

GUIDELINES FOR CONTRIBUTORS

1. The editor welcomes contributions to the Bulletin on the subject of sundials and gnomonics; and by extension, of sun calendars, sun compasses and sun cannons. Contributions may be articles, photographs, drawings, designs, poems, stories, comments, notes, reports, reviews. Material which has already been published elsewhere in the English language, or which has been submitted for publication, will not normally be accepted. Articles may vary in length, but text should not usually exceed 4500 words.
2. Format: The preferred format for text is MS Word or text files sent by email to john.davis@btinternet.com. Material can also be sent on CD or as a single-sided typescript, single- or double-spaced, A4 paper.
3. Figures: For photographs, colour or black-and-white prints as large as possible (up to A4). Slides and transparencies are also acceptable. Pictures can be sent electronically as jpg (do not over-compress) or tif files. For email attachments, do not exceed 20 Mbytes. Tables should be treated as figures and numbered as part of the same sequence. Drawings and diagrams should be in clear black lines on a white background. Each figure illustrating an article should carry on the back the author's name and a number indicating its relative position in the text (Fig. 1, Fig. 2 etc...). Captions for the figures should be written on a separate sheet in numerical order. They should be sufficiently informative to allow the reader to understand the figure without reference to the text.
4. The Bulletin does not use footnotes. Where additional information is required, notes should be numbered as a Reference with a superscript number. For very long notes, use an appendix.
5. References : Sources are referred to in the text by a superscript number. They are listed in numerical order under the heading 'References' (or 'References and Notes') at the end of the article. The Bulletin's convention is as follows:

For books: Author's name; Title of book, in italics; Name of publisher, Place and date of publication.
For papers and articles: Author's name; Title of article in single quote-marks; Name of journal, in italics (this may be abbreviated); volume number in Arabic numerals, underlined or bold; first and last page numbers; date, in brackets.

Examples:

A.E. Waugh: *Sundials, their theory and construction*. Dover, New York, (1973).

D. Colchester: 'A Polarized Light Sundial', *Bull BSS*, 96.2, 13-15 (1996)

A.A. Mills: 'Seasonal Hour Sundials', *Antiquarian Horol.* 19, 142-170 (1990)

W.S. Maddux: 'The Meridian on the Shortest Day', *NASS Compendium*, 4, 23-27 (1997).

If you simply wish to give a short list of books associated with the subject of the article, this may be given at the end of the article under the heading 'Bibliography', using the convention as given for 'Books' above.

6. Acknowledgements: These should be as brief as is compatible with courtesy.
7. The address of the author will normally be printed at the end of the article unless the author, when submitting the article, expresses a wish that this should not be done.
8. Copyright: The copyright of an article is held by the author. The copyright of photographs belongs to the photographer; authors who use photographs other than their own should obtain permission, and should acknowledge the source in the caption. Authors who re-publish elsewhere material already published in the Bulletin are asked to refer to the Bulletin in the re-publication.

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Front cover: Vertical dial dated 1903 in Park Street, Hitchin. It is mounted on the side of a house and can be seen from the street. It appears to be made from sheet metal with the markings raised from the back and then painted in black. The use of the zodiac signs is rather unusual and arbitrary, but they have taken all of them and have placed them clockwise around the dial starting at Leo (23 July) in the upper right corner and ending with Cancer (21 June) in the top left. It is interesting the way that some of these signs have been used to replace the numerals for 12 noon, 2pm and 5pm. Photo: Mike Cowham.

Back cover: St Nicholas, Harwicke, Gloucestershire. A beautiful mass dial entirely in pocks, with 'quincunx' markers at noon and service times. The offset for noon allows for the wall not facing direct south. ('Quincunx' is the five on dice.) Photo: Tony Wood

BULLETIN

OF THE BRITISH SUNDIAL SOCIETY

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EDITORIAL

As the new Editor of the Bulletin, my first and very pleasant task is to thank my predecessor, Dr Margaret Stanier, for the tremendous work which she performed over many years. Indeed, the Bulletin has had only two Editors in the history of the BSS and much of the success of the Society is due to the high standards which Margaret and Charles Aked set for the Bulletin. They will be a hard act to follow. I do have one advantage over them and that is the technological progress in printing and computing which makes achieving a neat layout much easier than it once was. 'Cut-and-paste' meant exactly that for the first editions of the Bulletin and I know that much effort used to be expended in making low-contrast pictures suitable for black and white printing. Margaret will remain as a valued member of the editorial team and I am hoping she will continue to help me avoid too many grammatical errors.

I am not planning to introduce large or immediate changes to the style and format of the Bulletin. The returns from the

recent Readership Survey are still being analysed but they show that no wholesale changes are called for—another testimony to Margaret's work. But I will try to act on the suggestions made. This might mean commissioning (no fees though!) papers to fulfil the demands of our readers.

I am keen to encourage new authors to contribute articles. Our regular contributors provide much valued input but it would be good to get some new slants on the subject of dialling. To this end, we plan to instigate an annual prize for the best paper from an author who has not previously written for the Bulletin (Readers' Letters excepted). So, if you have an idea for an article, short or long, now is the time to put pen to paper or fingers to keyboards. I will be very pleased to help out with the mechanics of producing a paper for anyone who has a good idea but who lacks writing experience.

John Davis

THE SUNDIAL IN THE CHAPEL OF HOLY TRINITY AT RUG

PETER RANSOM

In 2002 Patrick Powers contacted me about investigating a dial in North Wales. He had a picture and thought the dial was located at Rug in the Clwyd area of North Wales. Knowing that I visited my mother in a nearby area at least annually, he thought I might like to locate the dial. Thus began one of the strangest (dare I say spookiest?) coincidences of my dialling days.

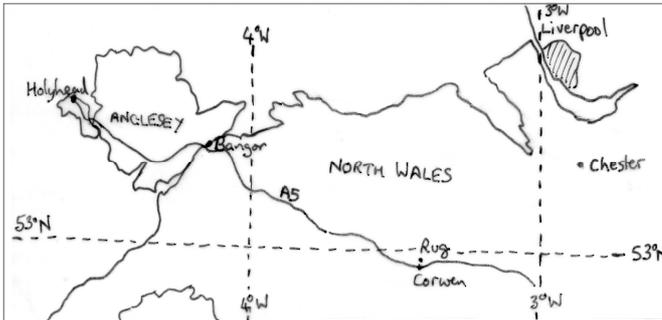


Fig. 1. Map to show the location of Rug Chapel in North Wales. It is on the A494 about 200 yards from its junction with the A5. OS sheet 125 SJ064438.

I had previously seen brown signs to Rug Chapel in passing along the A5 (Thomas Telford's great road from London to Holyhead that still has some of the original milestones *in situ*) before and thought that would be where the dial was located. Once before I had called at the Chapel only to find it closed out of season. It belongs to Cadw, the Welsh equivalent of English Heritage and members of the latter are allowed in without charge. It is open from about 1 April.¹ This time it was June when I visited and what a surprise I had when I entered the site.

There was nothing of dialling interest to be seen as I went through the gardens and approached the Chapel. There was a sort of pedestal that I thought might have had a dial on it at some point, so I was rather disappointed since there was



Fig. 2. This is Rug Chapel. It is near Corwen in North Wales.



Fig. 3. The ceiling of Rug Chapel.

nothing like Patrick's picture to be seen. However, the disappointment disappeared when I went into the chapel – one's spirit is raised immediately at seeing the most amazing decorations.

The private chapel was built in 1637 by Colonel William Salusbury (1580-1660), who defended Denbigh castle between 1643 and 1646 when the Parliamentarians attacked it during the Civil War. The exterior was reconstructed in 1854-55, but fortunately the Victorians left the interior intact so the rich decoration of 1637 'high church' features remains. The picture of the ceiling gives some idea of what you can expect to see. The aim of this article is not a chronicle of the chapel but the unexpected gnomonic gratification therein. At the east end of the north wall of the nave is a very unusual 17th century wall painting.

Yates² writes,

"Lavish use has been made of the elements traditionally associated with the subject. A central white panel or table top has at each end a painted turned candlestick with a lighted candle. Nearer the centre are an hour glass and a dial on which is painted 'fugit hora' (the hour flies). The main feature of the upper part is a skull surrounded by a garland containing seven roses. The lower part is occupied by a skeleton reclining on a pillow of coiled rope. Between the hour glass and the dial is the Latin inscription 'ut hora sic vita' (as with the hour so with life)."

There are four Welsh inscriptions below the table, the first of which comes from a carol written by Richard White, a Roman Catholic martyr executed in 1584. It means 'as the flame gradually consumes the tallow of the lighted candle

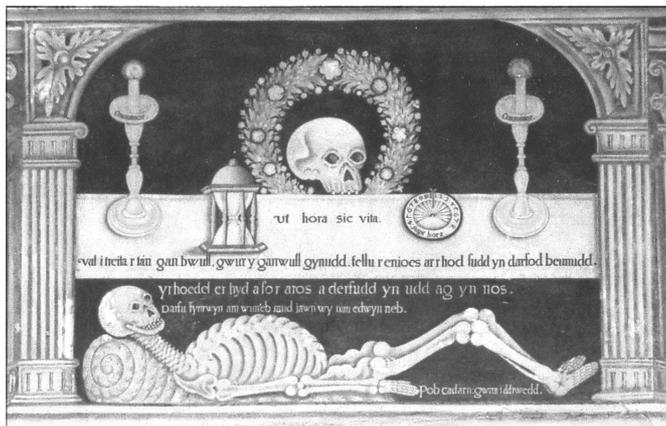


Fig. 4. The painting features the familiar theme of the transient nature of our sojourn on Earth and the inevitability of death.

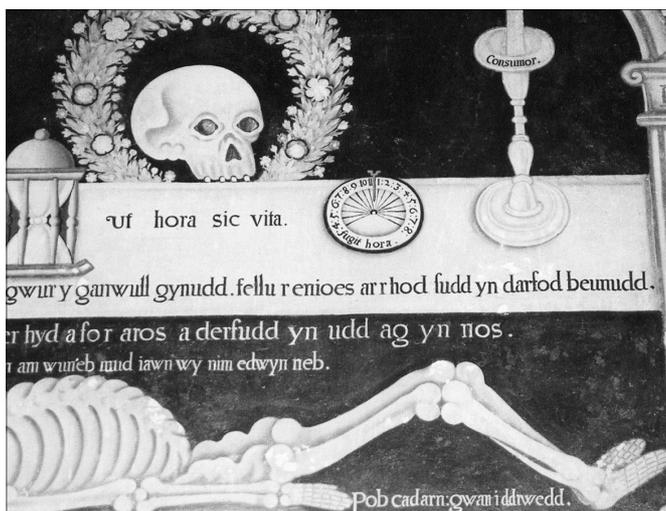


Fig. 5. Detail of the table with hour glass, wreathed skull, dial and candle.

so life on the orbit (Earth) perishes daily'. The other phrases are also concerned with the mortality of man and can be found in the appendix with their translations.

The dial is interesting. The gnomon does not reach the centre of the ellipse and the end is splayed out. One wonders whether this is some sort of nodus. I felt that there were some fascinating features in the dial so used Photoshop® to enlarge the dial in detail and then used it as a background in the dynamic geometry software, Geometer's Sketch Pad.

It looks as if the dial is a projection of a circular horizontal dial since by superimposing a grid and using the equation of an ellipse a very nice curve can be fitted round the feature to which the dial lines spread. Unfortunately the software cannot cope with implicitly defined functions, so the equation of the ellipse which would normally be written in the form:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

has to be written explicitly as:

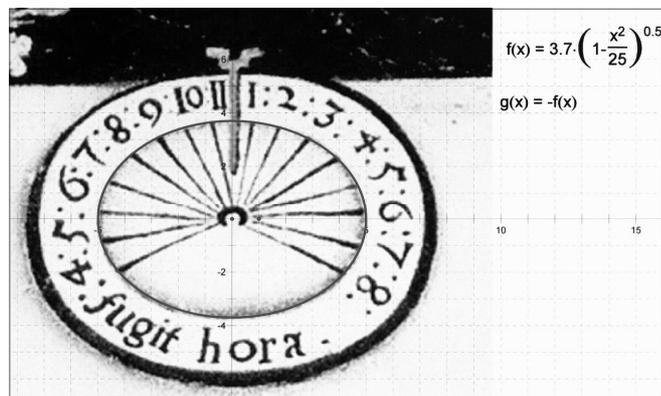


Fig. 6. Detail of the dial with fitted ellipse.

$$y = b\sqrt{1 - \frac{x^2}{a^2}} \quad \text{and} \quad y = -b\sqrt{1 - \frac{x^2}{a^2}}$$

for both parts of the ellipse to appear. Using function notation the upper part of the ellipse becomes:

$$f(x) = 3.7\sqrt{1 - \frac{x^2}{25}}$$

Since the lower half of the ellipse is the negative of this function we can define it as $g(x)$ where $g(x) = -f(x)$. The scale used on the dial is arbitrary – the point (1,0) can be grabbed and moved to any chosen position. (In school, I have found this is a useful tool for pupils to use when finding equations of curves such as the shape of parabolas. I have yet to pick up the courage to analyse dials with them! They superimpose a grid on a picture of a bridge and find the equation of the arches or suspension chains.)

Of course measuring the angles on a perspective drawing does not help check the accuracy of the hour lines – one needs to measure the angles in the plane of the dial. To measure the angles between the hour lines I realised that I would have to get rid of the perspective caused by not taking the picture perpendicularly to the dial on the wall and also by the artist's drawing (a circle is projected onto an ellipse when drawn from an angle to the vertical).

I did this by stretching the image in one dimension until I had obtained a circle. This I then used as the background in Geometer's Sketch Pad and then superimposed line segments along the hour lines. There are a few lines that do not seem to emanate from the same centre, so I have not included them in the analysis that follows. To me it seems as if there are two centres from which the hour lines radiate and since these are both in line with the sides of the gnomon this is what one would expect if the gnomon thickness is taken into account. However they do not lie on the 6 am/6pm line which is not straight anyway. The morning hours do not perfectly line up with the numbers on that side, however I have assumed that the lines represent the hours.

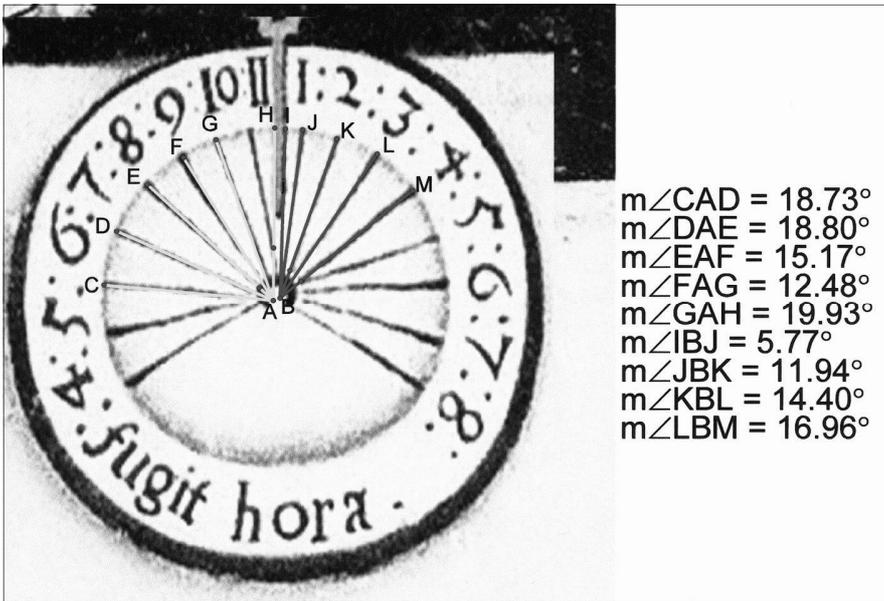


Fig. 7. Detail of the now circular dial with angles between the hour lines shown.

Now, if the dial is one that was made for the location of Rug it should be based on latitude of 53° north, since Rug is $52^\circ 59'$ North according to my gazetteer. Using the formula $\tan D = \tan(15t)\sin f$ where D is the angle the hour line makes with the noon line, t is the number of hours before (or after) noon and f is the latitude, these angles should be as shown in the following table with the measured angles for comparison.

Morning hours

time	6-7	7-8	8-9	9-10	10-noon
Measured	18.7°	18.8°	15.2°	12.5°	19.9°
Calculated	18.5°	17.3°	15.5°	13.9°	24.8°
Difference	0.2°	1.5°	-0.3°	-1.4°	-4.9°

Afternoon hours

time	noon-1	1-2	2-3	3-4
Measured	5.8°	11.9°	14.4°	17.0°
Calculated	12.1°	12.7°	13.9°	15.5°
Difference	-6.3°	-0.8°	0.5°	1.5°

Quite a reasonable match considering that it's a painting! Only around noon are these angles more than 2° out. I find this is a quite remarkable agreement. The two hours either side of noon show the biggest disagreement – but then perhaps I have been mistaken in assuming that the thickness of the gnomon has been taken into account.

This repays further investigation – I find it hard to believe that an artist would paint with this degree of accuracy by pure coincidence. Was it the case that the dial was drawn accurately on the wall and the artist was guided by the lines? Would some sort of X-ray show evidence of this? I

believe that there was some *very* sophisticated planning behind this dial and further research is needed – is there any evidence of a horizontal dial on the Rug estate about the time the painting was done?

Sorry Patrick – I never came across the dial you sent me to find, but this was one find that has intrigued me far more and without your information it is unlikely I would have visited this Welsh jewel. The analysis of this dial was first shown at the Newbury meeting in September 2003. This article was written on New Year's Eve 2005 when the image of Old Father Time reminded me of my mortality and spurred me into action.

APPENDIX

The following Welsh texts appear on the mural. I have written the Welsh text as I saw the letters. These differ slightly from the texts given in Yates² where some of the f 's are written as t 's. The translations are theirs, my Welsh being limited to just a few pleasantries.

val iftreila r fan gan bwll, gwur y ganwull gynudd, fellu r enioes ar rhod fudd yn darfod beunudd

(as the flame gradually consumes the tallow of the lighted candle so life on the orbit (Earth) perishes daily)

yrhoedel er hyd a for aros a derfudd yn udd ay yn nos

(lifetime, however long its stay, will come to an end by night and by day)

Darfu fyn rwyn am wuneb mud iawn wy nun edwyn neb

(My nose and my face are perished, very dumb am I, no one knows me)

pob cadarn gwan i ddrwedd

(every strong one is weak in the end)

NOTES AND REFERENCES

1. The opening times of the chapel are given by various web sites as being between 18 March or 13 April to 30 September from 10am to 5pm daily, but not Mondays and Tuesdays unless bank holidays. Check times at <http://www.llangollen.com/rug.html> or ring the custodian on 01490 412025.

2. W. N. Yates: *Rug Chapel Llangar Church Gwydir Uchaf Chapel*, Cadw, (1993).

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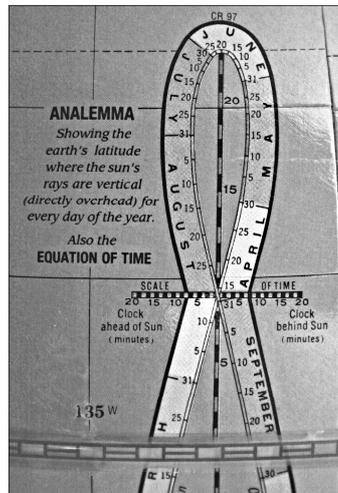
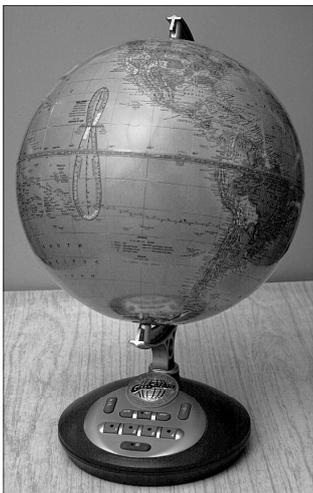
READERS' LETTERS

The analemma in other applications

Further to Christopher Daniel's thorough study of the invention and earliest use of the analemma (Christopher St J H Daniel: 'The Equation of Time: The invention of the analemma, a brief history of the subject'. Part I, Bull BSS, 17(iii), 91-100, 2005; Part II, 17(iv), 142-154 2005.), there is another question. When did it first appear in atlases and on globes?

I recall seeing it on an old atlas, and I searched in all our cupboards and bookshelves intermittently over a number of years, but it was not to be found. The feature, alas, no longer appears in modern atlases. If any members have old atlases that include an analemma I would be very pleased to know.

Quite by chance, a few years ago I saw a good quality globe in the toy department of a large department store. It was in the toy department because, apart from showing the earth, it is called a Geosafari Talking Globe, copyright Educational Insights, California. It has a keypad enabling several players to compete by answering questions put by a synthesised voice about countries, cities, rivers, etc.



The photographs show the globe and the analemma. Note how the analemma sits precisely between the tropic of Cancer and Capricorn. The caption makes the point that it is when the sun is directly overhead, as well as showing the equation of time. It will be intriguing to know just when geographers and map makers started to make use of the analemma in this way.

Douglas Bateman
Crowthorne, Berkshire

Thomas Payne

In the Readers' Letters section of the March issue (*Bulletin* 18(i), p.21), Tony Wood asked "who was Payne? Why 1789?". One is irresistibly reminded of Thomas Paine and his defence of the 1789 French Revolution in *The Rights of*

Man (1791-92), a response to Edmund Burke's *Reflections on the Revolution in France* and written while Paine was in England, he having returned there in 1787. But this may have nothing to do with the sundial's pedestal.

John Hayes
Chichester

Almost Dials

In 'Readers' Letters', BSS Bulletin 97.3, I broached the subject of 'almost' sundials, i.e. sculptures or monuments that with a little tweaking could have also served as time-tellers. Recently, whilst walking in London's Tower Hill gardens I came upon my best 'almost' dial to date. It is a memorial to merchant seamen lost in the Falklands war, and had been unveiled only last year. As the photo shows, it consists of an 8-point compass table on whose N-S axis stands a tilted anchor. The tilt exactly matches that of the real sundial seen behind it, so I did not need to pull out my well worn protractor in order to verify its credentials. A few well placed hour marks and you've got another dial for the Register!



For those more interested in the real thing, the dial behind was designed for London Underground Limited by John Chitty and..... but wait a minute - loads of information about it, and hundreds of other London and British sundials can be found in the excellent *Sundials of the British Isles* edited by and obtainable from Mike Cowham.

John Moir
London E11 2QA

BSS PHOTOGRAPHIC COMPETITION 2005

The 2005 Photographic Competition attracted 29 entries, almost twice as many as last year. The standard has remained high and the six appointed Judges were generally in agreement on the order in which to place the pictures. Unlike last year there were not any really controversial entries that split the judging but there were some rather cryptic titles. Some of these were perhaps too cryptic and several Judges may have missed their hidden meanings.

This year's First Prize goes to Ian Butson for his excellent photograph 'I Have the Inclination but not the Time' with a mark of 492 (82%). This is an excellent shot of a rather sad dial and his clever title was appreciated by all of the Judges. Some of their comments include: 'Lovely idea and title', 'Deserves an award for the best title' and 'Millwheel at base is a bit distracting'. He has been awarded a replica astrolabe with a suitably engraved plate on its display stand.

In second place is 'Caryatid' by John Wall with 483 (80.5%). This is a picture of a lady carrying a lot of hardware on her head. He has been awarded the runners-up prize, donated by sponsors Green Witch Ltd, of a replica Equinoctial Ring Dial. Judges' comments included: 'Plinth cropped, otherwise very nice', 'Well positioned but a pity about the presentation of the title'.

Third place goes to John Davis for his excellent picture of the fine stained glass dial at Merton Church in Norfolk with 468 points (78%). The Judges commented: 'Splendid factual record' and 'A well-balanced picture that works both as a record shot and as an ornamental pattern'.

Runners-up were Mike Shaw whose atmospheric picture 'Evening at the Adler Planetarium' certainly catches the eye. It shows a rather lonely dial on the waterfront in Chicago, photographed during his visit to last year's NASS Conference. Mike admitted that he had digitally removed an obtrusive lamp post from the picture but one Judge thought that he should have done the same with the vapour trails in the sky.

Another of Ian Butson's entries 'Steps of Time' was well received but there was some comment about the clutter of shadows confusing the result.

A further entry from John Davis, 'Newton in the Snow' shows a rather sad picture of a fine dial on a very cold winter's day, bedecked with snow but just catching the sun's rays. The main criticisms concerned rather tight cropping of the picture and the distracting background.

An entry from last year's winner, John Foad, was of his own colourful dial entitled 'Fly on the Wall'. The Judges generally liked this dial but I suspect that it was marked down somewhat by being merely a record shot. Some ex-

ternal detail, even a person viewing the dial, may have helped this receive a better score. They liked the colour co-ordination used for the mount and its title.

It is easy to criticise each of the pictures but a lot more difficult to compose them. Backgrounds do make a difference, good or bad, but often cannot be avoided. It is small things like this that make for an interesting competition.

There were many other excellent entries and it is hoped to feature some of these in colour in future Bulletins throughout the next 12 months.

The first 12 entries have been mounted in A4 clip frames and are available to anyone who wishes to use them for promoting the BSS. These may suit an art gallery, a stately home, a BSS event or just a local church event.

These entries show what can be achieved in our photography, usually being more than a simple record shot of a dial. The surroundings of a dial should be included where possible to show its location but the dial must not be too small as to be insignificant.

We would like to thank the six Judges who carefully scrutinised each picture and gave us their valued opinions. They were Graham Stapleton, Tony Ashmore, John Foad, Jill Wilson, Jane Walker and Patrick Powers. Four of these also acted as Judges last year and John Foad, as last year's winner, was invited to join the judging panel. In most cases the Judges closely agreed with each other showing few violent likes or dislikes. Marks ranged from 82% at the top to 41% at the bottom of the list (a good spread of 2:1) with the majority clustered around 70%, so a good effort from all entrants.

The Competition will run again in 2006 and entry forms should be sent out with the September Bulletin. Rules will remain much the same as for 2005, but we may need to reduce the maximum of three entries per person to just two. We may also make a few small changes to improve the marking system following the remarks made by some of the Judges. If you would like to be considered as a Judge for next year we will be pleased to hear from you. Contact Mike Cowham or any Council member. In the meantime keep your eyes open for that 'special shot' as it could win next year's competition for you.

I think that many members would like to know how the marks were awarded. There were nine categories with different numbers of marks for each. These were: Choice of Dial, 12 points; Artistic Merit, 12 points; Focus, 8 points; Exposure, 8 points; Illumination, 8 points; Title, 8 points; Print Quality, 12 points; Presentation, 12 points and Overall Impression, 20 points, making the maximum score for any



First Place

I Have The Inclination But Not The Time - Ian Butson

picture 100 points. Note that the Overall Impression carries the greatest number of points and is real indication by that Judge of his/her like *or dislike* for the entry.

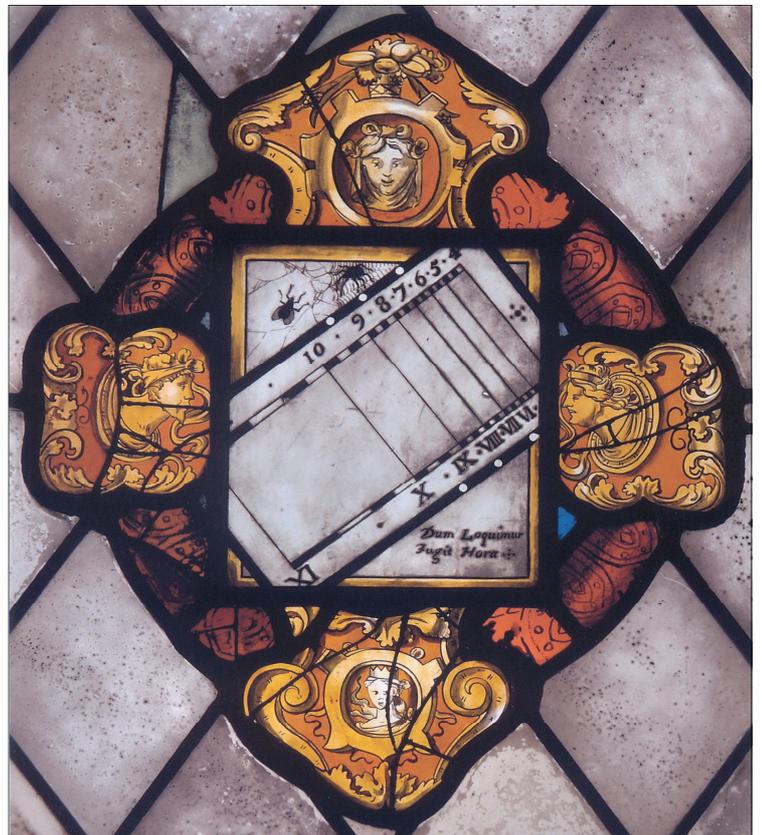
Where one of the Judges themselves has entered the Competition they were not allowed to mark their own photograph but the scores of the remaining five were averaged to complete the scoring.

*Mike Cowham.
April 2006*

Many thanks are due to Mike Cowham for his seamless organisation of the event again. Three of Mike's own photographs would have featured highly in the competition if he had felt able to enter them without prejudicing the judges: perhaps he will get a chance for future competitions – Ed.



Second Place
Caryatid - John Wall



Third Place
Merton Church Sundial - John Davis



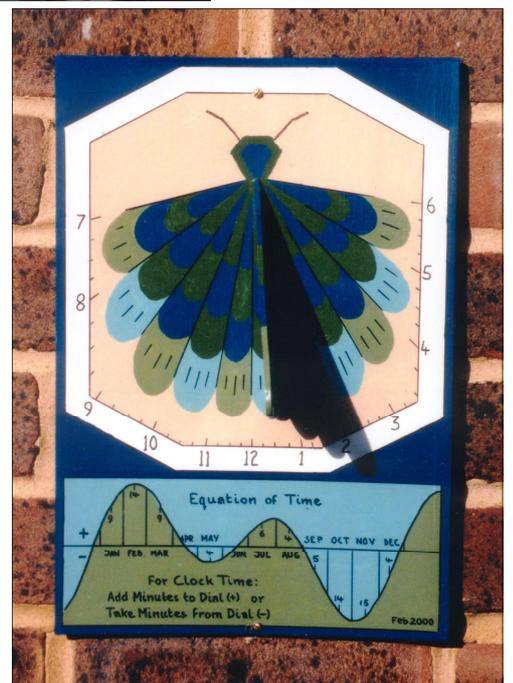
Evening at the Adler Planetarium - Mike Shaw



Steps of Time - Ian Butson



Newton in the Snow
John Davis



Fly on the Wall
John Foad

PHOTOGRAPHIC COMPETITION

Highly Commended pictures

MINUTES OF THE 17TH ANNUAL GENERAL MEETING

COLLINGWOOD COLLEGE, DURHAM, 23 APRIL 2006

1. The meeting was opened by the Chairman, Christopher St J H Daniel, at 12:45 pm. About 70 voting members were present.

2. Apologies were received from Michael Maltin, Peter Ransom and David Pawley.

3. The minutes of the 16th Annual General Meeting held at the Royal Holloway College, Egham, on 3 April 2005, had been circulated in advance, were taken as read, and were approved by a show of hands. There were no matters arising and the minutes were adopted, and signed by the Chairman.

4. The reports of the Honorary Secretary and other members of Council had also been circulated. There were no matters arising, and no queries from the floor.

5. Council member's reports

Secretary: Doug Bateman. *Liaison.* Since the last AGM I have dealt with 32 enquiries by letter, several by e-mail, and a few by telephone. Many have sought advice about setting up dials or information about dials in their possession. Whilst we are therefore helping to 'educate the public' as part of our charitable status, few of the enquiries have led to membership. The number of enquires is similar to those made in the previous year.

Restoration: Graham Aldred. A few enquiries for advice have been received. These vary from a desire to repair or restore a personal sundial or one in a public place to a desire to learn more about the history and value of a dial in order to sell it, (although the Society as a body cannot give valuations). In all cases extensive advice and information is readily given and the enquirer is encouraged to visit the BSS web site to view the dial makers list. It is also encouraging that there is generally more public awareness that neglected sundials are old scientific instruments that are worth protection and restoration.

The successful replication of the Henry Wynne DH dial by the combined efforts of three BSS members is a very significant achievement and is certainly a measure of the outstanding professional and scientific skills that exist within the Society. Other successes include the restoration of the dial at Blandford Forum. Work is in progress to restore the heliochronometer at Bromley House. The installation of the replica of the combined Horizontal/Equinoctial Sundial at Lyme Hall has been delayed until spring 2007 due to extensive scaffolding towers erected on the site for roof repairs.

Mass Dial Group: Tony Wood. Discovery and recording of mass dials continues undiminished. Extensive reports from John Lester in Warwickshire and North Worcestershire together with Ian Butson in Buckinghamshire and Oxfordshire have been sent in. A recent request for information about dials in the Oxford Diocese has led to a decision to start the database entry for this region.

Ted Hesketh's archive and Frank Poller's records additionally have resulted in this region being most thoroughly covered and collating into the archive has resulted in 14 files being assembled (cf. 13 files for Suffolk alone). Another request from Mike Cowham for information on Saxon dials has led to a reassessment of the status of some mass dials. It is hoped that the mass dial Register can provide a corpus of data for a detailed study of Saxon dials.

There is an increasing awareness of mass dials on the Continent and it is to be hoped that similar 'Central Agencies' to ourselves can be established. Mike Cowham is liaising with continental recorders about this. Other aspects of mass dials have surfaced; there are some in museums (surprisingly) and some internal dials are reported but they may be later than the usual medieval period associated with mass dials.

Museums Survey: Tony Wood. There has been a slowing down in Survey activity but three survey batches ('phases') have been sent out. A high response from the north of England was recorded with a good response from two phases covering the Midlands. Of major benefit was a reply from Derby Museum and contact with the author of the book on Derbyshire Clockmakers (Maxwell Craven OBE). Whitehouse of Derby and several other makers have surfaced from our survey for Jill Wilson to incorporate into the second edition of the 'Biographical Index'. Visits arising from the survey were made to the Worcester Porcelain Museum and Lydiard House near Swindon to help the curators there and assistance from Registrar Patrick Powers is gratefully acknowledged for the latter visit. The Survey will continue and a publication of the results is planned when 'complete'.

Editor: Margaret Stanier (Report by Deputy Editor - John Davis) The Bulletin layout is now done entirely in-house. This eliminates one of the possible sources of typographical errors. Also, the cost savings have allowed us to introduce 4-pages of colour on a routine basis. Electronic copies of the Bulletin are being generated for all new issues and we are hopeful that issues back to around 1999 may

also be regenerated for future indexing and possible electronic publishing.

The two major papers on the history of the analemma from Christopher Daniel, published in consecutive issues of the Bulletin, have been prepared with additional illustrations as 'BSS Monograph No.1' in standard BSS format. With the gracious support of the author, this is now available for sale.

The 'Readership Survey' distributed with the March issue has produced approaching 100 replies, a good rate of return. The details are being analysed and will be acted on wherever possible, though the mix of published papers is to some extent dependent on what members submit to the editorial office. A recent upturn in both major papers and shorter, less technical, items has allowed a modest expansion in the size of the Bulletin – please keep them coming!.

Biographical Index: Jill Wilson. The first edition containing just over 2100 makers was published in 2003, having taken more than 10 years to collect and compile. The draft of the revised edition is now well forward and will contain over 4100 makers. Not only are there some 2000 new names, the majority of the previous entries have been updated. For the additional names and material I have to thank those who have sent me quantities of information and all sorts of help. Many of the newly listed makers may be categorised as local makers whereas others have become known because a dial has turned up in a sale or a museum catalogue.

Membership: John Foad. Membership continues to fall slowly from its peak of 611 in the year 2000. We are now 471, down from 494 last year. Over a quarter of our members reside overseas and their number is actually growing. In England we have members in 55 counties, and beyond the UK we can be found in 27 countries. Most recently we have been glad to welcome our first member from Russia.

Two changes have been made that affect joiners from now on. The rules have been altered so that subscriptions are due on the anniversary of the month of joining; and an updated and illustrated edition of the *Dialling Miscellany* has been prepared. The *Miscellany* has always been distributed to new members, as an introduction to the Society. If any existing members would like a copy of the new illustrated version, it is now available at the price of £5, to cover direct production and postage costs – or it can be purchased at the Durham AGM at a special price of £4.

A growing number (about three quarters) of our UK members have now signed a Gift Aid contract, giving the Society a tax benefit of over £1,800 a year. Not everyone is willing or able to join the scheme, but I will continue to try to recruit the remaining quarter.

On a technical note, the membership database has been transferred from Lotus to Microsoft Excel. This is the Society standard, and ensures compatibility with our financial systems. As the most widely used spreadsheet, it will also ease eventual transfer to a successor to the post of Membership Secretary.

Fixed dial register: Patrick Powers. The majority of the year has been taken up with preparing, publishing and distributing the various versions of Register 2005. Problems with the Society's computer system delayed the issue of the CD Edition and I would again like to apologise to all those affected for the quite inordinate delay that has occurred. Shipment of these editions is however about to start as this report is written.

The Society's archive of paper forms and photographs has been moved into commercial storage. Member's may gain access to it or to any item within it by arrangement with the Registrar.

Some very preliminary work has been conducted into the ways in which members might be able in the future to submit records and images electronically. However this also requires the establishment of an electronic archive and this will involve further consideration before it can be implemented.

The Mass Dial Register is still in use with Tony Wood at Version 1. There is one outstanding reporting problem which remains to be fixed. Data entry is not however affected.

At this year's conference I shall be entering my tenth year as Registrar and I now feel it appropriate to stand down from the post in the next few months. I would however be delighted to assist anyone who may be interested in taking on this role, a role which provides an ideal opportunity for anyone who would like to learn how to use MS Access. Recent changes to the archiving process and improvements in the design of the data system itself have made the job very much easier than hitherto.

Exhibitions: David Young. The Society has again been represented at National Science Week, Greenwich. In addition another local Science Week was supported. A small team represented us at the British Horological Institute last summer. I am very grateful for the hard work, for little reward, that is entailed.

BSS Web Site: Chris Lusby Taylor. Over the last year I have regularly updated the Web site content while, as previously, keeping the overall appearance and navigation almost unchanged. I have recently acquired new software that should allow me to redesign the site, and am currently planning the structure and aesthetics. I will be grateful for any ideas members may have for improved layout, navigation or content.

New content has been added to the Publications, Links, Dial Makers, Newsletter, Register Ramblings and Conference pages, including full reports on last year's Royal Holloway and Newbury meetings.

I have added a complete Table of Contents of The Bulletin from 1988. The Bulletin Readers' Survey is available electronically as an on-line form.

Publication sales: Peter Lane. Since taking over the responsibility for sales and publications from Margery Lovatt in October 2005, there has been a steady stream of requests for our publications. Other than one bulk order for *Oxford Sundials* from the Museum of the History of Science, most orders have been for a cross section of our stock. It would be fair to say that it has been reasonably quiet recently and, as we do not actively engage in pro-active selling, I think that we have to accept peaks and troughs. The system following transfer is working well with responses to enquiries and orders being turned around within a few days. Sales turnover in this period was £390.

Foreign tour: Mike Cowham NUREMBERG, 29 September to 5 October 2006. A visit to Nuremberg is being hosted by Ludwig & Louise Engelhardt and they are planning an exciting programme of visits to see some of the sundials of Franconia, including the major museums in Nuremberg itself. Nuremberg is the home of the fine ivory diptych dial and the Germanisches National Museum has a fine collection to show us. A coach tour has been arranged to Rothenburg ob der Tauber, Creglingen and Weikersheim and a further visit to see Franconian Switzerland, as its name suggests, a very scenic area.

The inclusive cost for the visit with all meals, except one lunch, and a good quality hotel in the city centre is just £450 per person, double room sharing. Air or train fares will be extra. Some spaces are still available and you should book for this exciting visit as soon as possible.

Treasurer's Report: John Davis. The 2005 Accounts, kindly audited by Geoff Parsons, are shown separately. Turnover is substantially less than last year due to the lack of a foreign tour and the return to a more average-sized conference. The underlying finances remain sound. Note the following points:

* The headline figure shows an increase in funds of c. £7k. This is rather misleading as we managed to collect a substantial number of payments for the Durham Conference during December (much more than at the same time in 2004). Also, payments for the CD version of the Register 2005 have been received but the costs have not yet been incurred. Nevertheless, the financial position of the Society is strong and we do not need to increase the subscriptions.

* The subscription income has increased slightly de-

spite the drop in membership. This is largely due to the winding-up of the 5-year payment scheme.

* The Gift Aid claim for c. £1820 was slightly higher than previous years: John Foad is thanked for doing most of the work in preparing the claim and getting new members to sign up to the scheme.

* A new Grants Policy has been published: we are awaiting applicants.

I am standing down as Treasurer in order to allow me to concentrate on editorial duties. Graham Stapleton has bravely allowed his name to be proposed as a replacement and I wish him well in the post.

7. Election of Officers

Nominations had already been proposed and seconded. There being no other nominations from the floor, the following were approved by a show of hands, and the Chairman declared them duly elected.

Chairman, Secretary and Treasurer: Chris Daniel, Doug Bateman and Graham Stapleton respectively.

Members of Council: John Davis, Graham Aldred, Patrick Powers, Tony Wood and John Foad.

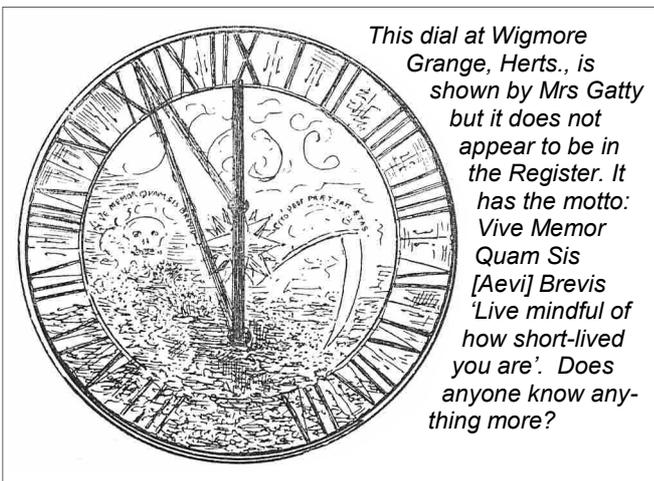
8. Any Other Business

The Chairman thanked all members for coming to the Conference and expressed his particular appreciation for the contribution of the American contingent.

The suggestion was made from the floor that we might consider a musical evening after the next Conference. Some such entertainment had been provided with great success on trips to our sister societies abroad. It was suggested that Tony Moss would be a suitable person to investigate possibilities.

The meeting was rounded off by Jackie Holland reading her delightful poem, *The Enigma of Time*.

There being no other business, the Chairman closed the meeting at 12:55 pm.



BRITISH SUNDIAL SOCIETY
Accounts for 2005

Income and Expenditure

	INCOME				EXPENSES	
	2004	2005			2004	2005
General						
Subscriptions (1)	£12,465.40	£13,203.64	Subscriptions		£0.00	£52.00
Gift Aid (2)	£1,642.85	£1,819.79	Bulletin (5)		£10,783.35	£7,866.13
			Publications (6)		£1,115.00	£3,007.64
			Officers (7)		£3,040.17	£2,331.27
Events						
2004 events (total)	£51,148.00		2004 events (total)		£50,564.93	
Holloway 2005	£1,899.50	£13,513.70	Holloway 2005		£0.00	£14,515.13
Durham 2006 (8)	£0.00	£4,567.00	Durham 2006 (8)		£1,033.00	£67.00
Cambridge 2007		£0.00	Cambridge 2007			£1,248.00
Sales etc						
Sales (9)	£2,697.25	£5,149.60	Sales (9)		£2,224.57	£620.59
Auction	£0.00	£0.00	Auction			
Advertising (3)	£457.68	£55.60	Advertising (3)		£199.75	£0.00
Donations (Somerville)	£634.00	£249.15	Donations (Somerville) (13)		£630.00	£0.00
			Library (10)		£100.00	£131.00
			Internet (11)		£393.88	£146.88
Finance						
Interest	£1,393.66	£1,573.43	Banks/Insurance (12)		£1,179.51	£749.67
Special						
Awards 05	£790.00	£0.00	Awards 05		£48.00	£2,198.05
			Photo competition			£83.09
Other						
Offprints	48.75	£0.00	Offprints		£48.75	£0.00
Misc	£0.00	£0.00	Misc		£71.35	£27.75
St. Katherine Cree Fund	£68.42	£0.00	St. Katherine Cree Fund (4)			
TOTALS	£73,444.79	£40,131.91			£71,605.54	£33,044.20
NET INCOME	£1,813.25	£7,087.71				

Notes for 2005

1. Amounts paid in US dollars have been converted to sterling at the exchange rate in force when balances have been repatriated, or at the rate on 1/1/2006 for the balance held in the USA.
2. The amount for 2004 is for the 2004 subscriptions less a repayment to the IR.
3. Advertising income for adverts in the Bulletin & Newsletter, expenses for Society adverts in other journals.
4. These donations, held on behalf of the St. Katherine Cree Sundial Restoration Fund, are **not** part of the BSS assets.
5. Four editions paid for in the year. Includes postage costs of c. £500 per issue.
6. Printing of the publications: Register 2005.
7. Includes postage, leaflets, travel, computing sundaries, meeting room costs etc.
8. Advance deposit for the 2006 Conference and early payments from members.
9. Sales of booklets, sweatshirts, slides, ties etc by Margery Lovatt, Jane Walker & David Young
10. Subscription to the Bromley House Library (Nottingham) and purchase of books.
11. Hosting of the BSS website and domain name costs.
12. Bank costs (inc international), credit card costs, Society liability insurance.
13. The Andrew Somerville Memorial Fund contains all donations to the BSS and its reserves are part of the general BSS Assets. Expenses include the annual Somerville Lecture and grants.
14. The BSS Library valuation is based on the 2003 value by Rogers Turner Books with allowances for new purchases and of 1.5% p.a. for inflation.

General Notes.

- A. The accounts are prepared on a payments and receipts basis. That is, money is booked when it is received or spent (i.e. when cheques are written, not presented). This is in line with the Charity Commission's guidance.
- B. The year-end funds are held mainly in approved investment accounts as well as current accounts.
- C. Events are priced not to make a loss, with a nominal contingency of 5%.
- D. Stocks are valued at nil as they are unlikely to have any value if the Society were to be wound up. This does not impact our cash flow.

	2004	2005
Current account balance	£7,075.83	£1,771.33
Deposit account balance	£16.43	£16.51
BSS USA current account balance	£1,287.47	£1,028.81
Charities Office Investment Fund	£28,692.04	£41,765.39
TOTALS	£37,071.77	£44,582.04
Change in funds (inc. USA) during the year	£1,813.25	£7,510.27
Income received (UK only) during the year	£73,444.79	£40,131.91
Expenses incurred during the year	£71,631.54	£33,044.20
Excess of income over expenditure (UK only)	£1,813.25	£7,087.71
Andrew Somerville Memorial Fund	£1,073.14	£1,322.29 Included in above amounts
St Katherine Cree Restoration Fund	£1,148.42	£1,148.42 Included in above amounts
Library Valuation	£15,750.00	£16,635.00 Not included in above amounts (note 14)

Auditor's Comments

The accounts were clearly and accurately presented. The software-base accounts management system developed by the Treasurer provided a simple and efficient means to audit the accounts, and provides a reliable foundation for future management of the Society.

NAME	POST	SIGNATURE	DATE
J Davis	Treasurer	<i>J R Davis</i>	28/2/06
G Parsons	Auditor	<i>G Parsons</i>	23/4/06
C Daniel	Chairman	<i>C Daniel</i>	23/04/06

SIR CHRISTOPHER WREN'S DIAL TO BE MOVED?

The beautiful dial by Sir Christopher Wren at All Souls' College, Oxford, c.1658, is known worldwide. It is currently high on the wall of the Codrington Library, having been moved to this position in the 1870s from its original position on the southern chapel wall in the front quadrangle. The move started a 130-year grievance with Oxford traditionalists who argued that the dial is not properly aligned in its new position, and also that it upsets the 'consummate symmetry' of the North Quadrangle. A leading voice in the campaign to have the dial restored to its original location was Oxford librarian John Simmons. Mr Simmons published a history of All Souls and its build-



ings and also a pamphlet proposing the dials return. He was a lecturer and Senior Research Fellow at All Souls and spent much of his career in Oxford libraries in charge of Slavonic books. He died last year, aged 90. He has left a share of his £888,000 estate to All Souls, but with the condition that the sundial is removed from the Library and "re-erected where it was originally positioned by Sir Christopher Wren, that is to say over the south front of the college chapel". A spokesman for All Souls said "The college has not yet seen the will, I believe". Watch this space for further news!

information from The Oxford Times

BOOK REVIEW

Sundials – History, Art, People, Science.

By Mark Lennox-Boyd

Francis Lincoln Limited 2006. Hardback, 314mm x 260mm, 144 pp, 118 photographs in full colour and some 90 illustrations, including line drawings, in black & white or incorporating colour.

ISBN 13: 978-0-7112-2494-0 ISBN 10: 0-7112-2494-3.

Price £30 (Special offer of £25 inc. p&p to BSS members: Direct Sales, Bookpoint Ltd, 130 Milton Park, Abingdon, OX14 4SB).

This handsome book on sundials by Sir Mark Lennox-Boyd, Patron of the British Sundial Society, is one of several English sundial works that have appeared within the last two years; but it is one that stands out from others for a number of reasons. It is a large format publication that is colourful and beautifully illustrated, making it attractive to the eye for anyone who happens to pick it up and browse through it. In this sense, it is a glamorous ‘coffee-table’ book; but I venture to suggest that it is this very character that is likely to draw the interest of the ordinary member of the public. As the title suggests, it is really a history of the subject; but one which illustrates the art of sundial construction and the people who were involved in creating these instruments of scientific beauty. Furthermore, the book is written in an easy unassuming style, balancing history with science and art, carrying the reader onwards with short anecdotes about people, places and things. The most likely questions are asked and answered, supported by clear and simple drawings, so that the theory of the subject may be readily understood, whilst the large superb colour plates encourage the reader to turn the pages of the book until it is finished!

Following the ‘Introduction’ to the book, Lennox-Boyd has arranged his work into ten ‘chapters’ or historical sections, covering certain periods of time. The first, entitled ‘Prehistory,’ discusses primitive man’s awareness of the apparent motion of the heavens and his concept of time. It deals with the construction of early calendars, pyramids and stone circles, pointing out that several such circles are to be

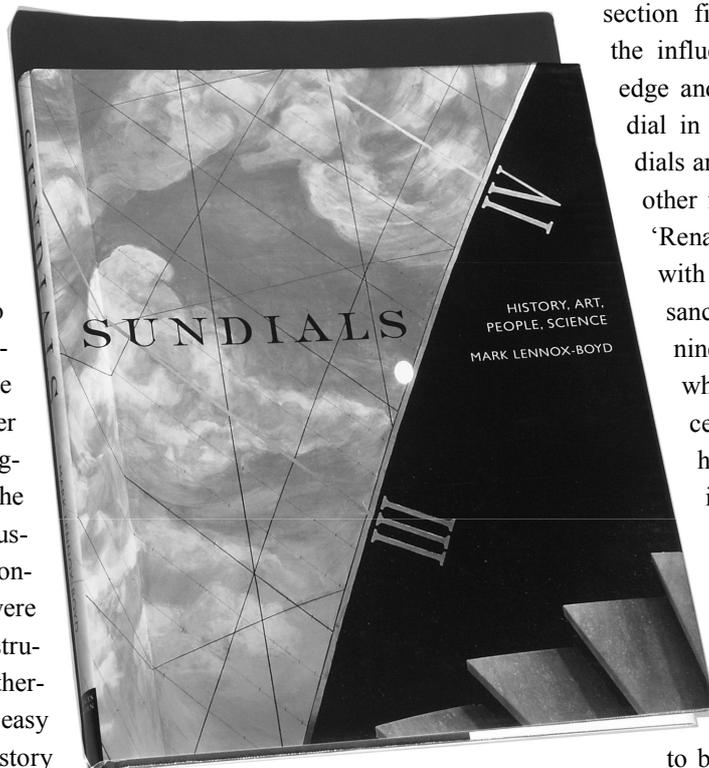
found in the United States of America, one of which is dated at 1500 BC. The second period, ‘Egypt, Greece and Babylon,’ concerns ancient classical times and the ‘invention’ of the sundial. One particular example, the hemispherical sundial attributed to Berosus, the Chaldean astronomer from Babylon, invented about the year 270 BC, is aptly illustrated by the author’s own modified *hemispherium* at Holker Hall in Cumbria. The third section, entitled ‘Rome,’ follows the absorption of Greek science into the Roman empire, with descriptions of the great Egyptian obelisks, removed to Rome as spoils of war, notably that taken by the great Emperor Augustus in 31 BC and set up as a sundial in the Campus Martius. Section four, ‘Islam and the Medieval Church,’ continues with the effects of Arabic science on the construction of the sundial, whilst

section five, ‘Renaissance I’ discusses the influence of this scientific knowledge and the development of the sundial in Europe. Portable and pocket dials are duly introduced, as are many other forms of sundial. Section six, ‘Renaissance II’ continues the story with the achievements of Renaissance scientists, concluding with nine pages of beautiful pictures, in which the author’s own magnificent reflective dial, inside his house La Meridiana at Oliveto in Italy, is wonderfully illustrated. The remaining sections cover such matters as the calendar and the great meridians used to determine specific religious dates, the massive sundials of India and those

to be found in China, followed by the story of the sundial in the British Isles and abroad from the 17th century to the present day. The book concludes with an appendix on the theory and geometry of the sundial, with excellent diagrams and mathematical proofs, a bibliography, a short glossary, acknowledgments and an index.

The delights of this book arise from a well-told story, giving background details that are seldom found in any one volume. It is a book that all members of the Society are likely to find desirable as an acquisition for their libraries, and, if it be thought that, as Chairman, I have been too enthusiastic about our Patron’s work, it is simply that this is the best book on the subject of which I know!

Christopher St J. H. Daniel



MASS DIALS—where did it all end?

TONY WOOD

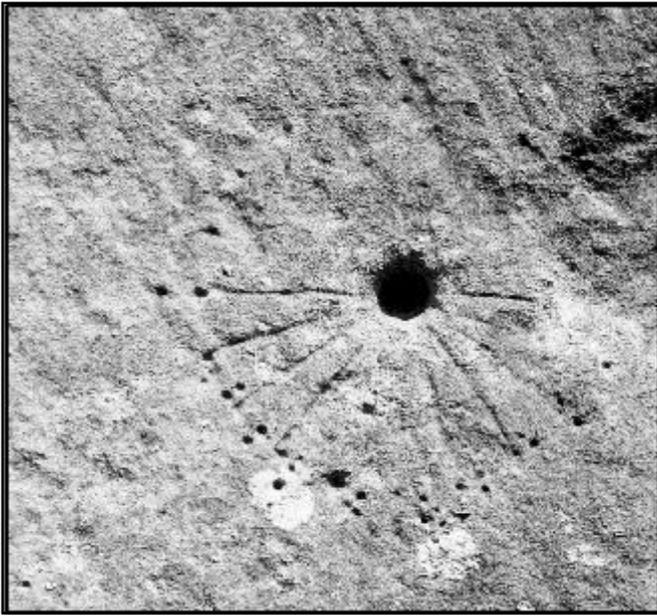


Figure 1

The dates of mass dials can only vaguely be surmised. Their beginnings and endings are consequently indistinct with ‘transitional’ forms occasionally being offered as an explanation for some dials not fitting into our current categories of Saxon, medieval and scientific.

Towards the end of their currency numbers were carved round their circumference. Consequently such dials are regarded as ‘late’ but even within this classification there is variation in that the numerals may be Roman, Hindu-Arabic or sometimes in a ‘dot’ form as at Avening in Gloucestershire (Fig. 1). Full interpretation is difficult but the mark-



Figure 2

ings are clearly numerical and based around ‘noon’ at 12 o’clock as opposed to the Terce and Nones of earlier canonical dials.

The final expression may well be in the form of a circular design with some attempt to delineate the dial with unequal intervals and possibly using an inclined gnomon set by eye and shadow observation – as distinct from a properly made ‘scientific’ dial, almost invariably square in layout from the geometric construction followed.

Fig. 2 shows such a dial at Sandhurst in Gloucestershire and its similarity to one at the Jacobi Church near Utrecht in Holland is striking. This is illustrated in Mark Lennox Boyd’s recent book ‘Sundials’ although the date of 1463? is far earlier than a late dated (1629) mass dial at Upton in Oxfordshire (Fig. 3). This latter dial is well into the ‘scientific’ era but probably was made in a rural area which still followed the old ways.

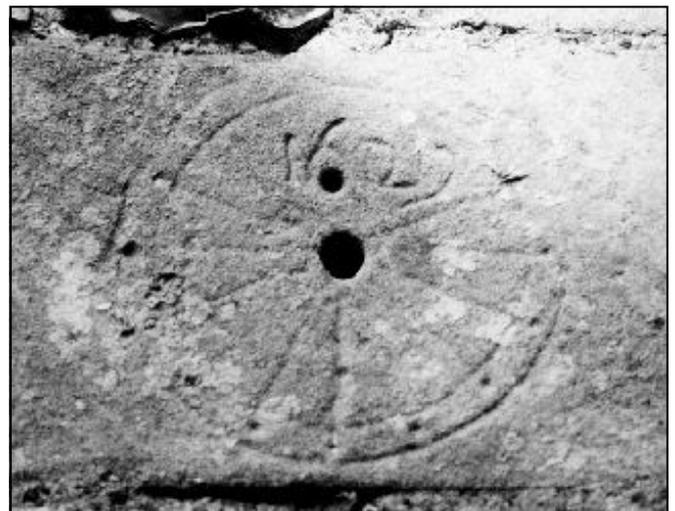


Figure 3

Some mass dials were ‘converted’ as at Selling in Kent or their circular form retained as at Ampney St Peter in Gloucestershire, but a scientific dial carved into the wall marked the next step and onto a separate stone the final jump to today’s dials.

At least the end is visible, if only in a few examples and ‘transitional’ reveals the struggle to reconcile the simplicity of ‘a peg in the wall’ with the care required to make an accurate gnomon and the move to an ‘equal hours’ regulated world provided by clocks.

[NB: The Jacobi Church dial may also be seen at:
<http://www.dezonnewijzerkring.nl/zw-arch/eng-home-zw-0301.htm>]

Reprinted from *The Recorder*, Durham edition.

VARIATION IN THE EQUATION OF TIME

KEVIN KARNEY

I have set myself the somewhat daunting task of designing a heliochronometer that is accurate to within 30 seconds for the next 250 years. It must operate anywhere in the world where the sun normally shines. The aim is to do better than both my father's Longine watch and Pilkington & Gibbs' engineering marvels. The Longine was within 30 seconds for 60 years. Pilkington & Gibbs is still doing well after nearly a century. One of the first steps in the design task was a rigorous study of the differences or errors between Civil Time and Sun Time. I use the word 'difference' for those items that are natural and therefore cannot be errors. The word 'error' is used when our carelessness, inattention or inability is to blame.

DIFFERENCE/ERROR CLASSES

Four classes of difference or error may be distinguished:

- **Astronomical Differences:**
Orbital Eccentricity, Rotational Obliquity, Luni-Solar Precession, Planetary Precession, Solar Aberration, Nutation Effects.
- **Sun Finding Differences:**
Locational Parallax, Atmospheric Refraction, Penumbral Effects.
- **Calendar Alignment Errors:**
Leap Year, Leap Second, Summer Time
- **Human Errors:**
Longitude set-up, Gnomon set-up, Plate Direction & Angle, Engraving

This article covers only those items marked in italics which are almost entirely responsible for the Equation of Time.

EQUATION OF TIME COMPONENTS

We have settled on the straightforward concept that our time should be based on the perceived daily spin of the earth and on its annual orbit around the sun. Furthermore noon should occur on average when the sun is overhead and the equinoxes on average occurring on the same date. Thus, our civil time is based on the concept of a **Mean Sun**, which *by definition* rotates at a **Uniform rate** around the **Equatorial plane**. Sundials however read the **Real Sun**, which *in fact* appears to rotate at a **Non-uniform rate** around the **Ecliptic plane**, which has an obliquity of 23.4° to the equatorial plane. The difference between the uniform and non-uniform rotational rates gives rise to the so-called Eccentricity effect. The angle between the ecliptic and equatorial planes gives rise to the so-called Obliquity effect.

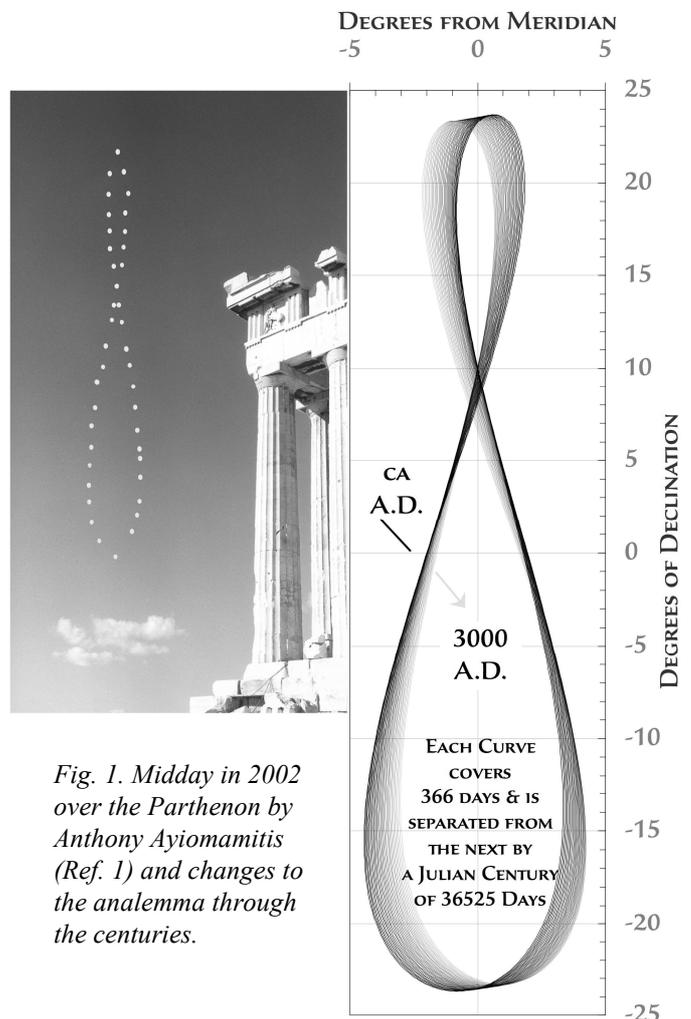


Fig. 1. Midday in 2002 over the Parthenon by Anthony Ayiomamitis (Ref. 1) and changes to the analemma through the centuries.

The Eccentricity effect is an offshoot of the operation of Johannes Kepler laws proposed in 1609. In his 1st law, he states that planets move in ellipses with the Sun at one focus; in his 2nd law, that a line joining the earth to the sun sweeps out equal areas in equal times. The laws imply that the earth is moving fastest when it is closest to the sun at perihelion (around 2 January) and slowest at aphelion. Compared with a uniformly moving mean ecliptic sun, the real sun races ahead after perihelion. But by aphelion, the mean sun has caught up as the real sun slows down. In the second half of the year, the mean sun is ahead of the real sun, which only catches up again at perihelion. This is shown in Fig. 2.

The eccentricity of our orbit around the sun is only 0.0167 – the orbit is very nearly circular. However, it does give rise to a difference that is nearly - *but not quite* - a sine curve with an annual period, of magnitude $7\frac{1}{2}$ minutes and phased with perihelion/aphelion.

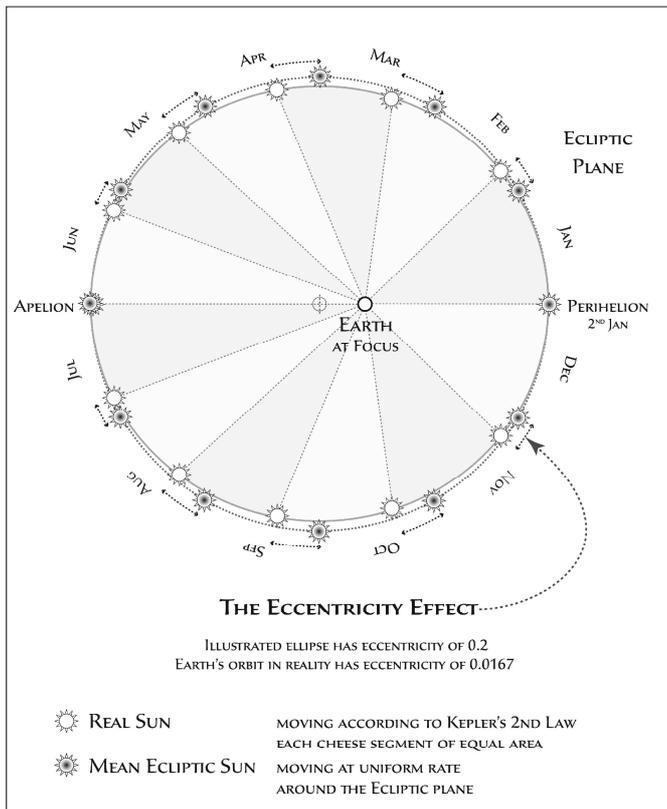


Fig. 2. The Eccentricity Effect of the Equation of Time.

The Obliquity effect can be viewed as the result of projecting the path of the real sun (in the ecliptic) onto the plane of the mean sun (in the equator). Fig. 3, which for simplicity shows a 'mean ecliptic sun' rather than the real sun, illustrates how this manifests itself. At both the equinoxes and the solstices, there is no difference, but at all other times, there is a difference that turns out to be nearly a sine curve of biannual period, with a magnitude of 10 minutes and phased with the equinoxes.

The sum of the eccentricity and obliquity effects, together with a number of relatively minor other effects, add up to give the familiar shape of the Equation of Time (Fig. 4) and its alternative guise as the analemma (Fig. 1).

A table showing values of the Equation of Time was first published by Thomas Tompion in 1683, using data probably supplied by the Astronomer Royal, John Flamsteed. Since then, numerous methods have been proposed to calculate the values. See Refs. 2-5 for a few examples.

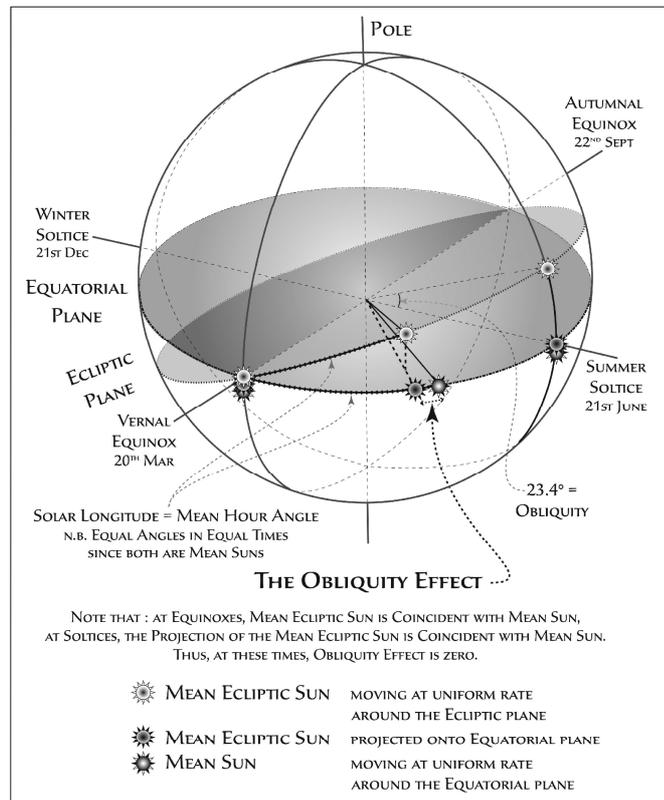


Fig. 3. The Obliquity Effect of the Equation of Time.

EQUATION OF TIME CHANGES

Referring to Fig 4, there are four values that dictate the shape of the Equation during a given year.

- The value of the eccentricity of the earth's orbit;
- The date/time of Perihelion;
- The value of the earth's obliquity;
- The date/time of the Vernal Equinox.

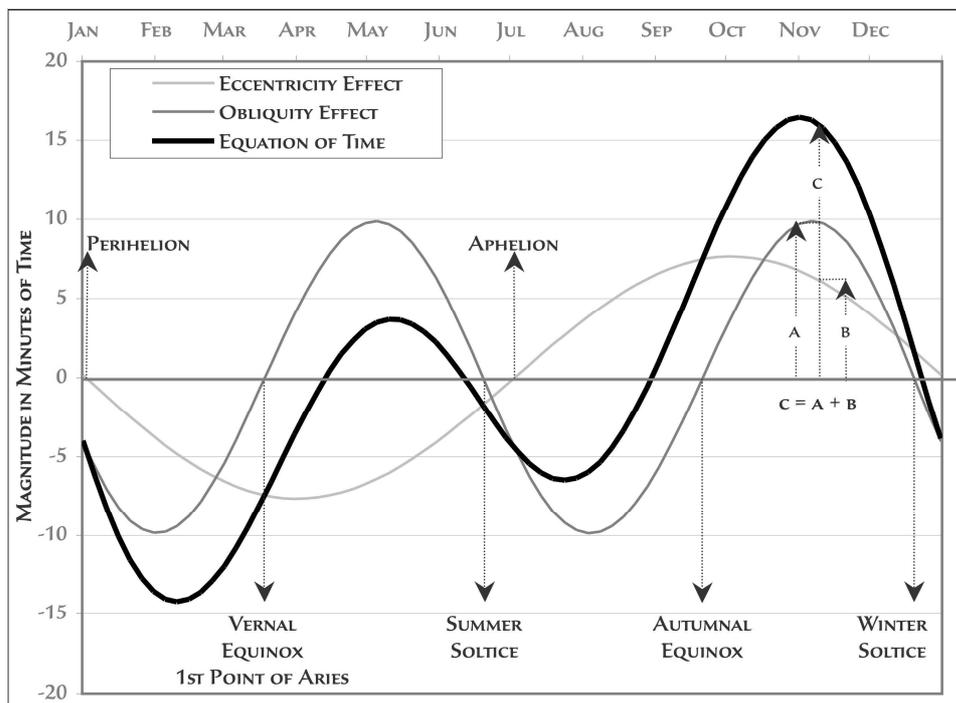


Fig. 4. The Equation of Time, made up of its two major components.

All of these are changing slowly with time as a result the gravitational pull of the Sun, the Moon and other planets, each of which moves in a plane that is *not* the same as the equator. In the case of the Sun and Moon (and marginally Jupiter), the pull acts unevenly due to the equatorial bulge of the Earth's shape. The varying pulls cause a general short-term periodic wobble in the earth's axis called Nutation, which has only a minor effect on the Equation of Time. It also causes a number of longer-term larger-scale effects called Luni-Solar Precession (see A below) and Planetary Precession (see B, C & D below).

A) against the backdrop of the stars, the whole axis of the earth gyrates like an out-of-balance spinning top in a 25,770 year cycle. This is a major astronomical effect: e.g. North no longer points at the Pole star; the pyramids are no longer aligned with the correct stars; the astrologer's 1st Point of Aries - the Vernal Equinox - is now in the constellation of Pisces).

However, on the one hand, it has only a very minor effect *long term* on the Equation of Time, because we have chosen the length of our civil year - which averages at 365.242500 days - to match the mean equinox-to-equinox 'tropical' year of 365.242191 days. This ensures that the Equinoxes do on average stay at the same time of the year : see the horizontal dotted line in Fig. 5.

But, on the other hand, however, the saw-tooth shape of the curve which echoes our leap years does cause significant *short-term* variation - see the upper saw-tooth in Fig. 5. On each successive year, the time of the equinox is shifted by ¼ day, until it is pulled back 'into line' by the 4-year and 100-year leap year cycles. If a given leap-year is taken as a base-line and considering mid December when the rate of

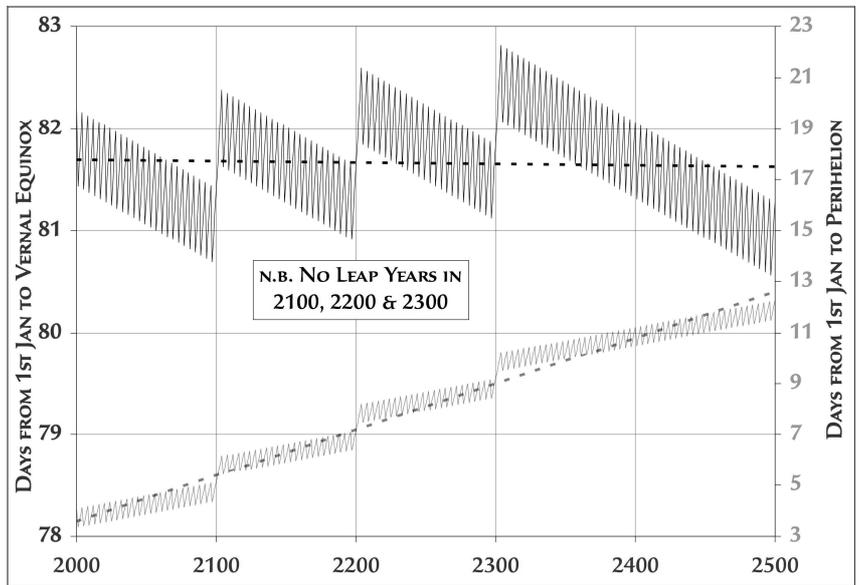


Fig. 5. Changes in the date of Perihelion & Vernal Equinox over Time.

change of the Equation is greatest at 30 seconds/day, the Equation will vary by 7.5 secs in the 1st year following, by 15 secs in the 2nd, by 22.5 secs in the 3rd. It will then partially 'self-correct' in the following leap year.

B) the ellipse of the earth's orbit around the sun is itself turning against the background of the stars in a 21,000 year cycle. This is a significant effect in relation to the Equation of Time, since it shifts the time of perihelion in relation to that of the vernal equinox - the lower saw-tooth in Fig. 5.

C) the obliquity of the Earth ranges between 22.1° and 24.5° in a 41,000 year cycle, mainly under the influence of Jupiter - see the lower line in Fig. 6.

D) the eccentricity of the Earth's orbit changes in a complicated manner in cycles of 96,000 and 413,000 years - see the upper line in Fig. 6.

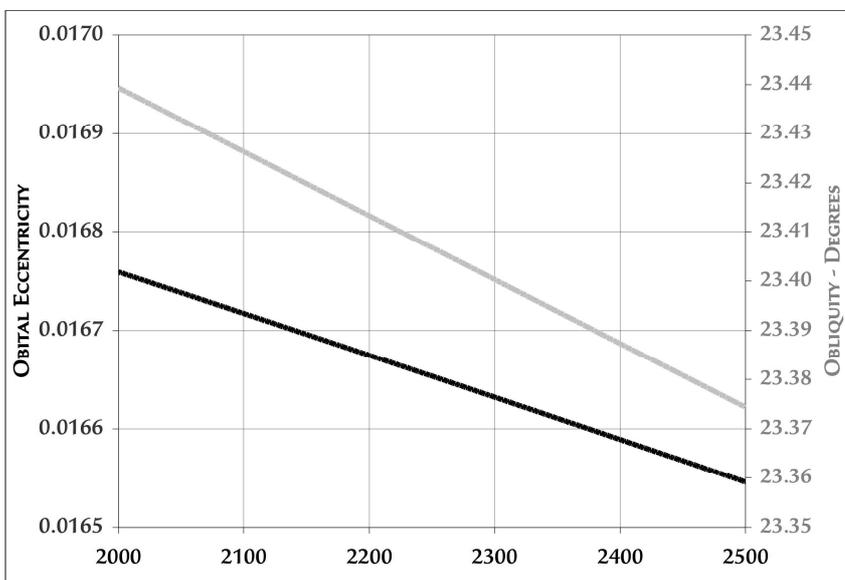


Fig. 6. Changes in Orbital Eccentricity & Obliquity over Time.

This effect (the Milankovitch cycle) is believed by some to be one of the astronomical effects that causes climate change. The Northern hemisphere will warm as perihelion (when the earth receives the greatest amount of the sun's radiation) is moving towards its summer.

ADDING THE CHANGES

Fig. 7 shows these four items together over a 500 year period. One sees:

- almost no change in the obliquity effect (the lines marked by diamonds),
- a slight reduction in the magnitude of the eccentricity effect (the height of the lines marked by circles),
- a significant shift in the position of the eccen-

tricity effect, as perihelion gets nearer to the vernal equinox (the position of the lines marked by circles).

The plain lines shows the result of adding the two effects to give the Equation of Time, providing significant change.

Fig. 8 illustrates the effect over three millennia. The same data in analemma form are shown in Fig. 1. Important observations are:

- variability is mainly controlled by the period between perihelion and the equinox;
- in the long term, since our calendar fixes the average date of the equinox, the change in date of perihelion, as a result of planetary precession, is the prime variable.
- in the short term, this period is mostly changed by the vagaries of our leap year cycles;

IS THE VARIATION IMPORTANT?

From Fig. 8, it is concluded that:

- old dials have old tables which become progressively more out-of date;
- new dials, which incorporate a table or curve, should ensure that the Equation used is appropriate for the expected lifetime of the dial and duly dated;
- designs for heliochronometers must seek the means to

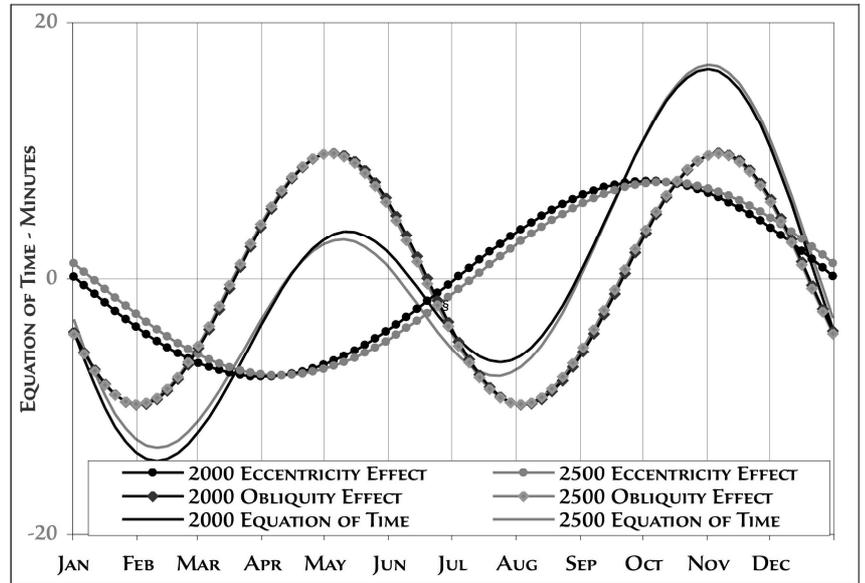


Fig. 7. The Equation of Time, made up of its two major components.

overcome the variability or accept that accuracy will degrade. Figs. 9 and 10 show the error introduced if Equation of Time values for the Year 2000 are used in successive years. These show bands reflecting the various leap and non-leap years cycles and the progressive change within each band. Note that errors of almost 40 seconds are reached within 200 years.

Subsequent articles will trace strategies to eliminate the effect of leap year cycles and how to combat the longer-term perihelion drift. They will also cover the other sources of error or difference.

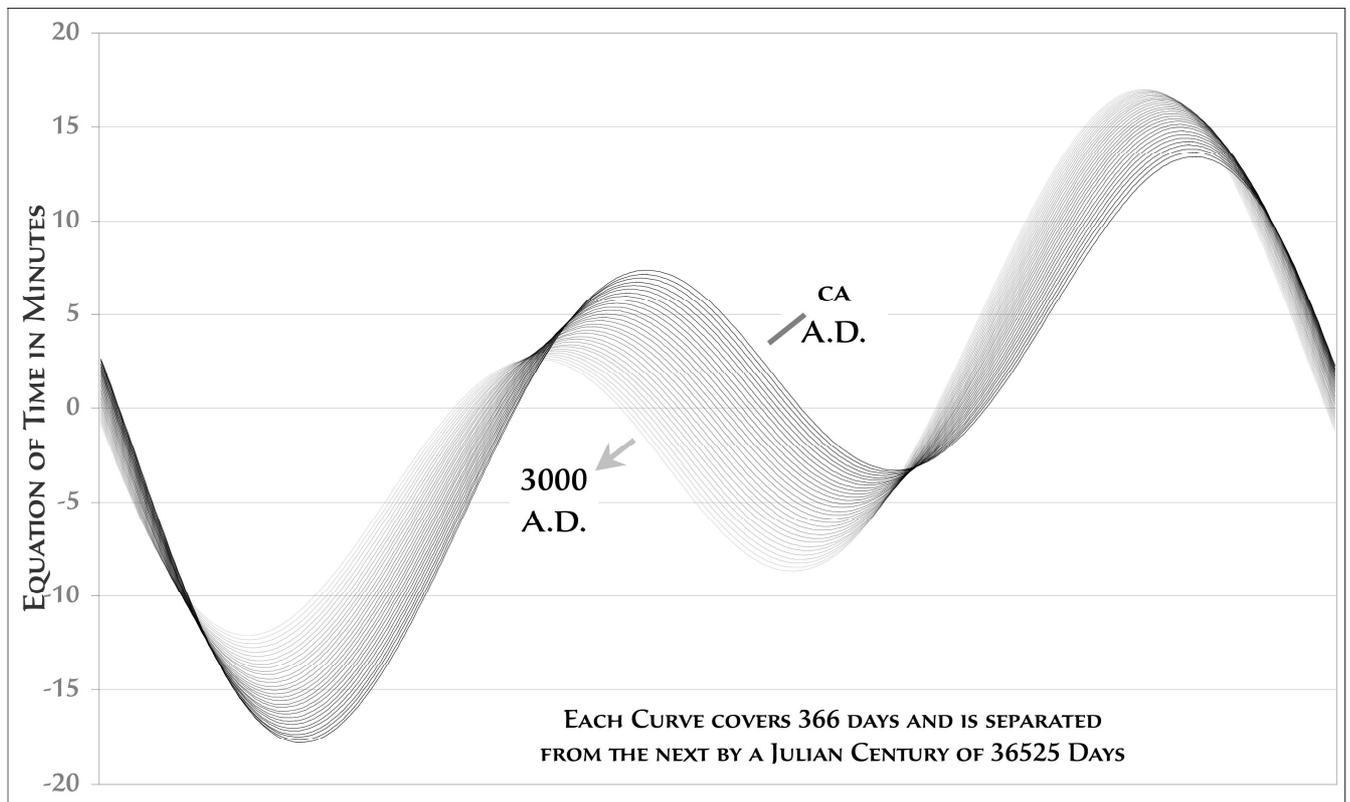


Fig. 8. The Equation of Time over three millennia.

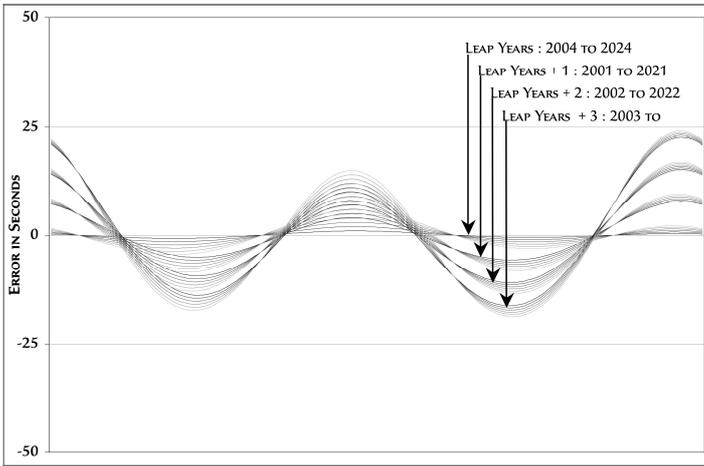


Fig. 9. Error bands if Year 2000 E-o-T values are used during period 2000 - 2024. Note the banding resulting from the leap-year effect (refer to Fig 5.). In each band, the darker lines represent the earlier years. The horizontal axis represents one year.

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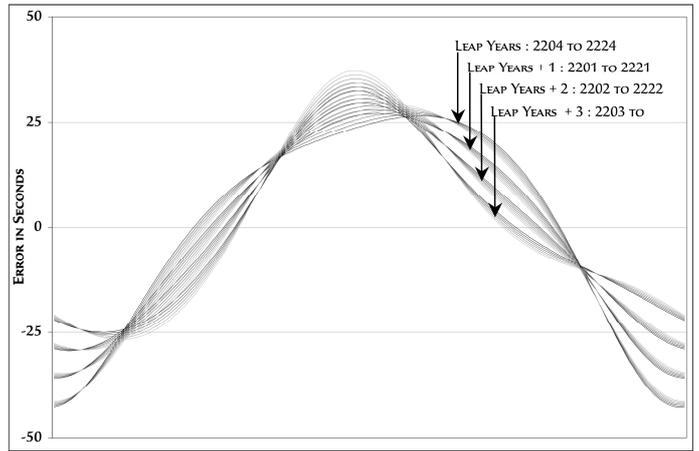


Fig. 10. Error bands if Year 2000 E-o-T values are used during period 2200 - 2224.

5. For the Equation of Time with ultimate precision, see NASA/JPL's: <http://ssd.jpl.nasa.gov/cgi-bin/eph>

GENERAL NOTES

1. For an animation of E-o-T build-up and changes, and for a coloured version of this document, see <http://precisedirections.co.uk>
2. Readers who would like a print of Figures 1 and 8 in colour, please e-mail the author.

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SUNDIAL DELINEATION USING VECTOR METHODS

Part 4 – Direct East and West Dials

TONY WOOD

[Readers are reminded that the meanings of symbols used in this paper do not follow the normal BSS convention. See the first part of the series (Bull. 17(iii) pp.121-127) for their definitions here. Ed.]

The next sections deal with cases of direct east, direct west and polar dials. They have in common the fact that following the appropriate rotations of the dial plate the gnomon lies in the plane of the dial plate which then must be moved 'back' to receive a shadow. This involves a further axis transformation; this time linear and along the Oz axis in each case.

In general, for a shift of d along the Oz axis (see Fig. 16), the transformation is:

$$z_N = z_O - d$$

z_N being the new co-ordinate and z_O the equivalent in the original co-ordinate system.

For the three dials here considered:

- 1) d is negative and
- 2) the nodus is moved to a point on the gnomon immediately 'above' the origin of the dial plate axes, its co-ordinates then becoming $(0, 0, -d)$.

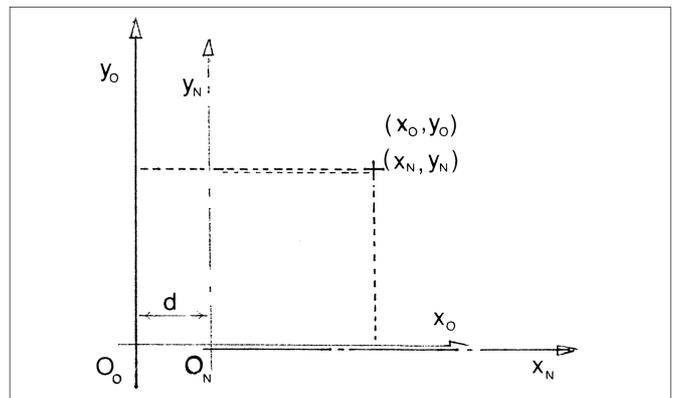


Fig. 16. Co-ordinates in axes transformed by linear displacement along Ox.

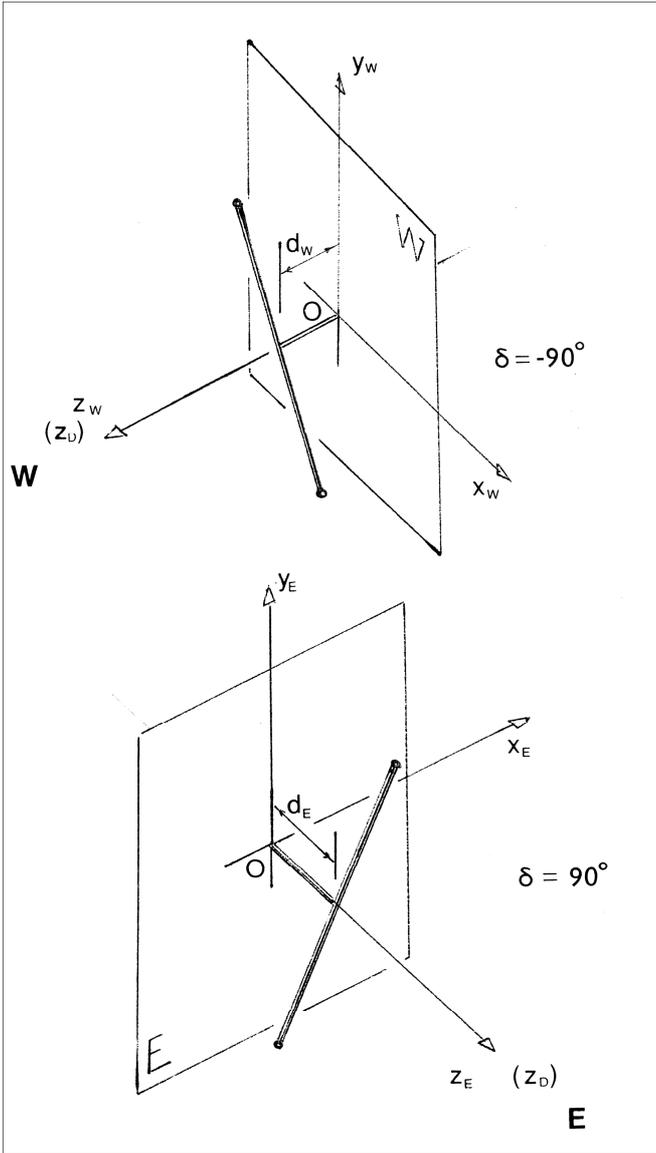


Fig. 17 (top). Direct West vertical dial. Axis system.

Fig. 18 (bottom). Direct East vertical dial. Axis system.

VERTICAL DIRECT EAST DIAL

The first transformations are a rotation of $180^\circ - \lambda$ about Ox_G to vertical direct south, and then $\delta = 90^\circ$ to face due east. See Figs. 17 & 18. The 'shift backwards' of d_E is given by:

$$x_E = x_D \quad y_E = y_D \quad z_E = z_D - d_E$$

The equations for the hour lines then become:

$$y_E = x_E \tan \lambda - d_E \times (\tan \alpha / \cos \lambda)$$

(remembering that d_E is taken as negative).

The declination lines appear most conveniently in parametric form. For the nodus at $(0, 0, -d_E)_E$

$$x_E = (d_E / \cos \alpha) \times (\sin \lambda \sin \alpha - \cos \lambda \tan \epsilon)$$

$$y_E = (-d_E / \cos \alpha) \times (\cos \lambda \sin \alpha + \sin \lambda \tan \epsilon)$$

and the equinox line ($\epsilon = 0$) is given by:

$$y_E = -x_E / \tan \lambda$$

The substyle angle (η_E) is λ and the corresponding time is $T_{24} = 06:00$. The gnomon is parallel to the dial plate and $-d_E$ from it.

The sub-nodus point is trivially $(x_n, y_n)_E = (0, 0)_E$ and the nodus height above the dial plate is:

$$(z_n)_E = -d_E$$

Illumination Times

The horizon limit L_H is as given in the horizontal dial section.

The sun position limit L_S is 12 noon. The dial is illuminated from sunrise to noon.

VERTICAL DIRECT WEST DIAL

The results follow as for the direct east dial (Figs. 17 & 18) but $\delta = -90^\circ$.

The hour lines are given by:

$$y_W = x_W \tan \lambda - d_W \times (\tan \alpha / \cos \lambda)$$

with d_W negative.

The declination lines are given parametrically by:

$$x_W = (d_W / \cos \alpha) \times (\sin \lambda \sin \alpha - \cos \lambda \tan \epsilon) \quad \text{and}$$

$$y_W = (d_W / \cos \alpha) \times (\cos \lambda \sin \alpha + \sin \lambda \tan \epsilon)$$

with $y_W = x_W / \tan \lambda$ for the equinoxes ($\epsilon = 0$)

The sub-style angle (η_W) is $180^\circ - \lambda$ and the corresponding time is $T_{24} = 18:00$

The gnomon is parallel to the dial plate and separated from it by $-d_W$.

The sub-nodus co-ordinates are $(x_n, y_n)_W = (0, 0)_W$. The nodus height from dial plate is

$$(z_n)_W = -d_W.$$

Dial Illumination

Similarly to the direct east dial, the dial face is illuminated from 12 noon to sunset.

To be continued.

SUNDIALS OF BUCKINGHAMSHIRE

IAN R BUTSON

Two previous articles in the BSS Bulletin have reported the investigations of sundials in various counties using references obtained from 'The King's England' series of books by Arthur Mee. In the article by John Davis 'In Arthur Mee's Footsteps'¹, he reported mainly on the dials of Suffolk but with the inclusion of a few others in East Anglia and Kent. In John Lester's article 'In Pursuit of Shropshire dials'², he sought out those in that county. Inspired by their approaches and success, I felt that this was a technique that I could usefully adopt. Having a reasonable knowledge of Buckinghamshire and continuing associations there, this seemed to be the obvious choice for my researches.



Fig. 1. 'The Deanery, Marlow'

Arthur Mee's *Buckinghamshire*³ would be the initial source of information but locations which noted mass dials, as detailed in T.W. Cole's *Origin and use of Church Scratch Dials*⁴ would also be investigated. The opportunity would also be use to visit and report further on the dials as recorded in the *Sundial Register 2000*.⁵ From my past experience when visiting other counties, previously unreported dials could be found at churches and churchyards. With this in mind, it was decided that all churches and cemeteries as indicated on current OS maps of Buckinghamshire would be visited, as well as National Trust (NT) properties.

MEE'S AND COLE'S LISTINGS

Across the county, Mee notes the existence of twelve fixed dials and fourteen scratch dials at various locations. Nine fixed dials were still found to be visible but with two hav-



Fig. 2. 'Thames House', Marlow.

ing been removed for safe keeping, viz. (i) that at Broughton, being a horizontal dial by Henry Sutton mounted on an 18th century font and now kept within the church, and (ii) the bronze horizontal dialplate previously mounted on an old preaching cross stump at Dinton, now stored securely. This latter dial was the subject of an article by Christopher Daniel.⁶

The vertical dial on the church tower at Quanton, having decayed beyond repair, was removed in the 1970s. However, discolouration of the tower stonework still indicates the past position of the dial.

Mass dials were found at thirteen of the fourteen sites noted by Mee but that at Stoke Poges could not be found. Possibly this was lost by the replacement of some stonework on the church.



Fig. 3. St Bartholomew's church, Fingest.



Fig. 4. Dial House, High Wycombe.

Thomas Cole⁴ notes mass dials at ten locations. Nine of these were found with the tenth being the Stoke Poges one.

OVERALL FINDINGS

In total, 80 fixed dials were recorded during my travels. These were mainly found on churches, in graveyards and in cemeteries, but also in locations open to the public (e.g. NT properties). Where a dial was seen on private premises, permission was sought to record it unless it was so obviously publicly visible. Additionally, a further 27 pedestals for horizontal dials were found on graves but sadly with their dial plates missing.

Mass dials were found at 75 separate locations with a total of 190 inscribed dials found. The largest number of mass dials found at one location was at Hillesden where eleven separate mass dials were recorded, along with two fixed dials and much graffiti. Although the location listings of Mee and Cole did not entirely agree with each other, by combining the two a total of nineteen separate locations was produced. From these results, it is seen that a systematic investigation of all the churches in a county has produced a worthwhile result with many more locations having mass dials than given in their publications.

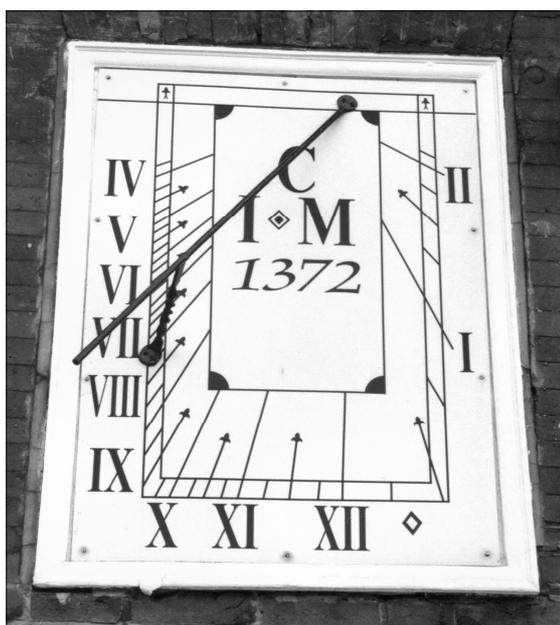


Fig. 5 (left). 'Sundial Antiques', Amersham.

Fig. 6 (below). Mass and transitional dials at The Old Church, The Lee.



All the dial reports and photographs have been passed to the appropriate BSS Registrars.

SOME PARTICULAR DIALS

Possibly one of the most frequently viewed dials in Bucks is the vertical declining dial above the gateway to 'The Deanery' on the Causeway at Marlow, close to the suspension bridge which spans the Thames (Fig. 1). This has now been joined in the town by the impressive 'Akelar Equatorial' dial, located in the nearby May Balfour Gardens. This dial was recently featured in the Bulletin.⁷ For those who may wish to spend some pleasant moments taking in the views of the river, weir and bridge, a vertical declining dial by F. Barker & Son (Fig. 2) may be found on 'Thames House' overlooking Marlow Lock.

High in the Chiltern Hills at Fingest, a simple horizontal memorial dial (Fig. 3) may be found in St Bartholomew's churchyard. The church is well known for its massive Norman tower which has a twin saddle-back roof.

At nearby High Wycombe, a small replica sundial features in the architectural moulding above the doorway of 'Dial House' in Crendon St. (Fig. 4). This 'Dial House' replaced an earlier one which was located nearby but was demolished in 1936 as part of a road widening scheme. Following the demolition, the original fine glazed brick dial was ultimately delivered to the town museum, badly broken into several pieces. The final outcome is unknown. On the outskirts of the town at Hughenden Manor (NT), the past home of Benjamin Disraeli reveals a vertical dial on the corner of the stable buildings. A small commemorative sundial which was presented to Disraeli by a fellow MP is also in the associated museum of Disraeli memorabilia.

In Amersham, a vertical dial (Fig 5) is visible at 'Sundial Antiques' in Whielden St. By taking a slight detour to The Lee from the Aylesbury Rd, a fine example of a mass dial

and also a 'transitional dial' with Roman numerals can be found on 'The Old Church', see Fig. 6.

At Weedon, an interesting scaphe dial (Fig. 7) can be found set into the wall of the Five Elms

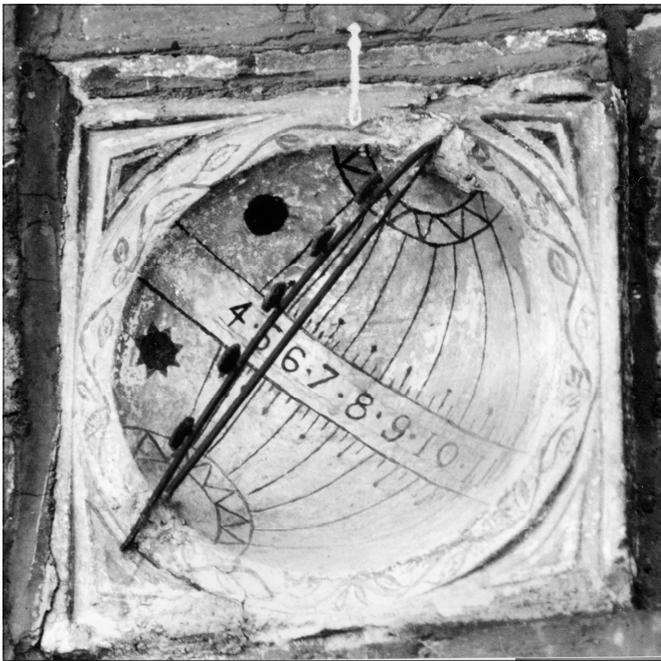


Fig. 7. 'The Five Elms', Weedon

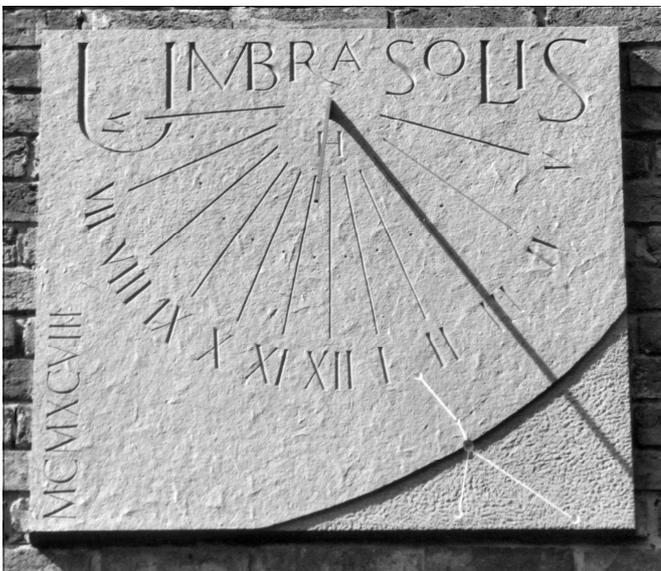


Fig. 8 (above). Hinton House, Weedon.

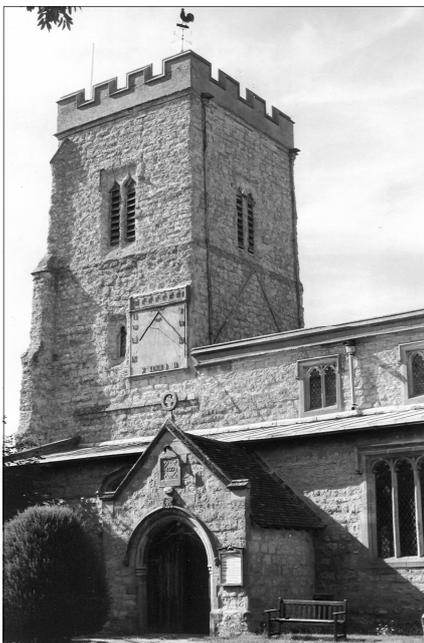


Fig. 9 (left and below). St John the Evangelist, Whitchurch.

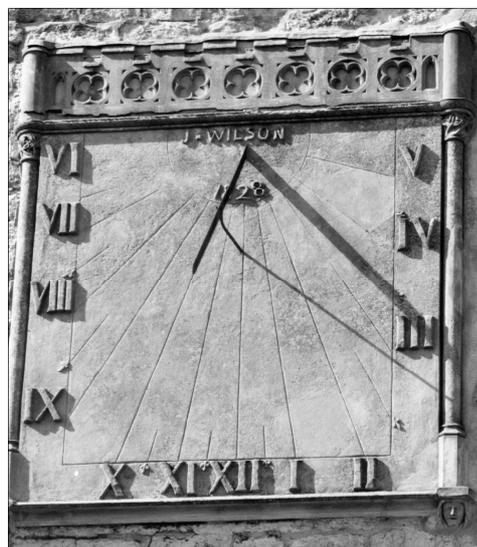


Fig. 10 (left and above). All Saints' church, Wing.

Fig. 11 (below). Ascott House, Wing.



public house. Nearby, a modern vertical dial is mounted high up on the gable end of Hinton House which proclaims 'Umbra solis' (Fig. 8). The curve at the bottom right hand corner represents the ecliptic with the constellation of Cancer positioned to show the time of the owner's wife's birth.

The village church of Whitchurch proudly displays an elaborate stone dial (Fig 9) which is almost half the width of the tower. With numerals and inscriptions carved in relief and surrounding columns and arcading, it is certainly impressive. A simple vertical dial is also to be seen above the front entrance to Whitchurch House on the Oving Road.

In All Saints' churchyard at Wing, an old bronze octagonal dial is mounted high up on a stumped preaching cross shaft, close to the vicarage gateway. Folding steps were needed to photograph the dial successfully! See Fig. 10. The building is considered to be one of the most important Anglo-Saxon churches in England with much surviving from the 10th century. There are several fine monuments and brasses within the church. In the gardens of Ascott House (NT) close by, once



Fig. 12. Solar Square, Milton Keynes.



Fig. 13. Midsummer Arcade, Milton Keynes.

a home to the Rothchild family, a horizontal topiary dial (Fig. 11) with finely clipped box and yew displays the motto: "Light and Shade by Turn but love always".

On the south western outskirts of the new city of Milton Keynes there is a large circular horizontal dial in Solar Square at Shenley Lodge. Commissioned by the Milton Keynes Development Corporation in 1986, it is constructed of brickwork and stainless steel (see Fig. 12). Incorporated into the dial are solar powered lights to indicate the time at dusk and on overcast days. For those that may want to venture into the main shopping area of Central Milton Keynes, another horizontal dial is to be found. Located in the pedestrian area of Queen's Court, Midsummer Arcade, amidst fountains and modern sculptures, the stainless steel dial is set on top of a circular stone seating area (Fig. 13). The dial plate is inscribed with seven declination lines with the zodiac symbols and the times of midsummer sunrise and sunset, as well as the normal hour lines.

To the north west of Milton Keynes, a sundial at Stoney Stratford commemorates a terrible fire which destroyed half the town in 1736. This vertical dial (Fig. 14) in Church Street displays the maker's initials and warns in Latin that 'Time and Fire destroy all things'.

Close to the northern border of Buckinghamshire, a modern vertical dial has been boldly inscribed onto an oak dial plate

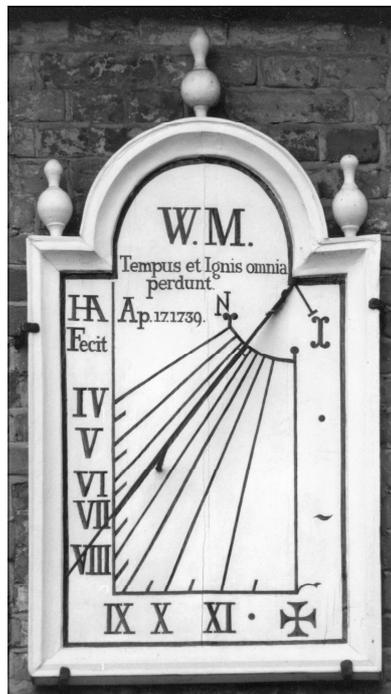


Fig. 14. Church St., Stoney Stratford.



Fig. 15. All Saints' church, Ravenstone.

at All Saints' church, Ravenstone (see Fig. 15).

The small village of Hillsden, close to Buckingham, stands remote in the meadows with only its church, parsonage and a few houses. The 15th century church is a delight with many fine features and monuments to the Denton family. During the Civil War the village and church were besieged and bullet holes are still to be seen in the north door. For the sundial seeker the church has its treasures also. On the worn stonework, eleven mass dials are to be found as well as the iron gnomon remains of a vertical sundial. More unusual, however, is a scaphe dial carved as a half-sphere into a buttress. This is inscribed '1601 GEORGE DEF-RASNE' with the motto below 'SIC TRANSIT GLORIA MUNDI'. Two niches exist to hold a vertical gnomon, as indicated by the insertion of a small twig in Fig. 16.

At Middle Claydon, the west terrace which overlooks the lake at Claydon House (NT) is graced by a fine horizontal dial by Thomas Heath.⁸ Mounted on an

elegant pedestal with spiral decoration, the dial (Fig. 17) is engraved with the coat of arms of the Verney family, an EoT scale, and the names of various cities with the exact times of noon. Of perhaps a similar era, an equally fine horizontal dial may be found in a small courtyard at West Wycombe House (NT), the home of the Dashwood family. Although no maker's name is apparent, the dial similarly displays the family crest and the family motto 'Pro Magna Carta'. An EoT scale, described as the 'Inequality of Natural Days' is also engraved onto the dial.



Fig 16 (above and right). All Saints' church, Hillesden.



Fig 17 (left).
Claydon House (NT),
Middle Claydon.

CONCLUSIONS

The dials noted above may be found on a route passing from the south of the county roughly in a northern direction. A number of other interesting dials may be found by taking slight detours from this path. The recently published 'Sundial Register 2005' provides locations and

information about other sundials found in Buckinghamshire.

For those who may consider using Arthur Mee's 'King's England' series of books to research sundials in their own locality, they should be regarded as a most useful source of information. Past experiences from my previous researches in several counties suggests that a very high proportion of the dials noted by his researchers still remain today. However, there may still be other dials not noted by him that are yet to be found. Happy hunting!

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B. III. *Embl. 13.*

courtesy of John Lester

Read on this dial, how shades devour
My short-liv'd winter's day; hour eats up hour;
Alas! the total's but from eight to four

Francis Quarques (1592-1644)
"Emblems" Bk III, XIII (1635)

TURNSTILE DIAL

LEN BURGE

Mrs & Mrs Wall's "Sundial For A Golden Wedding" appeared in the *Bulletin* in December '04. My wife and I cleared the same hurdle in the same year and, like them, we marked the date with a dial (she wishes to congratulate them on their stylish job). John Wall's dial is vertical and hung in a place of honour but mine, horizontal, remains footloose. Beside his stylish motto my DIY Latin creaks somewhat and, in contrast to his professionally-engraved glass, my dial leans heavily on the soldering iron and off-cuts from the plumber.

However modest its materials, my dial nevertheless claims a connection with a Stately Home. In a stately Cornish garden I came across an ordinary horizontal dial that had known better times and was now much degraded around the gnomon. Whereas a gnomon of any robustness has two distinct edges for throwing the shadow, calling for the usual noon gap in the scale, the working edges of this gnomon had been altogether rounded-off, as if coarsely scrubbed with something abrasive. What would such treatment have done for the time-keeping, I speculated? John Wall's dial enjoys just a slim 'spot of light' by way of gnomon and he calls such a gnomon 'virtual'; but where a thick gnomon like this Cornish one has been rounded off, what is left would seem to amount to a whole bunch of 'gnomons' within the space of the metal's thickness. How would this fit into sundial theory, and could such a thing be of any use?

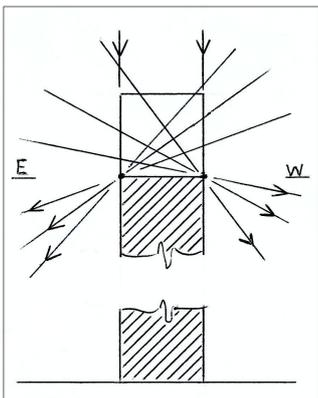


Fig. 1. Two working edges on a square-topped gnomon.

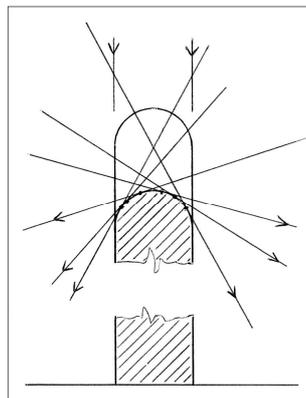
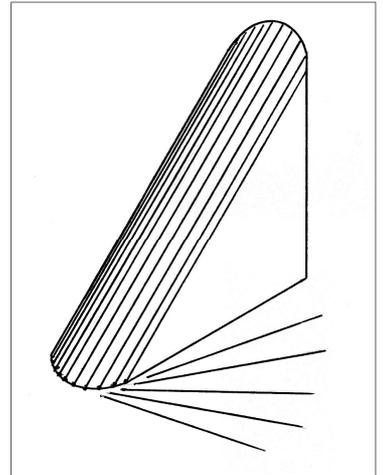


Fig. 2. The sun grazing a rounded top gnomon.

In figures 1 & 2 the behaviour of a square-topped gnomon (viewed in section looking north) is compared with that of a round-topped one. The gnomon's work in Fig. 1 is divided into two clear parts and the sun's efforts pass at noon from one working edge to the other. But with the round-topped gnomon (Fig. 2) the sun is throwing shadows from a continuum of tangent points, grazing the whole 'hump' in the course of the day. This, in comparison with Fig. 1, looks a smoother progression, though the behaviour on the

Fig. 3. Separate starting points for hour-lines.



rounded top does in fact include the same abrupt change at noon as on the square-cut gnomon. What is different is the plotting of the hour-lines down on the horizontal plate, instead of the hour lines starting from a single fixed point for a.m. and another for p.m.: each hour line (Fig. 3) has to start from a new point, i.e. the unique point down on the plate where the virtual 'gnomon' for that hour has arrived. Calculating such points would be tedious, but in practice there is a short-cut (see below).

Rounding-off the gnomon, once begun, can run away with you, and it led me logically to a cylindrical gnomon, as being in profile 100% 'hump'. Here I recalled that a *Bulletin* article some time ago (it was a review, I think) was hoping to report in a subsequent issue some American work on chunky gnomons; but I don't recall ever seeing such a follow-up. So, a bit short on ready-made theory, I began work on a horizontal dial designed around a rakish cylinder. A bit of copper pipe the plumber left behind was stout enough and also had the right bore to take a 2p coin bearing the date of our anniversary. The two sides of the cylinder's profile, offering at any time two candidates for the correct shadow-line, proved to be no problem; there is no confusion, because the correct line conforms to the trend of the hour-lines and the wrong one is obviously wildly irrelevant. The general effect of the plate layout amounts to something of a clockwise whirl and, as with a Catherine wheel (Fig. 4), there is no room for doubt as to which way the action is going.

My dial as a construction owes a lot to the soldering-iron and blow-torch, and also to the Birmingham firm of John Burns who supply letters and numerals in metal (or plastic); not cheap, but worth every penny. The lines of the scale divisions and the EoT graph are strands of copper wire stripped from an old mains cable (snatch-stretched to straighten and stiffen them); these were passed down through holes in the dial plate and turned over on the underside. All the lines, and the lettering and numbering, were coated with solder on the underside then 'sweated' onto the base plate of thick copper sheet which had also been primed locally with solder. Locating and aligning it all proved a

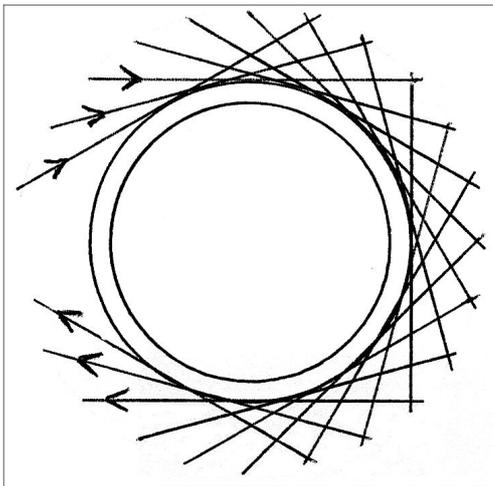


Fig. 4. Sun's uninterrupted progress around a cylindrical gnomon. N.B. no 'Gnomon Width Gap'.

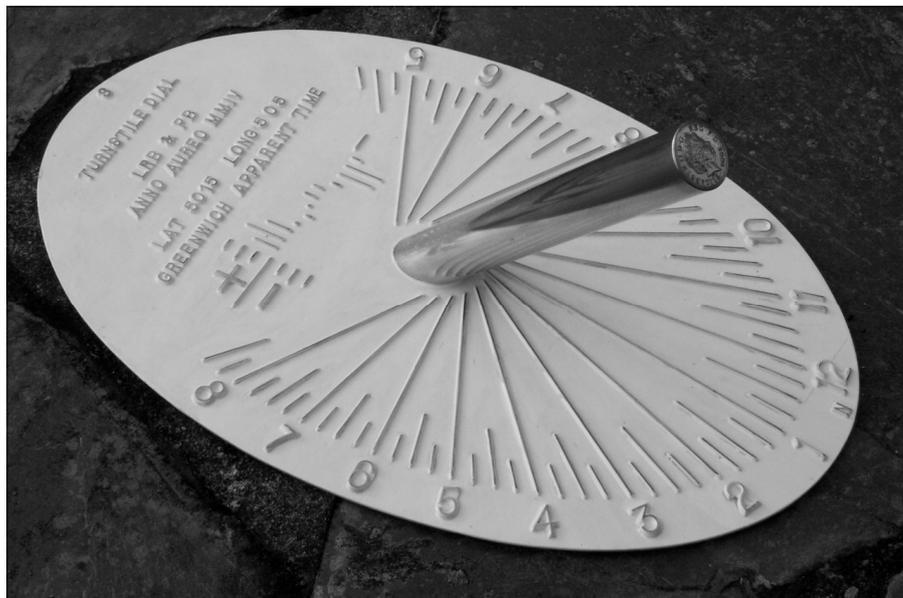


Fig. 5. The Turnstile dial, as made.

surprisingly flexible process: minute changes were easily made by warming up the spot from below (with the blow-torch) and nudging. A subsequent painting all over took care of solder smudges on the plate, after which all of the upper surfaces were scraped off and polished bright. As for the cylindrical gnomon, it was passed down through a hole in the plate to project a little below and peened over on the underside with a small hammer and soldered. The all-important alignment of the gnomon called for a couple of jigs which I had to contrive for soldering it simultaneously at the right elevation, along the correct baseline, and in the true vertical plane.

The proportions of the elliptical plate were adjusted to give the least variation around the scale in the size of the time-scale divisions. I tried using the elliptical proportions natural to a circle tilted at the angle of latitude, but that didn't quite do it (no doubt somebody will tell me why). The small N and S near the sharp ends are for the orientation of the whole thing; their alignment had to be displaced from the plate's centre-line because the gnomon blocks that as a possible line of sight. The Equation graph is a bit personal: I have never been able to memorize the whole thing, and this simple version at least serves to remind me of the general swing through the months of the year, having mid-month values against five-minute levels plus or minus, up and down.

The drawing procedure began with the chosen ellipse, plotted as a graph to the tune of:

$$y = e\sqrt{a^2 - x^2}$$

(my DIY formula for stretching a circle into an ellipse, e being the ellipticity ratio and a the semi-major-axis). At the centre a small ellipse of the same proportions was plotted for the base of the gnomon. The hour lines were added,

each at its calculated angle to noon, by simply drawing lines tangential to the small ellipse using a variable set-square appropriately set and slid along the tee-square: all quite painless. I have honestly forgotten whether I conscientiously calculated each plotting-angle down to the quarter hours, or perhaps resorted to interpolating the small fry by halving, etc., but at least they were all drawn tangential to the central ellipse in the proper mode of St Catherine's flying sparks.

The top of the gnomon started off with a '2004' 2p piece, but I was tempted into luxury by reading in the paper something disparaging about our copper coinage. It seems that copper - cheap enough, you'd think - is not used en masse for the coins; there is only a thin coating of it on top of 'steel'. Certainly there is something ferruginous under the skin; my copper-coloured 2p duly twitched in response to an enquiring magnet. So, reluctant to leave one's Sovereign out of doors in danger of rusting, I turned a 'silver' 2004 50p down to size on the lathe and mounted this on the tip of the gnomon, well-placed for Her to enjoy an early touch of the summer sun.

The name, by the way, just says what the virtual style does. The tangential gnomon line which runs down the length of the cylindrical surface - the line on which the sun grazes - moves around that surface as the day progresses. The essential style, that is, 'turns'. Turnstile. Oh never mind.

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SLUNEČNÍ HODINY – A SMALL CZECH SUNDIAL

PETER RANSOM



Fig. 1. The sundials outside the Štefanikova hvězdárna observatory in Prague.

This is a short note to inform BSS members who visit Prague that a small wooden do-it-yourself sundial is available from the observatory Štefanikova hvězdárna which is in the Malá Strana area. Sundial enthusiast and Prague resident Jan Šafář brought these to my attention after a visit there. The observatory has an interesting collection of concrete dials outside, as shown in the picture above.

The d-i-y sundial, designed by Jan Sifner, is made of thin wood and appears to be laser cut. I found the pieces easily separated though some of the narrow slits benefit from the use of a craft knife in places. The whole dial fits together so accurately that no glue is needed to hold it in place. With

the tenons on the edges matching it is like a 3D jigsaw. There are four dials on the cube: a horizontal and vertical south, east and west ones. On the east and west gnomons there is the equation of time using signs of the zodiac. Engraved on the base is “v.d. 50°” (an abbreviation for the Czech *východ délka*, or north latitude) and “s.š. 15°” (for *sever šířka* or east longitude). The centre of the Czech republic is not far from 50 degrees north, 15 degrees east and that way I suppose there is no longitude adjustment needed since 15 degrees corresponds to 1 hour! The cube has a side of 4cm and the total height including the gnomon is 8.4cm. The whole model is cut from a piece of plywood 2mm thick and 11.5cm by 16.5cm.

Visitors to Prague will come across many dials: the Klementium (Jesuit College) contains thirteen on its walls including a meridian line. My wife and I came across many more during the week we had exploring the city. The one described here is the only one that it was possible to bring back!

Members who do not get the opportunity to visit Prague can obtain one from me while stocks last at a cost of £2.50 which includes postage.

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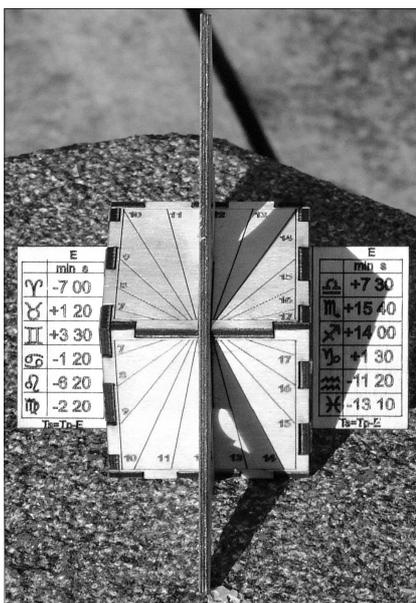


Fig. 2. The south and horizontal dials.

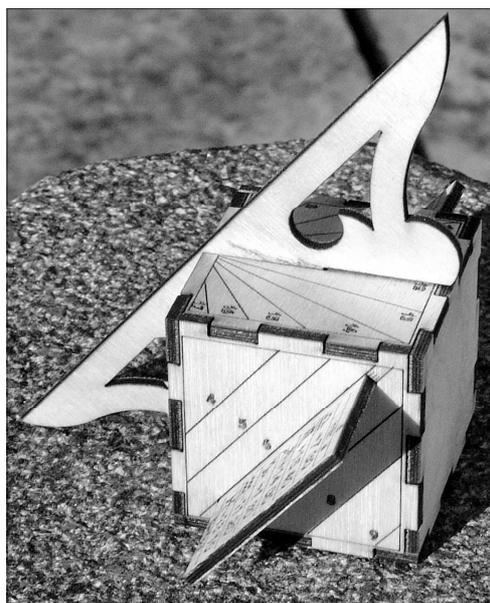


Fig. 3. Detail of the gnomon and east face.

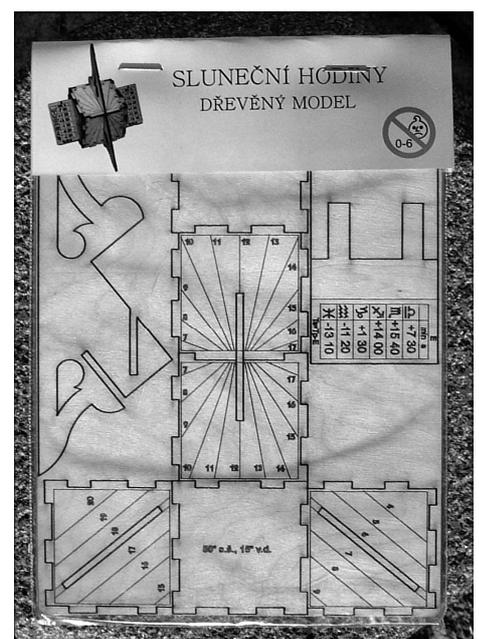


Fig. 4. The flat pack dial.

THE PYRAMIDICAL DIAL IN THE KING'S GARDEN AT WHITEHALL

MIKE COWHAM

Whilst investigating spherical dials, particularly that at Hilton in Cambridgeshire¹, it occurred to me that I should also look at other types of spherical dials, notably those made from glass spheres.

There are several ways of utilising both hollow and solid spheres to produce sundials. A transparent glass sphere is the ideal building block for an equatorial dial. It needs little more than a wire passing through its axis to act as a gnomon and a suitable hour scale drawing on the outside. It is then virtually identical to a standard armillary sphere but to enable the shadow to be seen from the outside of the sphere a semi-transparent white coating is required on one side.

Moxon² explains -

‘But because the Shadow of this Axis will not be discerned through the *Glass Body*, therefore you may with *Water* and *White Lead* ground together lay a *Ground* on the *Inside* of the under Half of the *Glass* to the *Horizontal Circle* for then the Shadow will appear.’



Fig. 1. Atlas holding a glass sphere, as illustrated by Moxon².

He illustrates such a dial in Robert Titchborn's garden (once Lord Mayor of London) where Atlas is seen to be holding up the World (see Fig. 1). Here the hour markings have been placed in a horizontal plane making it easier to read, especially when it is positioned above the observer's head. The lower half sphere has been coated internally with his special white lead paint to show the shadow.

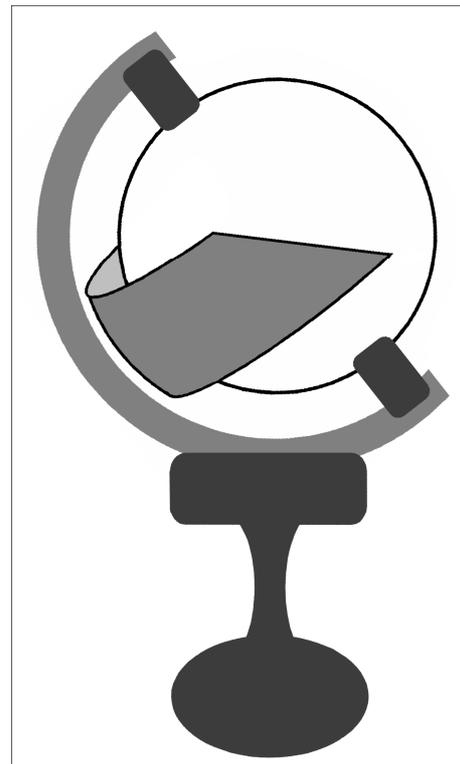


Fig. 2. Drawing showing the basic construction of a sunshine recorder.

A solid glass sphere or a glass sphere filled with water can be used to act as a lens and focus the sun's rays onto a scale set behind it. The focal point of a solid sphere is quite close to its periphery making quite a compact arrangement. This is the principal of the sunshine recorder (Fig. 2). Here the sun's rays are focused onto a wooden (or later a paper) scale that is effectively burnt away during periods when the sun is shining. Using this device a record can be made of a full six months of sunshine. By replacing the 'recording' surface with a semi-transparent arc it is also possible to make it into a direct reading sundial. This is the basic principle of the 'sundials for the blind' set up in 'His Majesties Gardens in Whitehall'.³ The famous dial set up there in 1669 by Reverend Francis Hall (Father Linus), professor of Mathematics in Liège is well recorded and a full description is given by William Leybourn. This description was put

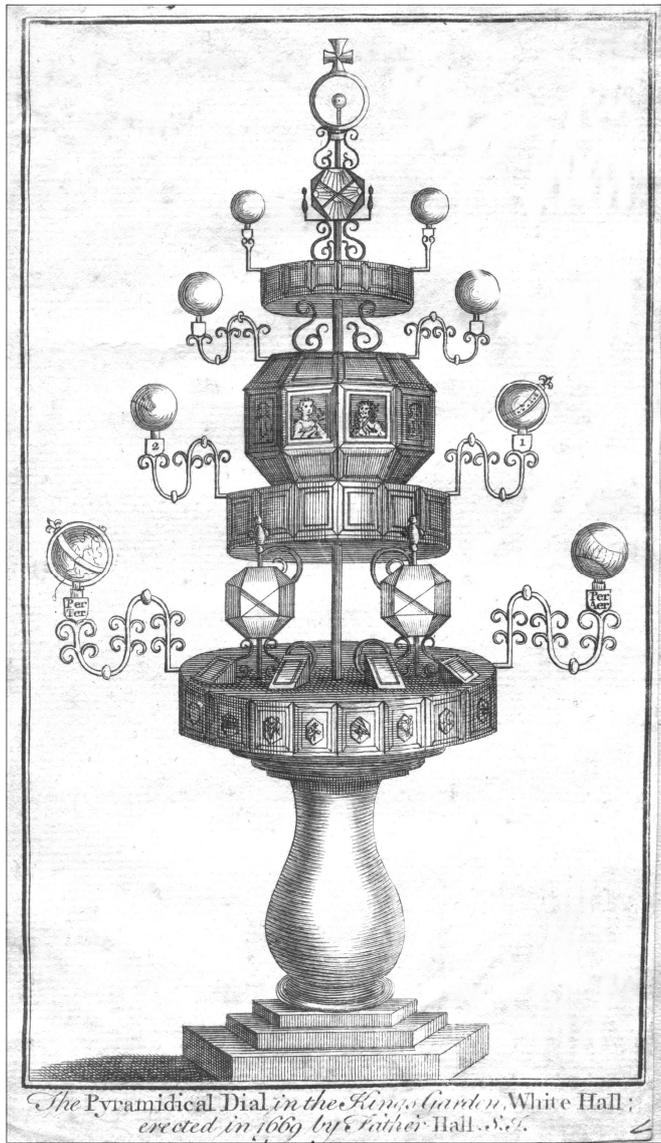


Fig. 3. The Whitehall dial from an early print.

into modern English by Charles Aked⁴ but I have only taken the parts about this remarkable dial that concern its spherical dials.

THE VARIOUS DIALS RECONSTRUCTED

The print shown in Fig. 3 (of unknown provenance, but possibly a later copy of Leybourn's print) is slightly different to that used by Leybourn⁴ being reversed left to right and, interestingly, it shows slightly different details on some of the spheres. However, we can not be certain that either print shows a true likeness of the original dial.

Those spheres showing details of the dials have been placed side by side for comparison in Figs. 4, 6, 7 & 10. In each case the sphere on the left is from the Leybourn illustration and that on the right from the print in Fig. 3. Note that both prints only illustrate two dials out of the four at each level for the sake of clarity, so the other dials must be reconstructed from Leybourn's notes alone.

Leybourn describes each of the dials in turn with a brief overview followed later by a more detailed description. Both of these descriptions have been placed consecutively in this article giving us a fairly good insight into the actual details of each dial's construction. From the descriptions of these various dials I have tried to imagine how each would have been constructed. Models have been built as necessary to illustrate how they may have been made.

Leybourn's descriptions start with the lower level of dials, working upwards.

Of the First Piece.

"There are also belonging to this piece, and issuing out of the sides thereof to the East, West, North and South, four iron branches supporting each of them a glass bowl which show the hour in four different ways."

"These four bowls show Common Hours four different ways: viz

The First by Fire by applying your Finger to the Meridians.

The Second by Water by the Rays of the Sun passing through the Water.

The Third by Air by two objects in the Globe reposing on your Eye.

The Fourth by Earth by a Terrestrial Globe described upon the Bowl."

These glass dials were, I believe, constructed as follows:

The first (fire) uses a solid glass sphere to focus the sun's power onto a hand placed just behind it. A blind person could then find the hour by feeling the heat from the sun and deduce the hour from some raised numerals. Braille was not invented at this time but basic Roman numerals would be quite simple to identify by touch. It may have had the advantage of a metal hour scale set around the

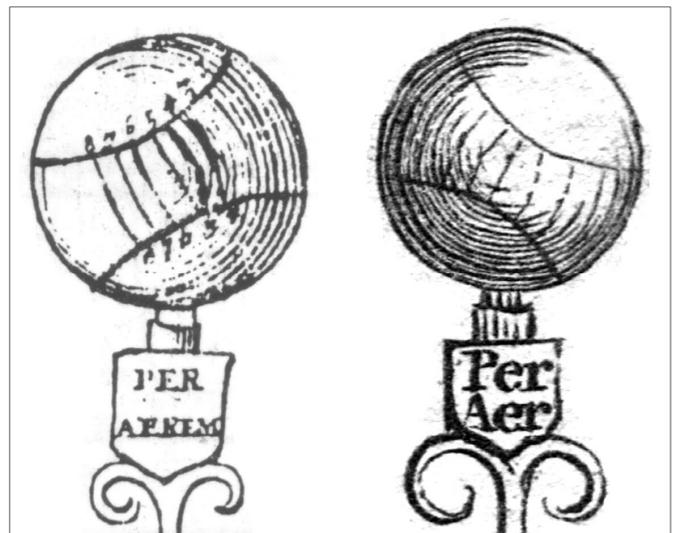


Fig. 4. The 'air' dial as illustrated by Moxon on the left and from Fig. 3. on the right.

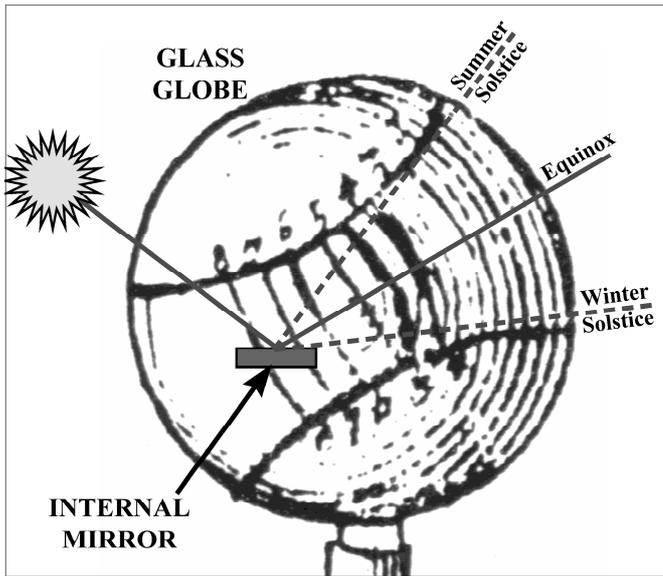


Fig. 5. Possible configuration of the 'air' dial to agree with the calibrations in Leybourn's illustration.

sphere at the focal point which itself would have become very hot in the appropriate place; something like the sunshine recorder already described. (A much larger dial of this type has been described as set up in Liège in about 1635 at the English College.)⁵ The second dial (water), this time filled with water, would probably have shown the time much like the first and is likely to have had a suitable chapter ring which may have been semi-transparent with opaque numerals or it may have been solid. The mechanism of the third (air), Fig. 4, is unclear from its description and illustration but suggests that the observer lines up two points within the sphere 'by eye'. The angles of the equator on the various dials shown in the illustrations vary but many are around 38.5° , the co-latitude for London. In the case of this dial the equator is set at only 30° (perhaps a small illustrator's error). One explanation for the statement "two objects in the Globe reposing on your Eye" may refer to a dial using some form of reflection internally from a small mirror, this being viewed through the transparent sphere and the sun's image being lined up with one of the external hour

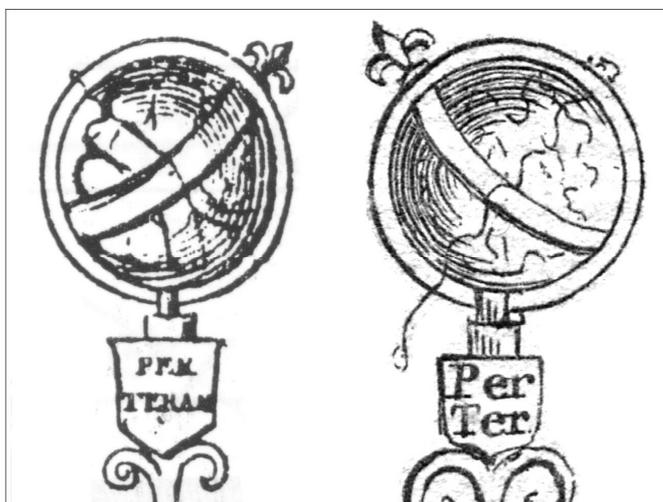


Fig. 6. The 'earth dial'.

lines. Looking directly at the sun is very dangerous so it would be wiser to use a mirror that is unsilvered or made of some other semi-reflective material to prevent eye damage. The necessary calibration can be achieved as shown in Fig. 5, with the mirror set horizontally but slightly moved from the centre in the globe.

The fourth (earth), Fig. 6, consists of a terrestrial globe showing countries and continents with perhaps a moving gnomon with a *fleur-de-llys* pointer to line up with the sun. Both drawings appear to have a thread with a plummet attached to the North Pole, perhaps for tracing lines of longitude.

Of the Second Piece.

"Out of the sides of this piece issue out four branches towards the East, West, North and South, and carry on each of them a glass bowl to show the hour, like those of the first piece, but in a different way. For one of them shows the hour by a style without a shadow, another shows it by a shadow without a style etc., whereas those of the first table show it by the four elements, fire, air, water and earth."

"These four dials are drawn upon four glass globes, of about five inches diameter and show the usual hour in several ways.

The first shows the hour by moving the style (which here is a fleur-de-llys fixed on a moveable equator) to and fro until it casts a shadow upon the globe, so shall the equator rest upon the hour.

The second shows the hour by observing where the part of the globe that is lit by the sun meets with the unlit part, for that will be the true hour.

The third shows the hour by the shadow of a style perpendicularly erected upon the superficies of the globe.

The fourth shows the hour by placing of your body so as to behold your face in the middle of a little convex looking-glass placed for that purpose in the South Pole

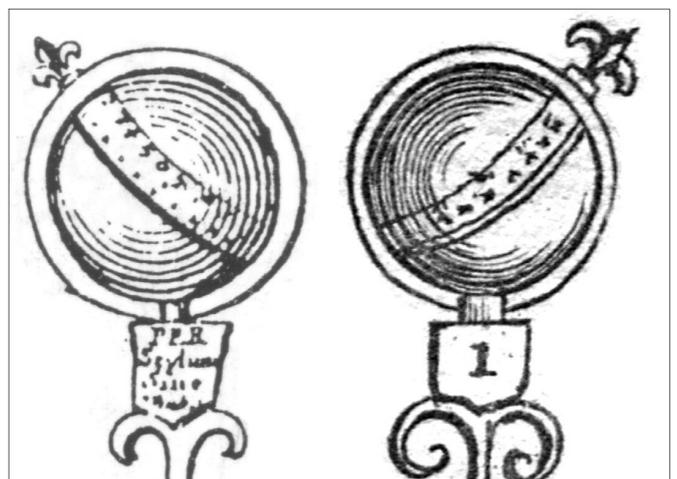


Fig. 7. The 'dial without a shadow'.

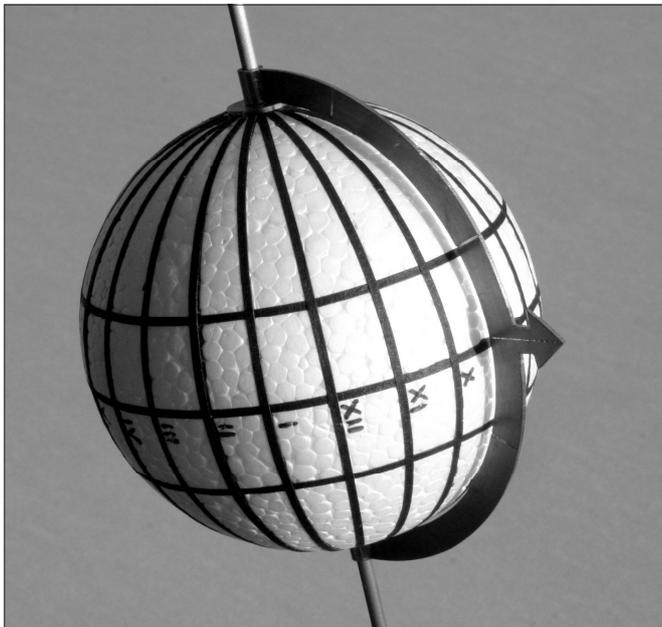


Fig. 8. Reconstruction of the 'dial without a shadow'.

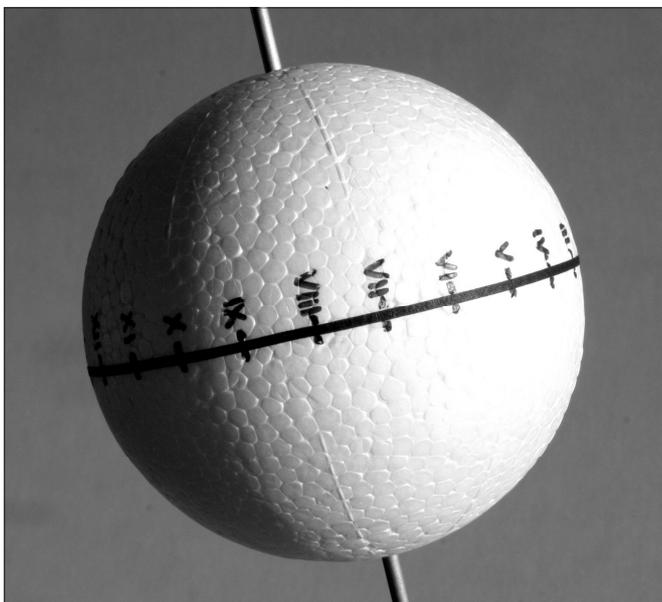


Fig. 9. Model of a 'dial without a gnomon'.

of the bowl or globe, you will at the same time (if the sun shines) behold the picture thereof at the hour."

The first of these appears to be similar to the fourth globe in the first piece but without the map (compare Figs. 6 & 7) and has a pivoted pointer that is moved in the direction of the sun until it produces the minimum sized shadow ("without a shadow"); see Fig. 8. The second is a plain sphere with its edges simply forming the shadows, these rather indistinct boundary regions denoting the hours (Fig. 9). This is what I have previously described as a crepuscular dial¹, a type with rather poor resolution due to the fuzziness of the shadow formed. The third (Fig. 10) may perhaps have been a form of polar dial using a vertical style. (Note that the vertical style is not illustrated in either print.) One reconstruction, Fig. 11, uses a simple pin gnomon but it could also have used one of a 'T' shape. This is not a very sensible surface on which to make a dial as it can only

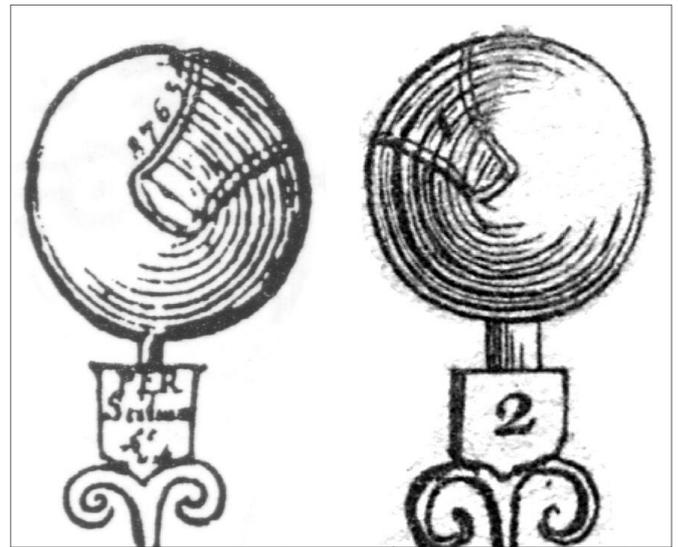


Fig. 10. Dial with 'a style perpendicularly erected on the superficies of the globe'.

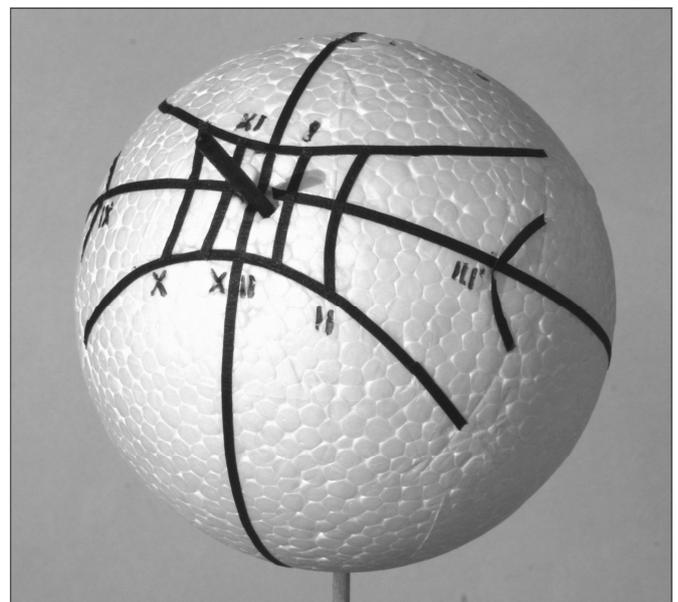


Fig. 11. Possible reconstruction of the dial in Fig. 10 using a vertical pin gnomon. Only the hours between 9am and 3pm can be displayed.

show the hours from 9am to 3pm unless the pin gnomon is made much shorter. Then the dial would be much too small to use. However, the calibrations as illustrated in Fig. 10 are not achieved, so there is some doubt as to whether the original illustration is correctly portrayed. In order to produce the scale shown there appear to be two different solutions. The first is to have an individual gnomon for each hour standing up from the surface like short fins. This seems unlikely and surely these would be shown in the illustration? Therefore I would suggest a second solution that uses a small mirror for reflecting the sun's light onto the hour scale on the opposite side of the globe in a similar way to that used for the 'air' globe, already described. The tilting of the dial scale close to 50° again suggests illustrator's error but if correct this could be achieved by using a slightly tilted mirror as shown diagrammatically in Fig. 12. The offset from the centre is necessary to get the effect of

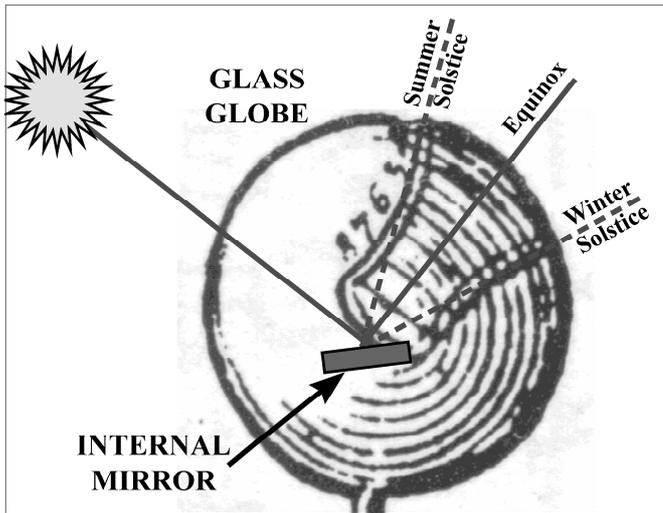


Fig. 12. Second possible configuration of Fig. 10 to achieve the illustrated calibrations.



Fig. 13. Clear glass dial with a convex looking-glass at its South Pole. Time almost 11:00am.

the solstice lines being wider apart around noon than at 6am or 6pm. Even so, the arrangement would probably not be very accurate especially when it was necessary to show the early or late hours as marked on the original. The hour scale itself would be a semi-transparent white. For the construction of the fourth dial we are told that it uses a “convex mirror at the South Pole to view the sun”. This has been replicated in Fig. 13, making a rather attractive design. The image of the sun is then seen at the correct time according to the outer hour scale, and as the mirror is convex, reducing the size of the sun’s image, it is less likely to blind the user.

Of the Third Piece.

“Moreover, from the top of this globe issue four iron branches towards the four corners of the world, each of them carrying a glass bowl, proportionally less than those of the first and second pieces; on which bowl dials are described, but differing from the former, showing the hour according to the several ways of counting the hours. These bowls are painted on the

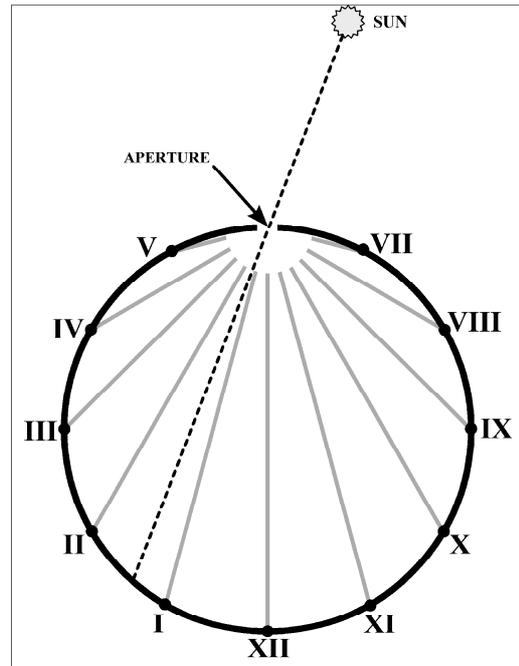


Fig. 14. Cross section of a dial made from a hollow sphere, as seen from its North Pole.



Fig. 15. Model of hollow sphere in Fig. 14.

inside with thick colour to keep out the light, except for a little space left clear, like a star, for the sun’s beams to pass through and show the hour, and the place also where the hour lines are drawn, only painted on the outside thinly with white colour that the light passing through the said star may be seen and show the hour.”

“The four bowls are gilded over, except where the hour lines are drawn, which is thinly painted over a white colour with the result that the sun’s rays passing through a little star, left clear on the top of the bowl and making the like star of light upon the hour lines, may be seen to note the hour. The hours are such as to show the hours according to the different nations.”

The third stage too had four globes. These globes were gilded hollow spheres and a small hole was left for the sun’s rays to enter and form a spot (“like a star”) on the opposite side on a thinly painted area (Fig. 14). A reconstruction of this dial (Fig. 15) shows the sort of result

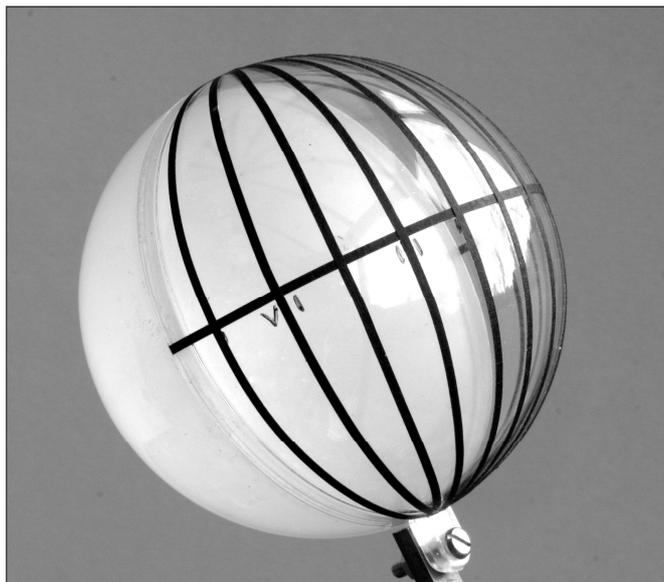


Fig. 16. Construction of the 'transmission' dial.

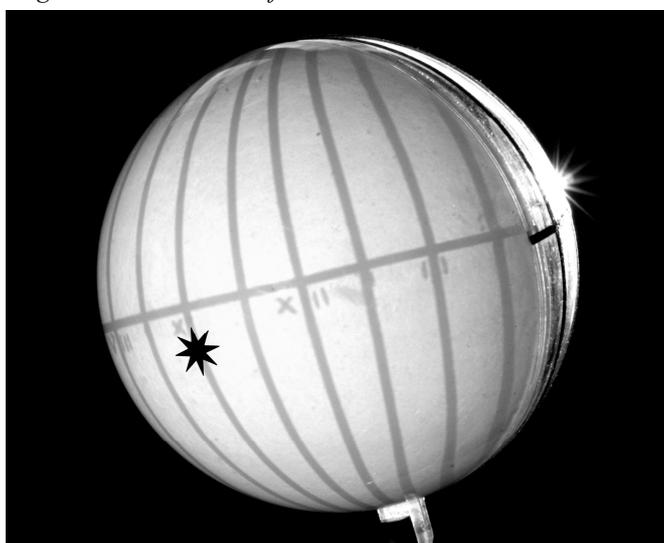


Fig. 17. The 'transmission' dial in use. Time 10:00am.

obtained. Leybourn also says that each of these dials was arranged to show the time in different nations. This means that these four dials would probably show equinoctial hours as illustrated, Babylonian hours beginning at sunrise, Italian hours beginning at sunset and perhaps unequal hours.

Of the Fourth Piece.

"From the top of this table issue forth iron branches each carrying a glass bowl, just like those of the first, second and third piece, not only because they show only the usual hour, but also because here the hour lines are all left clear for the sun's beams to pass through, that by so passing they may exhibit the like dial on the opposite side of the bowl; which side is for that purpose thinly painted over with white colour, that the said hours may be seen and show their hour by their passing over a little star, painted in the middle thereof."

The dials in this section were probably using a similar technique to those on the third stage except that the lines and marker would be reversed making these 'transmission' di-

als, see Figs. 16 & 17. Here the hour lines are on the front of the globe with mirror-image numerals. These simply form a shadow on the opposite painted side, the time being deduced from the position of the central 'star'. Leybourn describes clear lines, which would have given a more distinct negative image on this north side, but otherwise it would be the same as my reconstruction. These four dials would also have shown the hours 'according to the different nations'.

The fifth piece does not have any spherical dials and is not described here.

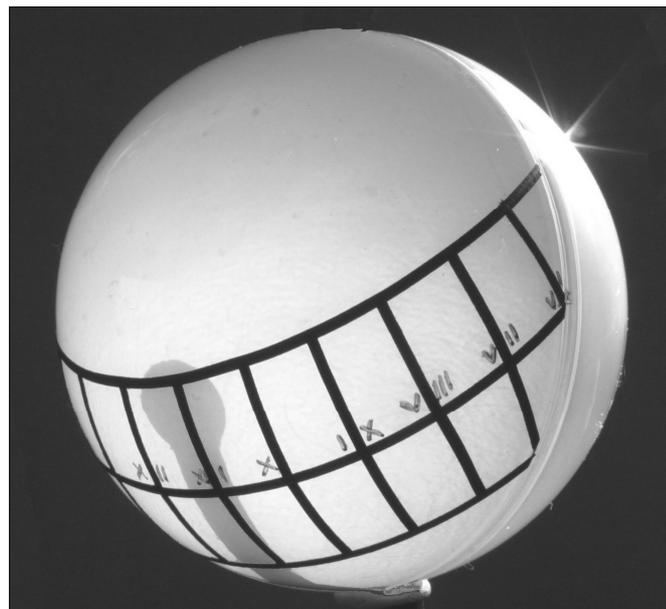


Fig. 18. The 'last or highest piece' with a ball showing the time of 11:10 near to the Winter solstice.

Of the last or highest Piece.

"The highest piece or top of the pyramid is a glass bowl of some seven inches diameter, standing on the foot of iron placed on the middle of the fifth piece. The North side of the bowl is thinly painted over with white colour, that the shade of the little golden ball placed in the middle of the bowl, may be seen to pass over the hour lines which are drawn on the said white colour, and note the hour. The bowl is included between two circles of gilded iron, with a cross at the top."

"The sixth and last piece is a great glass bowl, standing upon the fifth, supported by a foot of iron and encompassed with two iron circles. Which bowl also shows the hour by the shade of a little golden ball placed in the middle of the glass."

This highest piece therefore consisted of a plain glass globe, whitened on its north side and having a centred ball for its gnomon supported by a stalk. The centre of the ball's shadow will therefore indicate the time from the calibrations marked on the outside of the sphere. The shadow produced will also include that from the stalk supporting the ball (Fig. 18).

CONCLUSIONS

The remarkable Whitehall Dial as described by Leybourn is much more complex than I have attempted to detail above as may be seen from its drawing, Fig. 3, or that of Leybourn himself. It carried numerous dials of all types (horizontal, vertical, declining, inclining, reclining etc.) and was plainly a major gnomonical construction for its time. It would be very interesting to attempt a reconstruction of the complete dial although the full details of each part, as we have seen, may not be absolutely complete. The use of modern materials such as polycarbonate or acrylic in place of glass and by using alcohol, glycol or even oil rather than water in the spheres would make them less vulnerable to damage by the elements. Alternatively a small model for use indoors would make an impressive exercise.

The life of this famous dial at Whitehall was very short due to its delicate construction. It was badly damaged by frost in the winter of 1673 and the Earl of Rochester and his companions were discovered vandalising it by smashing its glass components.⁵ I wonder how long it would survive today in any public place?

NOTES ON CONSTRUCTION

Explanations showing how I constructed some of these replica dials may be appropriate. They have either been delineated on the surface of expanded polystyrene balls or by using transparent polycarbonate spheres (moulded in two halves). However, one (Fig. 15) was made from a plastic Christmas tree bauble with the glitter and paint removed with wire wool. The small convex mirror was also a shiny fragment from another bauble. All of these items are available quite cheaply at good model shops or Santa stores. The calibration lines were applied as a thin crepe drawing tape (normally intended for the creation of printed circuit board designs).

Laying out designs on a sphere is not always easy but I used the technique previously outlined⁶ where I used card templates. This made the process very much simpler.

The most difficult process was perhaps the application of the semi-transparent white coating on the inside of some clear spheres. Firstly I roughened the internal surface with some wire wool moistened with a detergent solution. This only gave a light matt surface with insufficient density to show a proper shadow. The next process was to coat the inside of the sphere with white plastic emulsion paint. Naturally this would be rather thick to let enough light through so I diluted the paint by about 50% with water. The already roughened surface was free from grease but a small quantity of detergent was added to the paint to help it flow. This was then applied with a soft brush. As the paint was very liquid it was then swilled around inside the sphere

until the coating looked even. Excess paint was then allowed to drip out being carefully blotted so as not to leave a thick rim. After initial drying the sphere was kept warm and dry for some hours. With some experience a perfectly flat semi-transparent coating is possible.

All of these dials were finally photographed using sunlight to get the most realistic effects. It was found to be very difficult to obtain good photographs in the instances where the camera was looking almost directly into the sun. This has made the background black but has produced some otherwise pleasing effects. Wherever possible the camera lens was shielded from the direct sunlight.

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The SE/SW dip-tych dials on Tobias Beau-chop's house, Alloa, Clack-mannan. It was recorded in 1989 by Andrew Somerville as SN1748 but in a poor condition and without its gnomons. Has anyone seen it more recently? Beau chop (or Bachup or Baak) was a master mason who was architect for the town hall at



Dumfries. His initials, together with those of his wife, Margaret Lindsay, appear in the panel under the dial. A full drawing is in the Eden & Lloyd edition of Gatty.

BSS ANNUAL CONFERENCE

Collingwood College, Durham. 21-23 April 2006

Chris Lusby Taylor

Collingwood College, just a short walk from Durham's wonderful mediaeval cathedral, was our home for a most stimulating and delightful conference bathed, uncharacteristically, in warm sunshine. The weekend followed the established pattern of talks on widely varying aspects of sundials punctuated by a visit to see local dials and the cathedral, a highly entertaining auction and just enough time to admire members' exhibits and the winning entries in the photographic competition.

Doug Bateman, our secretary, put together a programme that neatly interwove the ancient with the cutting-edge, the artistic with the mathematical. Indeed some members' other halves commented that they'd found the talks most interesting, to their surprise.



We arrived, from as far afield as Cyprus, Norway and the USA, in time for dinner on Friday. This was followed by just one talk: Kevin Barrett on the subject of Feng Shui and how its principles apply to the design and positioning of sundials. Believers in Feng Shui hold that the size,

orientation and siting of objects can affect the life forces of anyone nearby, so they try to eliminate all negative influences. Luckily, as Kevin showed us, most problems have a solution, but it's a complex subject and seems to need a great deal of study. In a short test, we correctly identified the Golden Mean as harmonious, but failed miserably to spot the optimum size for a pedestal. Happily, it turns out that the best position for a dial is the middle of a garden where the dragon and the tiger influences meet, but one must ensure that neither the gnomon nor the pedestal edges point into a room.

After that it was a relief to turn to considering Durham Cathedral, in a classic film that Frank Evans had obtained

on video and that served as an excellent foretaste of the following day's visit.

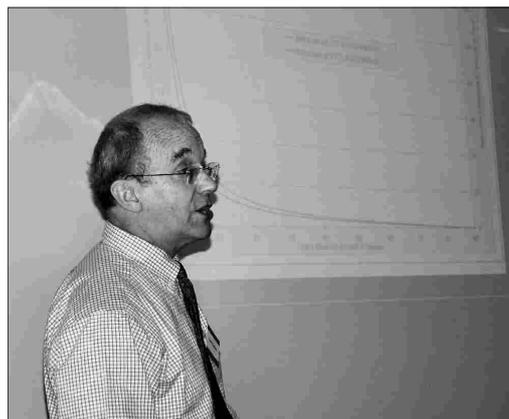
Saturday morning's first treat was Fred Sawyer's talk. To



celebrate his thirty-fifth wedding anniversary he set himself the task of inventing not one but two sundials. One was to feature the flaming chalice symbolic of their church and hint at osculation: the shadow 'kissing' the date line tangentially when set to the correct time. The dial was indeed in the

form of a chalice and the Equation of Time analemma ingeniously folded to look like a flame. The other dial was to incorporate two hearts, not as mere decoration, but, like the flame, inherent in the mathematics. For this, he took two apparently separate ideas from Peaucellier (that a sundial with an arbitrary style direction may have straight hour and date lines and that the inverse of a circle is a line) and hey presto! A sundial with two hearts. Brilliant. And the dials, exquisitely crafted by Tony Moss, were a highlight of the display of members' work.

Next up was Kevin Karney who gave us an extremely clear and beautifully illustrated exposition of the errors that can



beset a sundial reading, ranging from the mundane fuzziness of the shadow to the changes in the earth's orbit, and therefore the Equation of Time, over the dial's life of, say, three hun-

dred years. Having identified the sources of potential error, he described a proposed equatorial dial that overcomes them. All of them, to within 30 seconds: a goal Kevin set himself in response to his father's claim that his watch was more accurate than a sundial.



After coffee, the prize the 2005 Photographic Competition was presented by our chairman to Ian Butson for his humorous picture "I've got the inclination but not the time" [see p.54 for the full results].

Photo: Mike Cowham

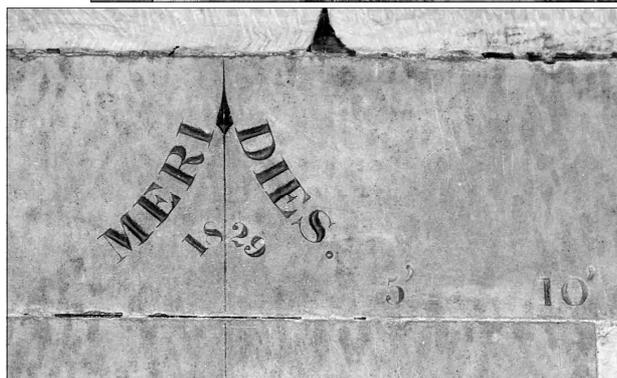


Next, we were treated to the Andrew Somerville Lecture, given as always by an eminent scholar in a field that sheds light on an aspect of the history of sundials. Durham Cathedral houses the shrine to the Venerable Bede and the area was important in the early Christian era as the border between the Celtic West and the Anglo-Saxon East, so it was most appropriate that we were honoured by a lecture from Professor Rosemary Cramp, Emeritus Professor of Archaeology at the University of Durham and past President of the Society of Antiquaries. She started by welcoming us to Durham University and apologising for the absence of the Vice Chancellor, a member of the Society, whose wife's birthday celebrations had, understandably, taken precedence.

Professor Cramp then treated us to a journey through time, from the seventh to the eleventh centuries, and through space from Antioch and Constantinople to Wearmouth and Jarrow. She argued persuasively that knowledge of scientific ideas had survived the fall of Rome via libraries. Bede had written extensively on sundials and knew that the Julian Calendar was drifting so that the dates of the equinoxes, and thus Easter, were incorrect.

The talk was illustrated by many slides of Bewcastle cross, Escombe and other local sundials. Her knowledge of the artistic conventions of the period, from Turkey to Ireland, allowed her to show where the various designs originated and their significance. Where, in the eighth and ninth centuries sundials had, she believes, been associated with monastic learning, they later became more of a status symbol in the north.

In all, a fascinating talk, and an excellent introduction to the afternoon's tour, organised by Frank Evans, which took in two Anglo-Saxon dials, one only recently recognised as such by Professor Cramp herself. Unfortunately, both dials are now rather indistinct, as is the meridian line in Durham Cathedral. England has only two or three meridian lines and this nineteenth century example has become worn almost to ex-



inction in the last few years, which struck us all as a great pity. Having just learned of Bede’s scholarly application of sundials to the issue of the calendar, some members proposed that we adopt him as the patron saint of sundialling.

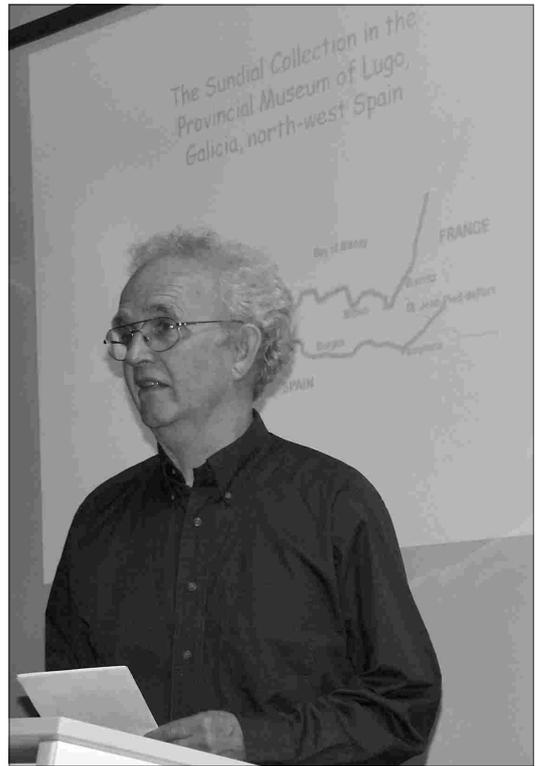
After a splendid dinner our Chairman Chris Daniel announced the winners of the 2005 Sundial Awards Scheme. Winners were presented with certificates by our Patron Sir Mark Lennox-Boyd, and he also presented a copy of his magnificent book on sundials to Dr Margaret Stanier on behalf of the Society to thank her for editing *The Bulletin* for the last nine years.

The best laugh of the weekend was afforded by David

Young, doing his traditional turn as auctioneer’s assistant. He eventually managed to find all the 96 lots in the catalogue and one that wasn’t catalogued but still sold to Julian Lush, even though he has no idea what it is! In all, the sale raised over £1000, the top prices including £65 for an Abercrombie and Fitch noon cannon and £130 for an Augsburg equinoctial dial by Johann Schrettegger. Many of the lots were gifts to the Society from the estates of late members.

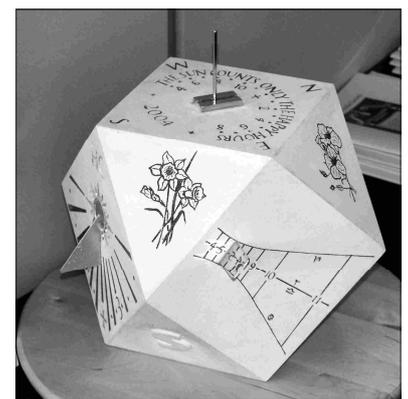
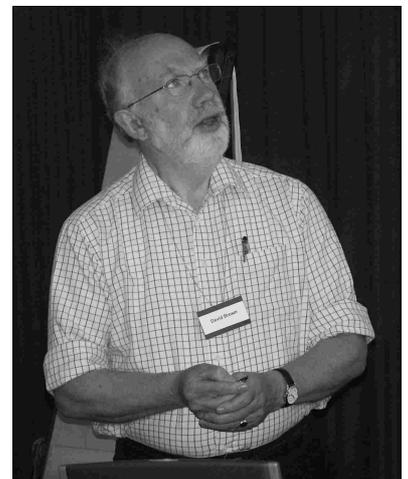
On Sunday, the author of this report gave his talk on a novel use for unwanted CDs as an accessory to allow Italian hours to be read on a conventional horizontal sundial. The virtues of Italian hours having been pointed out in last year’s Somerville Lecture, I thought it curious that so few English sundials showed them, especially since they are so much better handled by sundials than other time-keepers.

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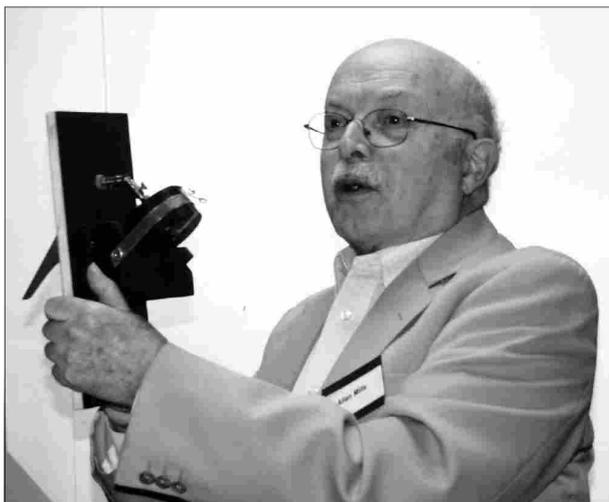


This was followed by Piers Nicholson’s slide show on sundials in a provincial museum in Lugo in northern Spain that he happened upon by chance. Although the provenance of each dial has not been recorded, they are known to be from large houses in Galacia and date to the eighteenth and nineteenth centuries.

There is no doubting the provenance of a David M Brown sundial, as they are all signed with his distinctive ‘dmb’ mark. Where Fred Sawyer works allusions into the mathematics of his sundials, David does so in the decorations. And what wit, imagination and erudition he uses! Who else would think to make the supports for a dial be in the form and exact size of organ pipes scaled to play A and C, for a dial in honour of the Wells Cathedral organist, Anthony Crossland. David showed us his beautifully designed



and crafted work in a dozen examples of the greatest variety, including one to be unveiled in June at Hertford College, Oxford.



After a coffee break, Allan Mills showed us a model he has made after the ideas of Robert Hooke, showing how Hooke's universal joint exactly models the relationship between a clockface and a dial face. Allan hopes to be commissioned to make such a model for a permanent site, where a clock would drive a pointer to allow a sundial to function 24 hours a day. He pointed out that all cars contain Hooke's joints in the transmission, so the car industry might be willing to celebrate the joint in this way.

The member who had travelled furthest to the conference, and the member whose dials have travelled furthest, was undoubtedly Woody Sullivan from Seattle.

His highly imaginative dials include a pig smoking a pipe, a six foot high shepherd's dial, and, of course, the Mars Dial: the first sundial on another planet. He's also behind the Earth Dial project, which assists beginners who make sundials that are then shared on the Internet for all to see via webcams. He is truly dragging us into the twenty first century.



While the British Sundial Society attempts to be the authority on sundials in the British Isles, we are always delighted to welcome speakers from around the world and to learn of their countries' history. Our last speaker, Johan Wikander, brought us back down to Earth from Mars, and back a thousand years and a thousand miles to Norway. Being so far north, the sun's azimuth is a more accurate representation of time than it is here, and he showed how the familiar compass rose divisions were used also to divide the day into eight tides according to the sun's azimuth. Some of the language seemed familiar, too: the word for 'west' was almost 'vista', appropriate for a people living on a west coast. As with Anglo-Saxon dials there cannot be certainty about how such early and primitive dials were used, but Johan gave us a plausible exposition.

The last business of the day was the Society's AGM, reported on p.57. We were finally sent on our way with a thoughtful poem by Jackie Holland on the subject of time. While there unfortunately isn't space for it here, please seek it out on our Web site.



Just some of the many replica dials and instruments on Leonard Honey's display.

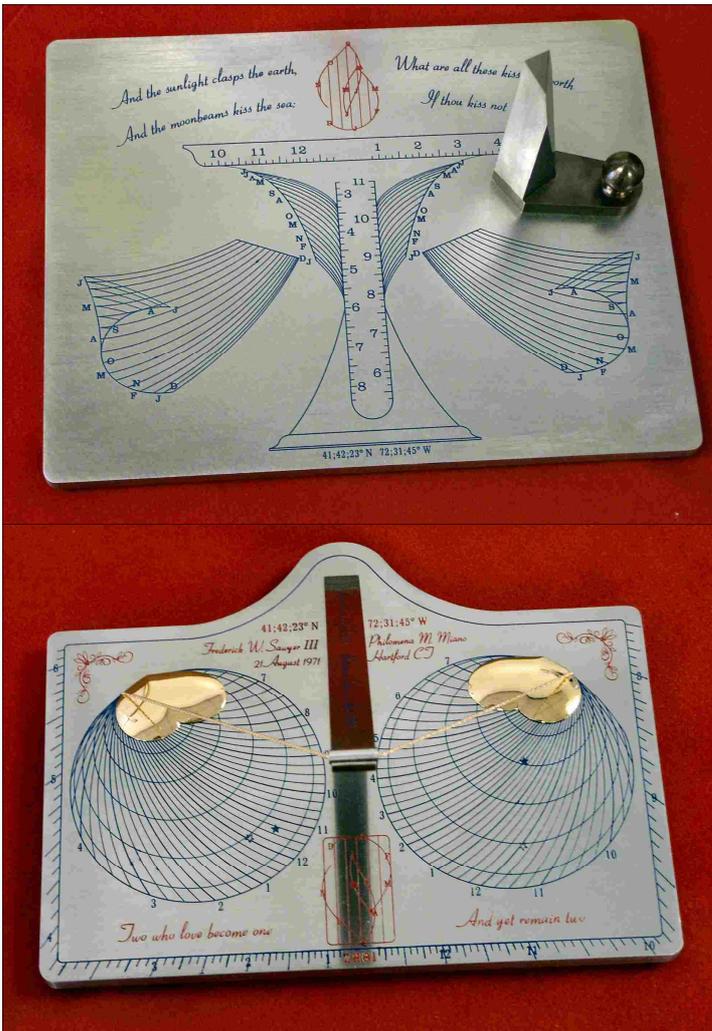


Prizewinners in the BSS Awards Scheme 2005: (L to R) Michael Harley, Sir Mark Lennox-Boyd (patron), Harriet James, Andrew James, Joanna Migdal, and Piers Nicholson. The other three prize-winners, Heiner Thiessen, Peter Scott and Steve Daggitt, could not be present.

Below: a jolly scene at the banquet, including Peter and Jane Walker and Jen and David Brown.

Below: two unusual dials designed by Fred Sawyer for his 35th wedding anniversary and made in stainless steel by Tony Moss.

Below right: retiring Editor Margaret Stanier is presented with a copy of our patron's new book, by the author himself.



A REVIEW OF THE HELIOCHRONOMETERS BY PILKINGTON & GIBBS

Part 1. The design and accuracy of the Gibbs Helio-Chronometer

GRAHAM ALDRED

Abstract

The Pilkington & Gibbs Helio-Chronometer¹ is a remarkable sundial with a justified reputation for mean time accuracy. In the 1906 promotional material an accuracy of within one minute of true clock time was claimed. In order to discuss this it is necessary to examine the construction of the basic sundial and the implementation of the mean time mechanism in some detail. The significance of original calibration marks is considered together with the effect of wear

and methods to obviate it. The results are derived from a study spread over several years that involved repair, testing and installation of over 20 Helio-Chronometers, complemented by measurements and close inspection of many more. Based on this experience some practical procedures are given in Part 2 for the recalibration and installation of Helio-Chronometers to recover their impressive accuracy. In Part 3 the design and accuracy of the Sol Horometer will be discussed and the two instruments will be compared.



Fig. 2. The various components of the Mk.2 Helio-Chronometer (the lower base plate is missing as discussed in the text).

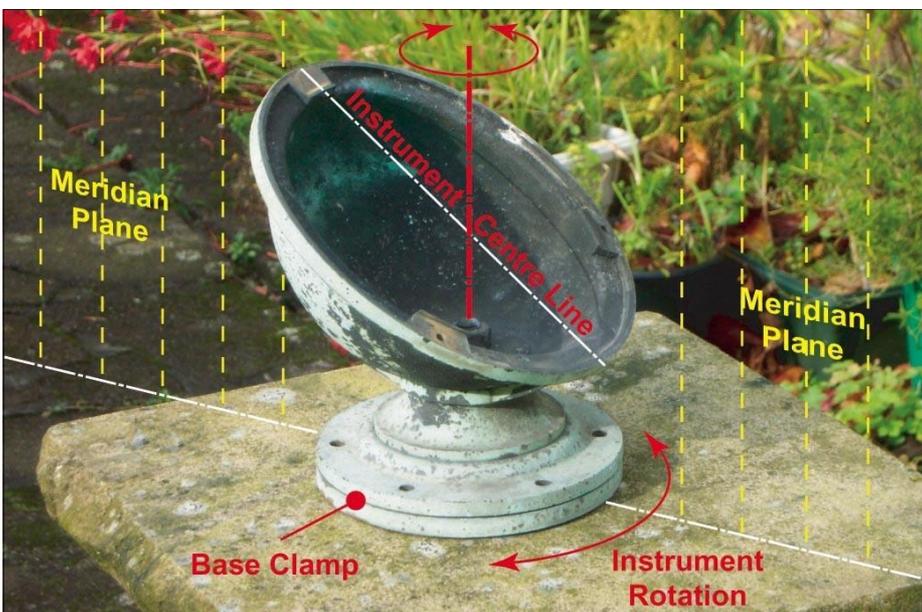


Fig. 4 (above). Mk. 2 HC detail of hour plate showing datum 'o' line and minute sector set on 'G' for a longitude of about 2.5° W.

Fig. 3 (left). The Helio-Chronometer showing the Instrument Centre Line (ICL) set in the meridian plane by rotating the instrument on the vertical axis and locked by the base clamp.

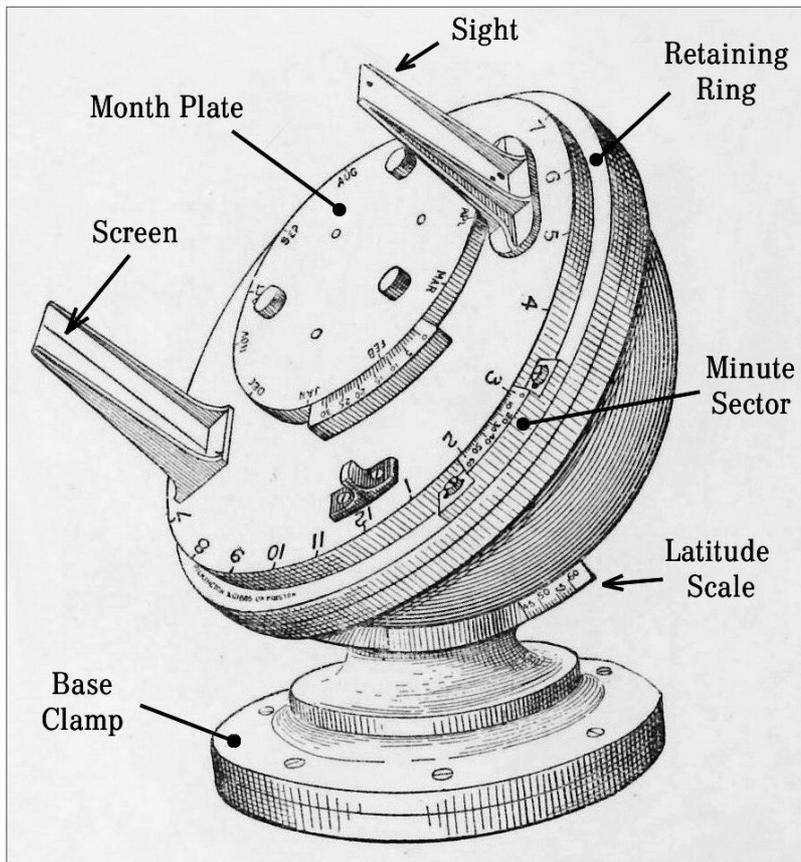


Fig. 1. The Pilkington & Gibbs Helio-Chronometer from an illustration in the original catalogue.

Introduction

Instrument serial numbers suggest that around 1000 instruments were manufactured. Production started in Preston, England, around 1905 and ceased about 1913; the residual stock ran out around 1922. Most sales occurred before 1911, many to remote countries. The practical appeal of this unusual sundial was that accurate mean time readings were available directly, no mental arithmetic was required and it was a universal off-the-shelf instrument exactly configurable for any location. P&G sold direct to the public initially and later used various retail outlets including Negretti & Zambra, who did not manufacture the instruments as has been suggested. The names of other minor retailers often appear on the centre of the month plate.

Although the hemispherical bowl arrangement is the most common mounting system with a latitude range of 43° to 60° (Fig. 1), alternative universal arrangements were developed to mount the basic equatorial plate assembly, which carries the sight screen system and the EoT adjustment device. Significant mechanical improvements were developed over time either to assist production, improve performance or to simplify setting up. These were introduced progressively on instruments after serial No 208: I use the terms Mk.1/Mk.2 for this differentiation. A southern hemisphere equatorial plate assembly was also developed to enable the Helio-Chronometer design to function anywhere in the world.

Whilst the majority of sundials are limited to two or three fixed parts, the Helio-Chronometer is an assembly of about twenty finely machined bronze components with many screws and special nuts (Fig. 2). The inherent equiangular properties of an equatorial sundial and the quality of the engineering design enabled over a thousand excellent sundials to be manufactured using batch production methods for probably the first and only time in the history of dialling.

The Mounting Assembly

One of the difficulties in visualising setting up the Helio-Chronometer arises because so many parts, especially the hour plate and the gnomon, are designed to move relative to both the mounting system and to each other. Nevertheless, there must be a notional line in the instrument that has to be fixed exactly in the meridian plane during installation. One must imagine the mounting system cut in two along an Instrument Centre Line (ICL). On the common hemispherical mount this line would include the diameter from the highest to the lowest edge on the inclined hemisphere shown in Fig. 3. Many HCs actually have faint lines scribed on the outer rim of the hemisphere (or other base) that define the Instrument Centre Line and on some early Mk.1 models these lines were labelled 'T' and 'B'. Unfortunately these lines can be lost due to corrosion or polishing.

The two circular base plates provide a fixed clamp operated by six screws that trap a flange on the bowl support column (Fig. 3) When the clamp is slack the assembled instrument can be rotated about a vertical axis to any azimuth, thus the ICL can be set to lie in the meridian plane. The lower circular base plate must be perfectly level. It is held to the pedestal by means of a captive rag bolt set in lead, often with mortar in the webs. Consequently many surviving HCs have lost their lower base plates due to the difficulty of removal from the pedestal. The inclination of the hemisphere defines the equatorial plane; it is adjusted to colatitude by releasing the large clamp nut seen inside the bowl in Fig. 3.

The Equatorial Hour Plate Assembly

A stationary retaining ring provides all the necessary bearings and retention for the moving hour plate and its EoT sub-assemblies. This retaining ring carries the minute scale, which is a one hour arc divided into 2 minute intervals. It carries an important reference line on the side at the mid (30 minute) point. This line was used in conjunction with other marks on the retaining ring to calibrate and customise each HC after manufacture (Fig. 4). The ring is screwed to

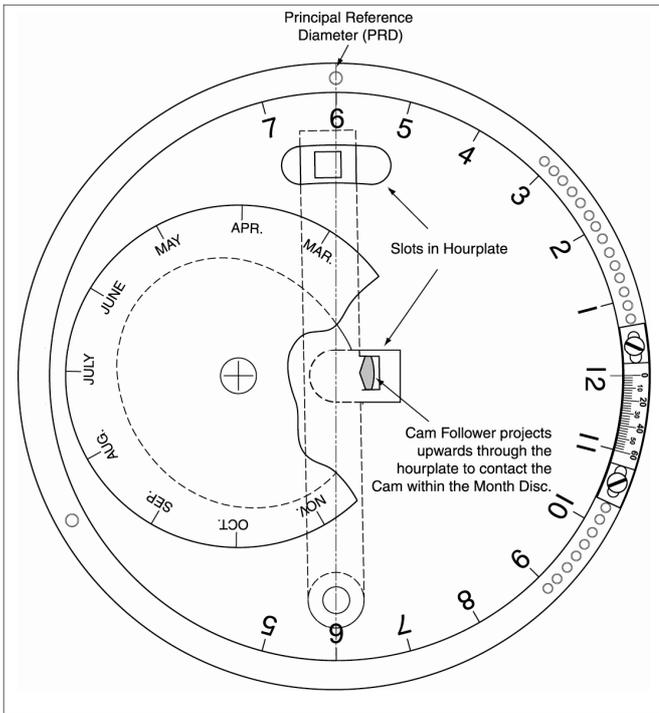


Fig. 5. Hour plate schematic cut-away showing EoT adjustment system and Principal Reference Diameter (PRD).

the hemisphere and thus the minute sector provides the initial stationary reference to the Instrument Centre Line and therefore the meridian. Nevertheless, the minute sector itself can be repositioned subsequently with respect to this specific datum to accommodate a customer's longitude on either side of a time zone meridian and/or to provide a Summer Time adjustment. On Mk.1 models the adjustment range was limited to only $\pm 15^\circ$ but the Mk.2 HC provides $\pm 37.5^\circ$.

The hour plate spans 14 hours marked by short lines at 15° intervals. When the hour plate is rotated these hour lines sweep past the minute sector in turn where they identify the number of minutes past the hour (Fig. 5). Although intuitively one would expect the noon label to be on the meridian at noon, on an HC it may be engraved at any angular position on the dial plate provided that the minute sector is positioned to suit. For engineering convenience and ease of use, Gibbs chose to put the minute sector at the due West position on northern hemisphere instruments. (On some early Mk.1 models, it was at the south position with the hour labels shifted appropriately.)

The Sight Screen System

The sight and screen are mounted at right angles to the equatorial hour plate so they will sweep out a polar cylinder when it is rotated (Fig.1). When the sight is presented to the sun, it casts its shadow onto the screen. It would be possible to judge the alignment of sun, sight and screen from this alone but this would be rather inaccurate. In fact one or both of two small holes in the sight will project images of

the sun onto the screen. This arrangement is a pin hole camera with optimum dimensions. The screens on most HCs are painted white to improve the contrast and assist the user to accurately find the centre of the shadow by rotating the hour plate until the image(s) lie on the centre line of the screen. This feature is fundamental to the inherent accuracy of the Helio-Chronometer.

In this initial discussion it is assumed that there is no EoT facility and that the sight and screen are permanently mounted to face each other precisely across a diameter on the hour plate, and therefore the sight holes and screen centre line also lie in the diameter plane. This diameter could be called the Principal Reference Diameter (PRD) and it connects 6am to 6pm on most HCs. So when the Principal Reference Diameter coincides with the Instrument Centre Line and the sun is on the meridian, the time indicated on the suitably positioned minute sector will be 12 noon (LAT). The two holes in the sight enable the HC to operate over the full declination cycle of the sun, so although the hour plate is simply equatorial, the instrument is an equinoctial sundial because the lower hole will pass an image during negative declinations. For ± 3 weeks around the equinoxes there will be two images because the sunbeams are nearly parallel to the equatorial plane. Both images should centre on the screen line simultaneously if the sight and screen have not been damaged. If the images are out of phase then errors will occur in either summer or winter readings depending on the date (and therefore the image used) at installation.

This simple model must now be developed. Assume that the sight is not screwed to the hour plate but it is fixed via a slot to an arm underneath the hour plate that is pivoted exactly underneath the screen centre (Fig. 5). The sight is free to move in a small arc, ($\pm 4^\circ$) relative to the Principal Reference Diameter (PRD). Assume that it is local noon and the sight arm has not been deflected from the PRD; the dial plate is then rotated until the image of the sun is centred on the screen, 12 noon LAT will be indicated by the hour label '12' pointing at 0 on the minute sector. Now without rotating or disturbing the hour plate, the sight is carefully pushed 'clockwise' (to the right) by an arc of 4° . This will cause the sun's image to move off the screen centre.

Relative to the polar sight, in the northern hemisphere the sun moves to the right (westwards) through 1° every 4 minutes. After 16 minutes the image will be re-established on the screen centre, the sun will have 'caught up' with the deflected sight and the time indicated will still be 12 noon. But the sun is no longer on the meridian, it has moved through 4° so the time is actually 12:16 LAT. So this is a sundial that has been temporarily biased to indicate a time that is 16 minutes slower than correct sundial time (LAT)

throughout the day. Therefore if it were located on the Greenwich Meridian on 3 November it would indicate Mean Time. (Assuming for this discussion that EoT on 3 November = 16 mins exactly.)

If the experiment was repeated with the sight carrying arm pushed anticlockwise by about 3.5° (14 minutes), the sun's image would be lost again but in this case it would not return to the screen until the next day at 11:46 LAT, 14 minutes prior to crossing the meridian. The relative positions of dial plate and minute sector have not changed so 12 noon is still indicated. So now this is a sundial that has been biased to indicate a time that is 14 minutes faster than correct sundial time throughout the day, exactly the right sundial to indicate mean time on the Greenwich Meridian around 11 February.

Clearly if a method could be devised to deliver the appropriate EoT angular offset to the sight carrying arm for each date of the year it would give rise to a mean time sundial.

The Equation of Time

Most diallists are familiar with the conventional Cartesian representation of EoT where the difference in minutes is plotted on the y-axis versus the date on the x-axis. It would be difficult to incorporate this representation into a mechanism. However, the relationship between two variables can also be expressed using polar coordinates. Imagine a circle of radius R with 365 equally spaced radii. Some consistent manipulation of EoT time values would allow a length that was a function of the EoT for the day to be calculated. For example, +16 minutes (Nov 3) could be arbitrarily represented by +16mm. If proportional EoT 'lengths' are added algebraically to the radius R for each day then the circle would be distorted approximately as in Fig. 6. This is a polar plot of EoT showing the original circle for reference and the dates at which EoT is zero at the four intersections. The reference circle is in fact the mean time circle. This is a much more useful version of EoT for incorporation into a mechanism.

If this profile was cut out of metal using the reference circle centre, it could be called an EoT cam. One revolution would present a whole year of EoT variation to any mechanical arm or lever that was pressed against the cam. If the arm happened to carry a sight as discussed earlier then the correct angular EoT offset for each day would be applied to the sight screen system.

The cam is fixed to the underside of a month plate on which 12 lines at appropriate intervals are labelled with month names (Fig. 5). These month lines point at a fixed day scale and thus define a specific date. At the mid point of the arm there is a knife edge, the cam follower, that engages

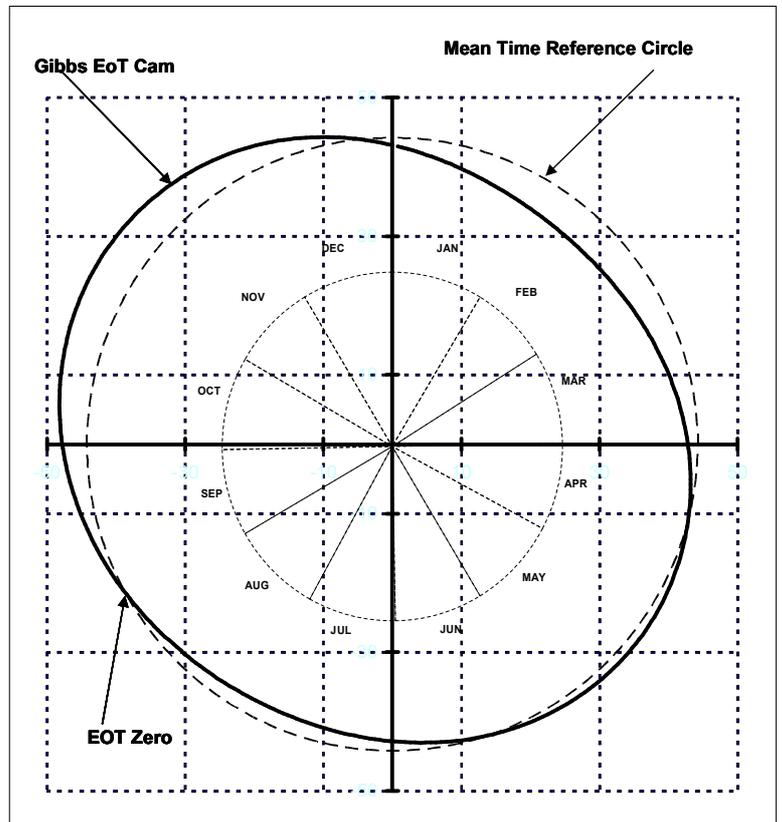


Fig. 6. The polar EoT plot to scale showing the relative relationships between the cam and the mean time circle with some date ambiguity at two EoT zero dates.

with the cam under spring pressure through a slot in the dial plate. The month and day scale must be exactly synchronised with the cam displacements during manufacture. The specific cam parameters are derived from the overall mechanism dimensions and EoT values.

EoT Zero Offset

In various studies it was noted that most HCs had lines and letters on the retaining ring beneath the minute sector centre line. A line would be expected to locate the centre of the minute sector at 97.5° clockwise from the ICL and perhaps another one to customise the instrument for the owner's longitude. However, measurements on more than 30 instruments revealed that the lines deliberately defined angles disposed on either side of 97.5° suggesting a more interesting purpose.

When any of the four EoT zero dates is selected it would be expected that the sight screen centre line (SSL) would coincide exactly with the Primary Reference Diameter (PRD) i.e. that SSL would lie on the major diameter giving zero sight deflection. Unfortunately this is not the case, the SSL at EoT zero generally lies at a small angle on one side or the other of the PRD and this offset angle must be accommodated when setting up the instrument. Each instrument had a specific EoT zero datum caused by the sum of the overall mechanical tolerances, in particular the length of the

cam follower knife edge. This may be illustrated by offsetting the familiar EoT graph from the $y = 0$ line by constant ± 3 or ± 4 minutes, the EoT relative relationships are still correct but the datum is not zero.

In production, the knife edge had to be manually filed to a target size but the desired result, getting SSL to coincide with PRD at each EoT zero, could only be assessed after the instrument had been assembled. If too much metal had been filed away from the knife edge then the zero position was lost forever and the arm would have to be scrapped. This must have been a worrying production problem for Gibbs until he realised that the sight screen line (SSL) does not ever have to lie on the primary diameter (PRD). Even at EoT zero SSL can lie on a chord (just as it does for all other none zero EoT settings) provided that in this case the minute sector is offset from the ideal datum of 97.5° to compensate.

This datum shift may be visualised as follows. In the 4° example discussed earlier, at 12:00 LAT when the arm was manually moved clockwise the image of the sun was lost. Instead of waiting 16 minutes for the sun to return to the screen the whole dial plate could have immediately been rotated anticlockwise to place the sight screen line, now a chord, parallel with the ICL (and therefore the meridian plane). This would re-establish the sun's image on the screen centre. The minute sector would then indicate 11:44 (GMT). This illustrates the normal operational EoT adjustment and, incidentally, that clockwise movement of the sight arm subtracts from the indicated LAT.

Now suppose, for some reason it was necessary to permanently negate this subtraction. This could be achieved by moving the minute sector anticlockwise to add back the 16 minutes. The EoT zero offset angle is negated using exactly the same process by repositioning the minute sector in the required direction to recover the current LAT. This explains why minute sector datum lines are not at 97.5° . Even at EoT zero, SSL lies on a *chord* that can be made parallel with the meridian. A full summary of component movements and consequences is given in Part 2 of this article. Typically, as Fig. 7 shows, the EoT zero offset angle on new instruments was generally larger than $\pm 1^\circ$ which, if it had not been accommodated, would have distorted the entire EoT adjustment by at least ± 4 minutes.

HCs generally carry calibration marks that defined the original EoT zero offset on the support ring and the hemisphere rim, although many have been lost due to corrosion and polishing (Fig. 4). On the Mk.2, the minute sector offset at zero EoT was labelled with 'o', meaning the instrument datum. The position for the customer's longitude, relative to 'o' and potentially on either side of it, was

labelled 'G'. Unfortunately there was a lack of consistency that may lead to confusion: the Mk.1 models have the EoT zero offset labelled with 'G' and often another unlabelled line for the customer's longitude (Fig. 7). It may be more than a coincidence that the only HC found that was 'perfect', one with a zero EoT zero offset, was SN 614, purchased by King Edward VII. A loyal demonstration by P&G that very cautious iterative filing of the knife edge was actually possible but probably not cost effective, particularly as it did not lead to the desired official royal endorsement of the Helio-Chronometer and payment was extracted with great difficulty.

Gibbs Serial No.	Datum Label	Original EoT Zero Offset (mins)	Original Longitude Label
148	G	+1.92	none
207	G	+0.64	line
383	o	+3.0	G
536	o	-3.0	G
581	o	-3.6	G
614	o	0.0	G
634	G	-5.6	line
720	o	+2.2	G
944	G	+2.12	none
527	line	-1.84	line
358	o	+4.30	G

Fig. 7. Examples of factory EoT zero offsets from several Helio-chronometers.

Location History

P&G HCs are mean time instruments configured for both latitude and longitude. So, unlike conventional sundials, they carry evidence of both co-ordinates. Adjustment is achieved by clamping various components in certain positions. Fortunately the original polished bronze surfaces were virtually protected from oxidation by clamping and therefore the differential corrosion pattern can reveal the history of previous locations in addition to the original factory longitude marks. Longitude may be calculated to within 15 minutes of arc or better, relative to the original 'o' mark. It is important to note that locations west of the Greenwich Meridian are defined by a minute sector position *anticlockwise* from the 'o' mark on the retaining ring. Figure 4 shows the calibration lines and labels on a Mk.2 HC that was located about 2.5° west of the Greenwich Meridian. Examination of the HC at the old Royal Naval College, Greenwich, located virtually at Longitude 0, showed that it had been set for $5^\circ 30'$ W for a very consider-

able time, so unfortunately it could never have helped the Nation's navigators with their studies.

Accuracy Considerations

The accuracy of the HC depends on the accuracy of the basic equatorial sundial in conjunction with the accuracy of the mean time adjustment device. The factors common to most sundials that greatly contribute to accuracy are orthogonal levelling, exact latitude adjustment and exact meridian setting. Use of engineering machine tools during manufacture and assembly ensured that mutual rectangularity of components was achieved to a high standard, thus transferring the basic latitude and meridian settings from the mount into the internal geometry of the instrument. The design lends itself to accurate installation by the use of latitude templates and the sighting system to find the meridian. Nevertheless, the precision of the any reading is limited by the physical size and division spacing of the small minute sector and the human ability to read it. These are constraints placed by the size and therefore the cost of the instrument. The 2 minute divisions are only 0.9mm between centres, with an interdivision gap of 0.6mm. With an hour pointer about 0.3 mm wide, a reasonable judgement about bisection can be made, but time readings better than one minute are rather speculative.

The Cam Follower

The accuracy of the mean time adjustment system is critically dependent on the original accuracy of the EoT cam profile and the subsequent EoT zero offset adjustment of the minute sector. The hour plate is about 8" (200mm) in diameter and this limits the sensing position and therefore the size of the cam. Consequently, the EoT mechanism is very sensitive to small profile errors and to wear. Calculations using measurements from several HCs indicate that 1mm of cam displacement will provide 2.84 minutes of time adjustment. This may be alternatively expressed as 17 seconds per 0.1 mm of cam lift or 0.35mm of profile error or wear will cost one minute. Figure 6 shows the EoT cam and illustrates the high sensitivity to small changes in cam lift as well as the date ambiguity around EoT zeros, particularly on 16 April and 14 June due to the small angle of convergence with the mean time circle.

Fortunately, the cam follower knife edge is more prone to wear than the cam edge itself because the knife edge is always rubbed under spring pressure when the cam is rotated. The rate is the same, 0.35mm of wear on the knife edge will alter the EoT zero offset by 1 minute. This means that as years pass the initial accuracy will be lost unless the minute sector is repositioned to accommodate the developing wear. The further consequence of knife edge wear is that the original 'o' and 'G' marks become incorrect and

should not be used to set up the instrument in modern times. A recalibration procedure will be described later.

The EoT Cam

The system is unlubricated and the extent of wear in both the cam and the knife edge depends very much on the amount of spurious and curious month plate rotation that has occurred during the last 100 years. Helio-Chronometers in public places suffer the most and in two extreme cases the residual knife edge had to be milled away and replaced with a new one (rather like crowning a tooth.). A modest estimate of month plate and dial plate rotation, partial or complete, is interesting. If there had been 4 movements on 4 days per week for 20 weeks per year for 90 years, (only 22% of the available days) there would have been over 29,000 movements. The contact area between knife edge and the cam is around 1mm² and there is high pressure in the last quarter of the year peaking around 3 November.

The cams are only about 2.5 mm thick and were cast in bronze from a pattern that defined the required profile approximately. Evidence suggests that the cam edge was hand finished by draw filing perhaps in a comparison jig with a hardened master cam. Most cams have a nick in the profile edge on 1-2 January that can be felt during rotation. This choice is not immediately obvious, but if a detent is located in the nick, the control arm will be stopped and the knife edge will be held on 25 December. This may have been used during initial calibration and suggests that 25 December is the master EoT zero. Some cams were very poor castings with depleted metal. Many of these were hammered to stretch the metal to try to recover the profile and were then used in production. For example, the cam in SN 750, the Royal Naval College HC, is extremely poor. It was extensively hammered around the whole profile even though it appears that this prestigious instrument was originally gold plated.

Uniform wear in the cam itself would not be a serious problem because the cam displacement ratios are maintained relative to EoT zero and any general shift in EoT zeros can be accommodated by recalibration. However, uniform cam wear is unlikely because the spring pressure varies throughout the year, high in November and low in February. But it is possible that this wear may be balanced against that caused by more frequent but incomplete rotation, which is more probable during the spring and summer months. A recent opportunity allowed two cams to be compared, one was thought to be unused, the other with average wear (Fig. 8). The displacements were measured to an accuracy of 1/100th mm at every degree of rotation. Relative to the unused one, the wear was reasonably uniform, around 0.24mm in November and 0.20 mm in February (41-34 seconds).

Fortunately, many cams have been protected from additional wear either because the spring broke (a common fault) or because, during the last 90 years, the rotating parts of HCs have become stiff and tended to seize up if not maintained or used. Figure 8 gives some results from a larger study of overall wear in cam systems and emphasises the requirement for recalibration after 100 years. The wear given is the sum of cam follower wear and average cam edge wear. SN 358 has worn by 6.5 minutes: an original ex-production 4.5 min. positive EoT zero offset has now become a 2 min. negative offset. This was recovered by adjustment as discussed earlier.

HC Serial No.	Initial State EoT Zero Offset		Current State EoT Zero Offset		Total Wear
	Mins: secs	mm	Mins: secs	mm	
383	3 : 00	1.06	1: 08	0.39	0.67
358	4 : 30	1.96	-2:00	-0.70	2.28

Fig. 8. Examples of drift of EoT zero due to wear in both cam follower and cam profile.

The Coincidence of EoT Zeros

Measurements on used HCs show the EoT zero offset angle is not the same at the four EoT zero dates, with differences of around one minute. In the recent comparison, the unused cam had three coincident zeros which was an important result but 14 June was positive by 73 seconds suggesting a factory deficiency. The used cam had no coincident zeros, with a spread of +24 to -56 seconds relative to 25 December and 14 June was again the most positive. The variation in EoT zero displacement is due to initial imprecision of the cam exacerbated by unequal wear. Figure 6 shows how sensitive the zeros are to the date due to the low eccentricity ratio of the cam. It is therefore suggested that 25 December is chosen for the EoT zero date for re-calibration because this gives the steepest angle of convergence of EoT with the Mean Time circle. The lack of EoT coincidence does not necessarily mean that the whole cam is wrong. Certainly, use of over 13 HCs, some for many months, suggests that mean time within ± 1 minute can be indicated by old HCs that have been recalibrated and carefully set up.

Summary remarks

Any inaccuracy in the mean time system due to cam follower wear or uniform cam edge wear can be eliminated by adjustment of the minute sector to a new datum. Any original deficiencies in the cam profile, EoT zeros or any non uniform cam wear will reduce the mean time accuracy at the affected dates and it cannot be easily neutralised. Helio-Chronometers will vary in achievable accuracy according to the random chances of history that affected their

location, use and wear. In the author's experience the adverse factors could combine to cause an error of around ± 90 sec on certain dates in an HC with average wear. However, it is frequently better than ± 1 minute. But the most significant and controllable factor is the accuracy of the Local Apparent Time reading that is provided by the basic equinoctial sundial. This is crucially determined by level, latitude and meridian setting, all of which must be established with great care during installation. This will be discussed in Part 2.

NOTE

1. The name 'Helio-Chronometer' was the registered trade name of the specific instrument discussed in this article. This word is used because most statements would not apply to generic heliochronometers that vary widely in implementation.

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TAILPIECE



This fine Heath & Wing dial in the Tiltyard Garden at Hampton Court Palace featured on the cover of the June 2005 Bulletin. Members who saw it on the Holloway Conference excursion will know that it was badly affected by droppings from the overhanging branches of the tree. Shortly after our visit, contractors were called in to lop off the branch causing the worst damage. Unfortunately, they managed to drop it onto the dial, breaking off a piece of the pedestal! This is now awaiting restoration.

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