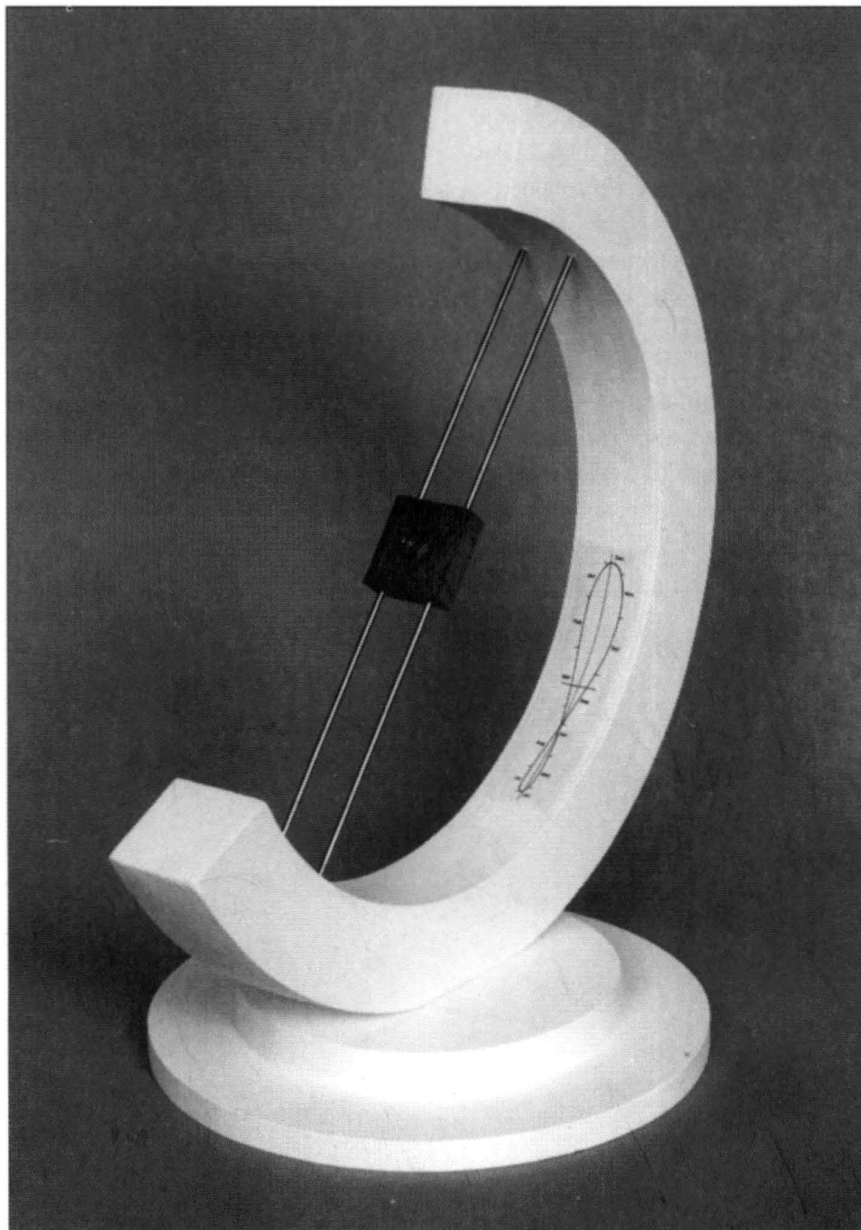
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Mr. Graham Aldred (Librarian & Restoration)
4 Sheardhall Avenue Tel: 01663 762415
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Cheshire SK12 2DE iclway.co.uk

Mr. D.A. Bateman (Secretary)
4 New Wokingham Road Tel: 01344 772303
CROWTHORNE douglas.bateman
Berks RG45 7NR @btinternet.com

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Mr. P. Nicholson (Internet Advisor)
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Mr. Peter K. Scott (Webmaster)
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Mr. Gerald P. Stancey (Treasurer)
22 Peterborough Avenue Tel: 01572 756444
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Dr. M.W. Stanier (Editor)
70 High Street Tel: 01638 741328
Swaffham Prior margaret@mstanier.
CAMBRIDGE fsnet.co.uk
CB5 0LD

Mr. Robert B. Sylvester (Membership)
Windycroft, Alexander Place Tel: 01229 465536
ASKAM-IN-FURNESS sylvester@windycroft.
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Mrs. Jane Walker (Education)
1 Old School Lane Tel: 01963 240421
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Mr. A. O. Wood (Mass Dials)
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Dr. I.D.P Wootton (Vice Chairman)
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