BSS Bulletin 17(iv)

The British Sundial Society

BULLETIN

VOLUME 17(iv) DECEMBER 2005

December 2005

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

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Front cover: One of 11 similar pairs of vertical dials high up on Heriot's Hospital in Edinburgh made by William Aytonne. These occur around the outside walls of the building and in the central courtyard. SRN 2070. Photo: Mike Cowham

Back cover: St Peter, Dunchurch, Warwickshire. The dial is very high up so it is likely that this 'Saxon' dial has been relocated. This is possibly the best picture of it that has been taken. Photo: Mike Cowham

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BULLETIN

OF THE BRITISH SUNDIAL SOCIETY

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VOLUME 17(iv) - DECEMBER 2005

CONTENTS

EDITORIAL

There are some pleasing sundial pictures in this issue. Readers, go on designing and depicting other people's designs! We are hoping to print the Bulletin with four colour pages per issue from now on, finances permitting. Most sundial pictures are all the better for being in colour.

There is a move by the International Telecommunications Union (ITU) to abolish the leap-second. This is the extra second inserted on 31st January some years, to compensate for the fact that the speed of the earth's spin-speed is gradually slowing down, lengthening slightly the duration of days and nights. The ITU says that leap-seconds make a muddle for IT time-scales; other time watchers say that everyone else in the world is able to write programmes sufficiently robust to cope with the occasional leap-second.

The proposal would allow clock-time to become gradually different from sun-time until the times differed by (say) half-an-hour, and then to make the re-alignment in one go. A decision on the matter is to be (or has been) made at the ITU conference in November 2005. Read the ITU's ideas at *www.ucolick.org/~sla/leapsecs/gambis.htm.*

What is the difference between a Sundial *Trail* and a Sundial *Garden*? Both of them bring interest and delight to sundial-enthusiasts. In the Garden, a number of dials of various kinds are close together, perhaps within sight of each other; this makes it easy to compare types and to decide for oneself which sort is the easiest to read and understand. The trail has the charm of surprise - wondering what is round the next corner.

The editor would be interested to know what factor/event/person/sight first aroused *your* interest in sundials. Write and explain, in a short paragraph. *Why* Sundials?

ERRATUM

In the report of the BSS Awards Scheme in the previous (September) Bulletin, the caption to Fig. 5 on page 111 erroneously located Steve Daggitt's design to Kidderminster School, rather than West Kidlington School. Our apologies - it seems that no matter how many people proofread each issue, something always slips through.

A POLYHEDRAL SUN-DIAL AT RIVINGTON, LANCASHIRE

PETER SCOTT

INTRODUCTION

The sun-dial described herein is a polyhedral dial of modern design which is located in the garden of my home at Rivington in Lancashire (Lat. 53° 36' N, 2° 33' W). It is shown in Figure 1.

Fig. 1. The completed Rivington sundial.

The Sun-dial was designed and constructed by myself and completed in December of 2004 after a year of preliminary design work and 12 months of actual construction. The design is based loosely on a sun-dial in Wakefield, Yorkshire and also one in Marsden Park, Nelson, Lancashire. The sun-dial is made from reconstituted stone and stands some six feet tall. The main distinguishing feature of the sun-dial is the unique head which is formed in the shape of an icosahedron (one of the five Platonic Solids). Upon each face of the icosahedron is mounted a triangular dial plate and a brass gnomon. All dial faces have been delineated to show Greenwich Mean Time (subject to EOT correction) and as such are corrected for the longitude difference from the standard Greenwich Meridian.

The sun-dial is located at the bottom of a landscaped private garden in such a position as to receive the light of the sun during the major part of the day.

My interest in sun-dials, particularly polyhedral dials, goes back more than 30 years and during that time I have designed and constructed numerous cardboard and MDF models of dodecahedrons, icosahedrons and rhombicuboctahedrons. I decided a couple of years ago that I should stop ‘messing about’ with models and make a ‘proper’ polyhedral dial of my own. By ‘proper’ I mean a dial that could actually go outside in the rain! The BSS sundial competition further encouraged me to produce something of merit. [The dial was Highly Commended in the Amateur category by the judges of the BSS 2005 Awards Scheme – see *BSS Bulletin* <u>17</u>(iii) – Ed.]

Polyhedral dials are without doubt the most difficult types of sun-dial that one can make. Peter Drinkwater, in his book *The Art of Sundial Construction* described these dial

Fig. 2. The Walton Hall dial

types as "a problem to the diallist which is entirely of his own making". Nevertheless, I decided to start work on this project in January of 2003. This article describes in detail the design and construction phases of the dial and the many problems that were encountered along the way.

THE 'PROTOTYPE' DIALS

My sun-dial is mostly based on a remarkable dial (shown in Fig. 2) that stands in the grounds of Walton Hall, Wakefield, the former home of Charles Waterton the famous Victorian conservationist. Waterton travelled extensively in South America and was one of the first people in the world to set up a nature reserve at his home. The dial was constructed in 1813 and was described in detail by his friend, Dr R. Hobson, in his book *Charles Waterton, his home, habits and handiwork*, first published in 1866:

> "On the southern side of the mansion on a slightly elevated mound, stands a most complete and very beautiful sun-dial, deserving of careful observation, inasmuch as it deflects great credit on the sculptor, the late George Boulby, who was a common mason at the contiguous and rural village of Crofton, in 1813. This dial is composed of twenty equilateral triangles, which are disposed as to form a similar number of individual dials, ten of which, whenever the sun shines out, and whatever may be its altitude in the heavens, are always in use, and ever faithful time keepers. On these separate dials are engraven, severally, the names of cities in all parts of the globe, which are placed in accordance with their different degrees of longitude, by which arrangement, the solar time, at each of the cities recorded on the different dials, can be simultaneously ascertained."

I first came across the Walton Hall dial in the 1980s when I was travelling around the country photographing sun dials. I became fascinated by this particular dial and also by another dial at Marsden Park in Nelson which is similar in design. The Walton Hall dial was constructed by the village stonemason and the story goes that Charles Waterton spotted it one day, in the mason's yard, when returning from a hunting trip. It is recorded that he paid the stonemason twenty guineas for it, a tidy sum that in modern money equates to about a year's wages. George Boulby must have been well pleased with this substantial windfall although Dr. Hobson writes: "the ingenuous and unaffected mason was infinitely more delighted to have the honour of his own artistic skill exhibited at Walton Hall, under the patronage of the Squire, than with the douceur which the sculptor erroneously considered far beyond its value." I can't believe that for one minute, can you?

The Marsden Park dial (shown in Figs. 3 & 4) dates from around the same period and was set up in the gardens of a mansion in Nelson, Lancashire. The mansion is now owned by the local council and the grounds are a public park.

Fig. 3. The Marsden Park, Nelson, dial.

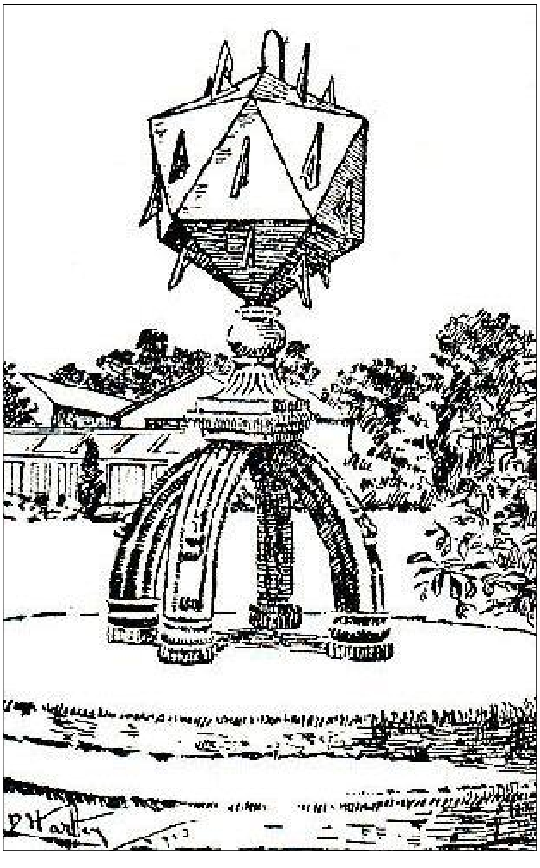


Fig. 4. Marsden Park, Nelson, dial as drawn by D. Hartley in 1913.

My intention was to create a modern sun-dial based loosely on the design of these two remarkable dials.

THE MAKING OF THE POLYHEDRAL SUN-DIAL

When I first started this project in January 2003, my plan was to recreate the Walton Hall Dial in every detail. However, after visiting the original dial and taking exact measurements, I discovered that it stands over seven feet tall and weighs (approximately) two tons. Although magnificent in its setting at Walton Hall, this was much too big for the average sized garden, particularly mine. It was clear therefore that I had to scale down the sun-dial somewhat. After a great deal of deliberation I eventually came up with a much smaller design using an 'off the shelf' plinth in reconstituted stone. Using a commercially available plinth allowed me to concentrate my design efforts on the sun-dial head and socle (the base on which the head stands). It also saved me a great deal of money in manufacturing costs.

Rather than engrave the dial faces directly into the stone faces (which is not possible anyway with reconstituted stone) I decided to have them engraved onto separate dial plates in the way that the majority of modern horizontal dials are produced. These would then be firmly fixed to the dial head with special adhesive.

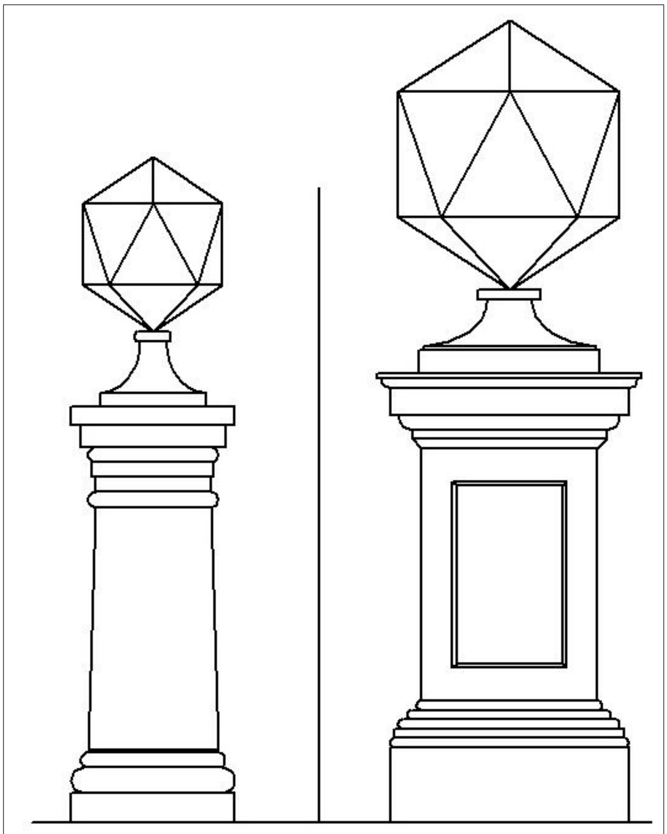


Fig. 5. General layout and size comparison of my dial (left) and the Walton Hall dial (right).

The overall design for the dial was sketched out on the PC (to scale – see Fig. 5) using DeltaCad software. This useful piece of software proved to be invaluable in determining the optimal size of the sun-dial head and socle in relation to the plinth, and also in making sure that the proportions of the finished dial would look just right. I wanted the sun-dial to be impressive and pleasing to the eye so the proportions of the dial were very important. After a lot of trial and error it was determined that the size of the icosahedron head should be 10" (measured along the edges of the triangular faces), with a 12" square socle base. This would give a sun-dial standing some six feet in height. The dial plates were to be 8" along the triangular edges leaving a small border to the edge of the stone polygon.

With the dimensions of the dial decided it was time to think about designing the sundials for each face. If you look closely at an icosahedron you will notice that the twenty faces point in all directions. None of the faces are upright (vertical) and very few of them point in the same direction. Also, when orientating the icosahderon, it can be stood upright on any of its faces or its corners. The traditional method of fixing an icosahedron to its base (based on existing dials) is to stand it upright on one of its corners and then turn it so that as many faces as possible are facing towards the meridian. If this is done it will be noticed that, no matter which way you turn it, only two of the faces will ever face towards the meridian (i.e. no declination) and neither of these will stand vertically. All of the other faces of the polygon will then decline from the meridian at various angles and recline, or incline, from the horizontal as well. Many of the dials are also north facing.

To place dials upon each of these faces the diallist needs to construct many complicated dial types including: South reclining dials, South inclining dials, South declining recliners, South declining incliners, North recliners, North incliners, North declining recliners, and North declining incliners. In fact, every type of declining/reclining, or declining/inclining dial that it is possible to construct. I could see that my job was going to be a difficult one.

I have a comprehensive library of dialling books but unfortunately none of them gave me much help with this project. Peter Drinkwater's book *The Art of Sundial Construction* gave me some pointers, but not enough to solve the whole problem at a stroke. In addition, none of the books that I owned, or had access to, gave me any idea what the angles of each face of an icosahedron made in relation to the meridian, or the inclination/reclination of each face to the horizontal. My first problem therefore was to determine these angles empirically and this had to be done before any dial calculations could be carried out.

To facilitate this, an accurate half size model of the icosahedron was constructed from MDF and mounted upon a firm base in the correct orientation. Great care was taken to ensure that the shape was symmetrical in every respect and that all faces were accurately constructed. Then, using a sliding bevel and a protractor, I measured the angles of each face in relation to the meridian and to the horizontal plane. This sounds reasonably easy but it actually took me quite a long time and required a great deal of care. I'm pretty sure that there must be a more scientific method of obtaining these angles but in the absence of a better way forward I carried on regardless. Once I had established the angles for each face of the icosahedron I entered them into a master table (Table 1).

Face No.	Declination	ALPHA	Inclination/ Reclination	BETA
South				
S01	Direct	0°	Inc 10°	100°
S02	36° W	36° W	Rec 10°	80°
S03	36° E	36° E	Rec 10°	80°
S04	36° W	36° W	Rec 52°	38°
S05	36° E	36° E	Rec 52°	38°
S06	Direct	0°	Inc 52°	142°
S07	72° W	72° W	Inc 52°	142°
S08	72° E	72° E	Inc 52°	142°
S09	72° W	72° W	Inc 10°	100°
S10	72° E	72° E	Inc 10°	100°
North				
N01	Direct	180°	Rec 10°	80°
N02	Direct	180°	Rec 52°	38°
N03	72° W	108° W	Rec 52°	38°
N04	72° E	108° E	Rec 52°	38°
N05	36° W	144° W	Inc 10°	100°
N06	36° E	144° E	Inc 10°	100°
N07	72° W	108° W	Rec 10°	80°
N08	72° E	108° E	Rec 10°	80°
N09	36° W	144° W	Inc 52°	142°
N10	36° E	144° E	Inc 52°	142°

Table 1. The angles of the 20 dial faces, as measured from the half-sized model.

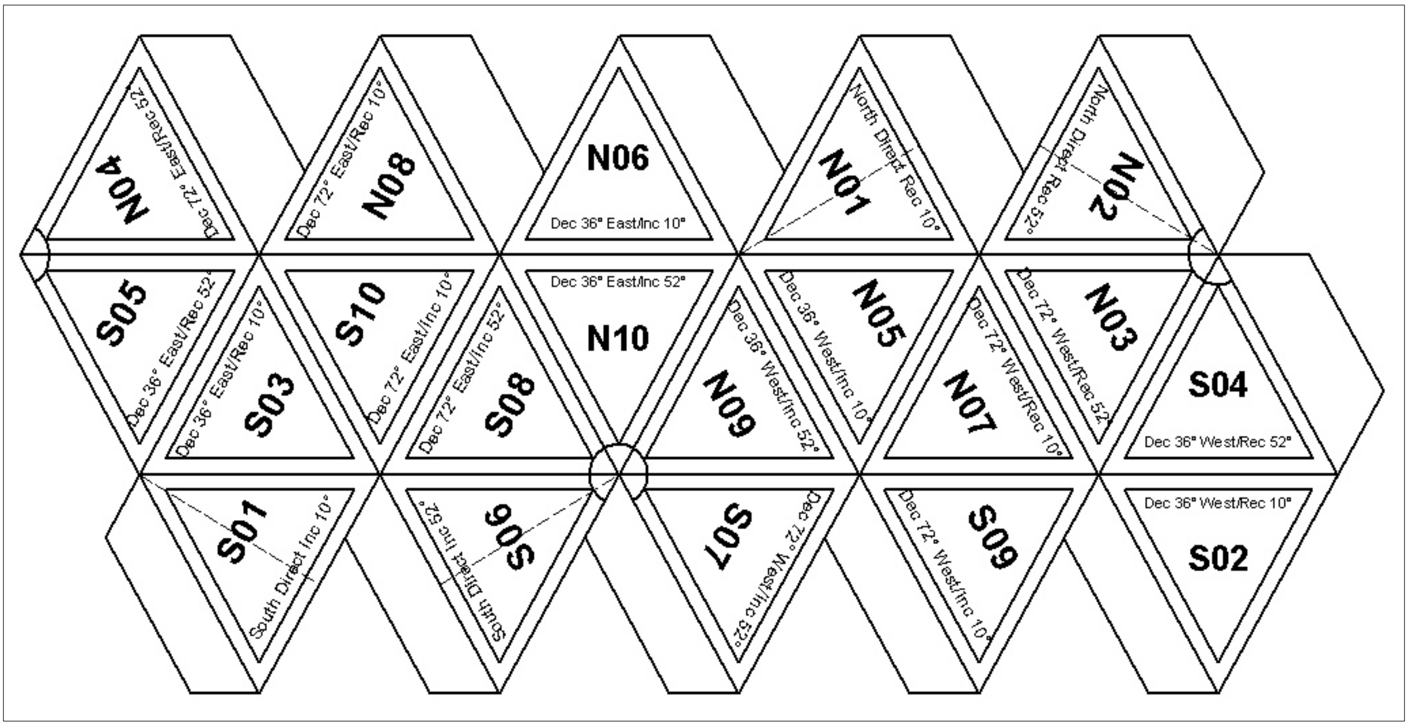
Now that I had the declination/reclination/inclination values for every face of the icosahedron I could start to design the actual dials. To help me to identify the various faces of the icosahedron during the construction process I produced a cardboard model and numbered each of the faces so that I could identify them easily. Each face was marked with a reference number, its North, South, East, West orientation, its declination from the meridian and whether it reclined or declined from the horizontal (see Fig. 6).

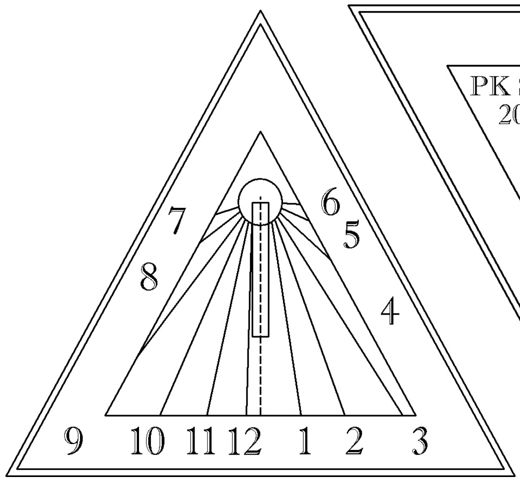
Calculating the hour angles

The hour angle values, substyle distances and style heights, for each of the twenty dials were calculated using a bit of software that I developed myself. I wrote a dedicated computer program in Visual Basic that calculated all of the values for all of the dials in one go. This saved me a tremendous amount of time. The formulas used in my program were based on Peter Drinkwater's geometrical methods from his book *The Art of Sundial Construction*. However, to make sure that I had done the job correctly, my calculations were then double checked using a commercially available dial drawing program (Shadows).

Once I had calculated the hour angles for each numbered dial I then drew each of the dial faces on the computer us-

Fig. 6 (below). The 20 faces of the icosahedron laid on as a flat sheet.





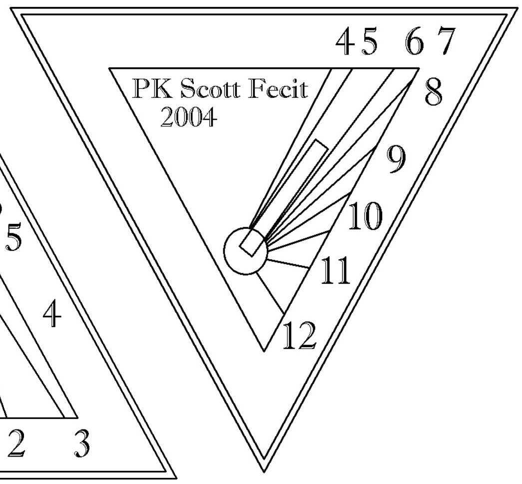


Fig. 7 (left). The design for the inclining direct south face S01 and

Fig. 8 (right). The design for the proclining north face N08.

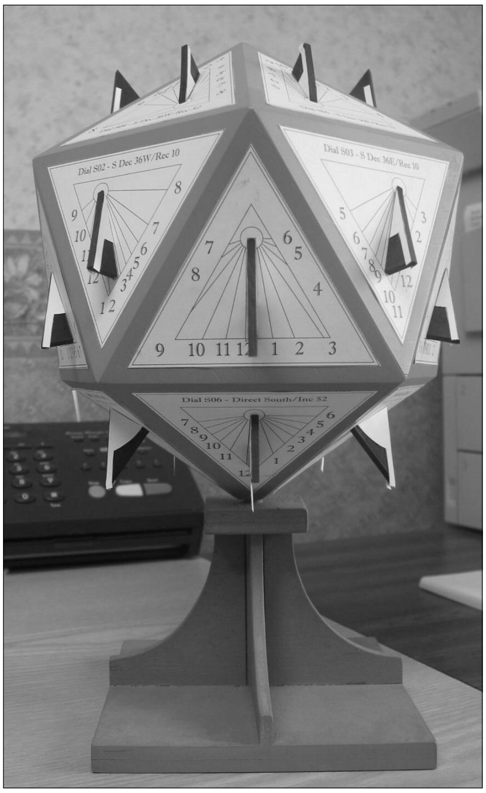


Fig. 9 (right). The half-size model.

ing DeltaCad. The individual face designs were based on research that I had carried out into polyhedral dials of the period. With there being so many dials it was important to keep the design simple and yet easy to read. The physical dimensions of the dials, font styles, line spacings and the various orientations required, were worked out as I went along.

The physical placing of the sub-style lines and the dial centres on each dial face were a particular problem as each face is orientated differently and the dials receive the sun at different times of the day and for different periods of time. See Figures 7 and 8 for sample designs. The trick was to place the dial centre (and thus the gnomon and substyle line) in such a position that hours of sunshine available on each dial face was maximised. Photographs of the actual dials at Walton Hall and Marsden Park were invaluable in this respect. Remember that there were no dialling books to refer to, all of this had to be worked out as I went along.

The laying out of the north facing dials proved to be a problem as the hour numbering sequences on these dials are reversed and difficult to get right. Also, marking the hour lines to allow for the thickness of the gnomon presented a few problems, particularly on the uppermost north facing dial and the lowest south facing dial. The reclinations/ inclinations of these two dials meant that they ended up almost as equinoctial dials consequently the gnomon width and lines were difficult to lay out properly. However, these minor difficulties were soon overcome (after much trial and error) and the dials were eventually completed.

After having gone through this complicated process I must say that I was left full of admiration for the dial makers of old who, without the advantage of modern computers, calculated all of these values by hand. Truly unbelievable.

Once I was happy with the design of the dials I printed them all out onto white cardboard and attached them to the half size MDF model (shown in Fig. 9), taking great care to make sure that they were fixed to the correct face and orientated correctly. Gnomons were then cut from 1/8" thick wooden sheet and glued to the dial faces on the substyle lines. Many of the gnomons were similar in size and height so I had to be very careful not to get them mixed up.

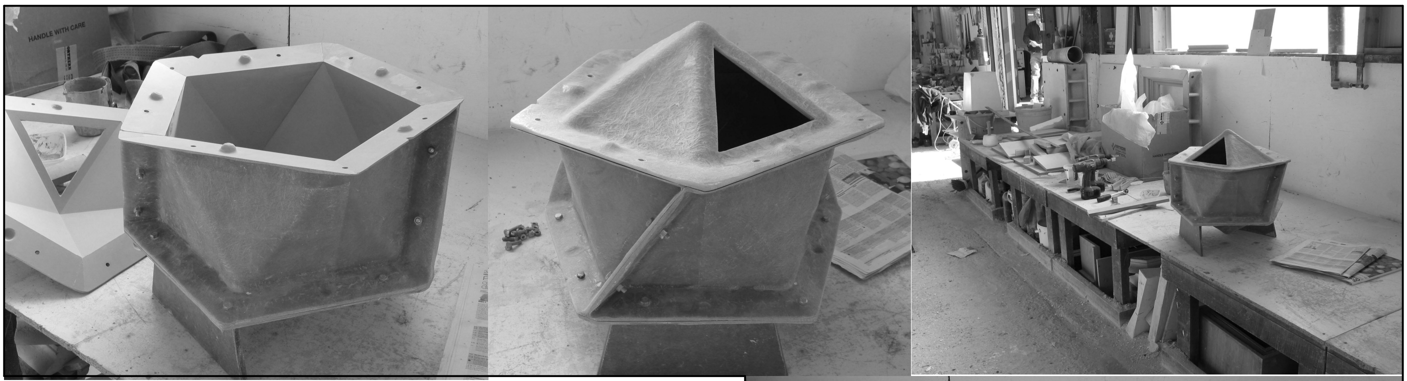
Imagine my delight when I placed the half size model out in the sunshine and saw for the first time the fruits of my labour. All of the gnomons pointing in the same direction (an achievement in itself) and the same time displayed on all of the dials (that were in sunlight). Amazing!

CONSTRUCTION

It had taken me 12 months to reach this stage but now that I had formulated a design and produced a working model I could start on the construction phase. The next job was to produce the sun-dial head and the socle for real.

January 2004

When I had first made enquiries into the cost of having a sun-dial of this size manufactured from solid stone it had become apparent this would be too expensive. I had a number of quotes from stonemasons but due to the complexity of the shape they were all too expensive. A couple of stonemasons even said they could not make the icosahedron shape as it was too complicated. Consequently, I decided to construct my dial from reconstituted stone, using an ‘off the shelf’ plinth from a reputable manufacturer. I was fortunate to come across a long established company (Imperial



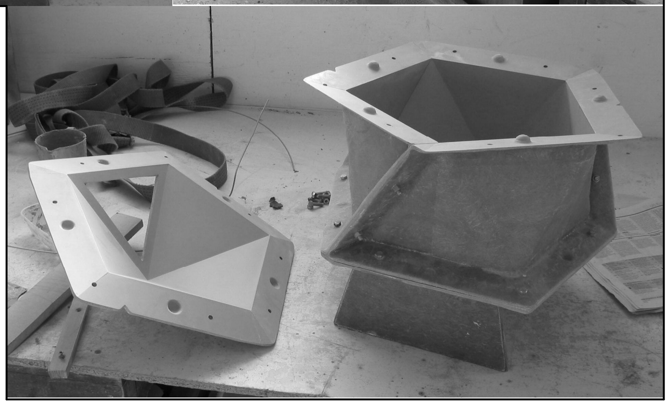


Fig. 10. Four views of the mould used to produce the icosahedron.

Stone) who promised me that they could produce the icosahedron and the socle and who also had a suitable plinth in stock for the dial base. I sent them my drawings and they prepared estimates for producing the required items.

May 2004

A mould (Fig. 10) was fabricated from full sized patterns which I produced in 6mm MDF. However, the socle proved very difficult to make in MDF (due to the curved shapes of the base) so Imperial Stone carved one from solid stone and then took a mould from that.

Imperial Stone are experienced manufacturers of stone ornaments and architectural mouldings but the icosahedron shape provided them with a real challenge. The mould had to be designed so that it could open in order to allow the finished casting to be removed. You will see from the photographs that the mould splits into three parts to accommodate this requirement.

Summer 2004

The moulds for the icosahedron head and socle were quickly produced and castings were then taken. The next problem that we encountered was fixing the sun-dial head to its socle. You will see from the original design drawings that the sun-dial requires the icosahedron to be fixed standing upright on one of its corners. Almost defying gravity! To achieve this the plan was to fix a stainless steel pin through the socle and into the base of the icosahedron thus giving it the necessary strength to stand up on its own. However, in practice this proved to be a difficult thing to achieve. Imperial Stone tried a number of methods, firstly by moulding the steel pin into the icosahedron, and then by drilling holes in the finished items. It was eventually found that the most accurate way to do this was to cast the socle and the sun-dial head first and then drill and fix a steel pin afterwards. A jig was constructed to make sure that the head was aligned properly with the socle and in the correct orientation.

With this problem solved the stone dial components were delivered to me in the late summer of 2004 and assembled in my garden. With the help of my son and my next door neighbour we man-handled all of the separate parts of the sun-dial down to the bottom of the garden. I had prepared a

Fig. 11. Four views of the reconstituted icosahedron, on its socle and pedestal, prior to fitting the dial faces.

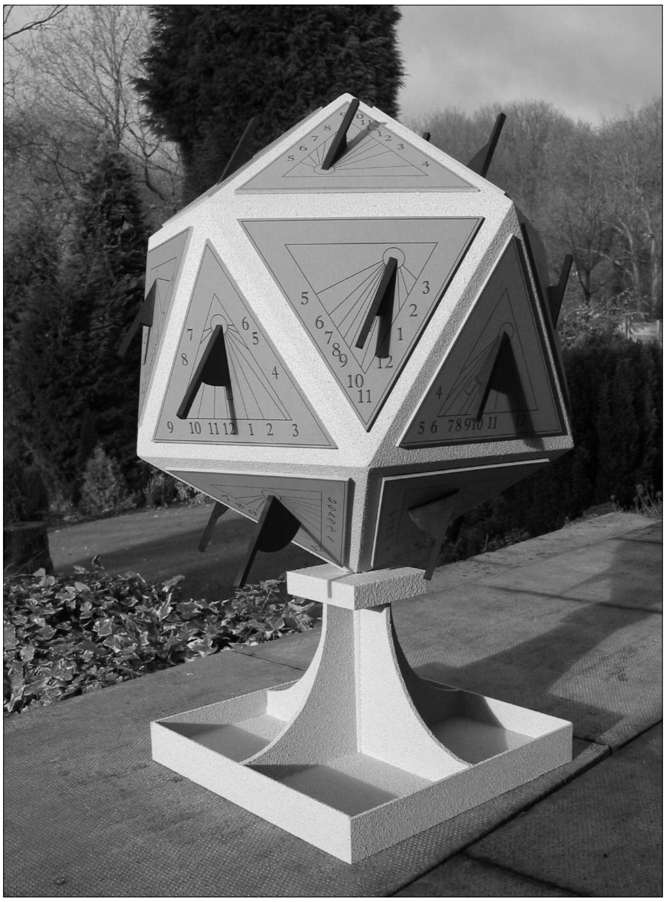


Fig. 12. The full-sized model.

concrete base for it some weeks previously. The icosahedron head was much heavier than we had expected but the three of us lifted it into position (with some grunts and groans) and we all stood back to admire the fruits of our labour, seen in Fig. 11.

All that remained to do now was to have the twenty dial plates engraved and the styles cut out in 6mm brass.

September 2004

It had taken me almost two years to reach this stage but I was now entering the final stage of the project. However, before proceeding I decided to look again at my calculations. A full size model of the dial was therefore constructed to 'double check' the calculations and to make sure that everything was OK before moving on to the (expensive) engraving stage. The half sized dial had served its purpose in the initial stages of the design process but I felt that a full sized version would be better for final testing. The full size model (Fig. 12) was made accurately out of 6mm MDF with 1/8" hardboard board dial faces and 1/4" MDF gnomons in black.

November 2004

Unfortunately the project stalled at this stage due to business commitments and a family holiday, consequently the part finished sun-dial stood alone in the garden for many weeks (taking admiring glances from neighbours) but with no work being carried out on it at all.

The deadline for the BSS Sundial Competition was fast approaching but I figured that I still had plenty of time to finish the dial. However, I had a nasty shock in the middle of November when, by chance, I read through the rules for the competition and discovered, to my horror, that the cut-off date was 11 December and not 31 December as I had thought! Panic set in as I realised that I had to complete the dial very quickly and I only had a few weeks left to do it in.

The last minute dash

Conscious of the 'need for speed', I made finishing the dial a real priority. I contacted a computer engraving company and a waterjet cutting company and got both jobs underway pronto. The dial plates were engraved on 'state of the art' computerised engraving equipment from CAD DXF files taken straight from DeltaCad. My initial design had called for the dial plates to be made from 1/8" engraved brass but due to cost restraints the dial faces were eventually made from brass-effect acrylic material. Although not authentic, this material is very easy to work with and allowed me to replicate the overall effect of brass for much less cost. The acrylic material (known as *Traffolyte*) is made up of a sandwich of brass material on the surface with black acrylic material underneath. When the engraving cutter cuts down through the surface of the plate the black material shows through and there is no need for filling of the engraved lines. This type of material is used by sign manufacturers and is actually quite hard wearing and very suitable for exterior use. It also has the added advantage that it does not discolour with time meaning that the sun-dial faces will always be clearly legible. Although for our purposes this is a second-best option, I can't help thinking that the sundial makers of old would have used this material in preference to brass had it been available to them. Some of the dial-plates, together with the gnomons, can be seen in Fig. 13.

With very few days to go to the deadline, the gnomons were profile cut by waterjet from 6mm thick brass and then fixed to the dial plates from the back with brass machine screws. I provided computer DXF files to the supplier (Control Waterjet Cutting) and they produced the gnomons within seven days of receipt of the order.

One of the slight problems with waterjet cut items is that they taper slightly. A small amount of manual finishing and polishing was therefore necessary to ensure that all of the brass gnomons were accurate and square with the dial plate. A jig was constructed to drill the gnomons so that the fixing holes aligned perfectly with the locating holes in the dial plates.

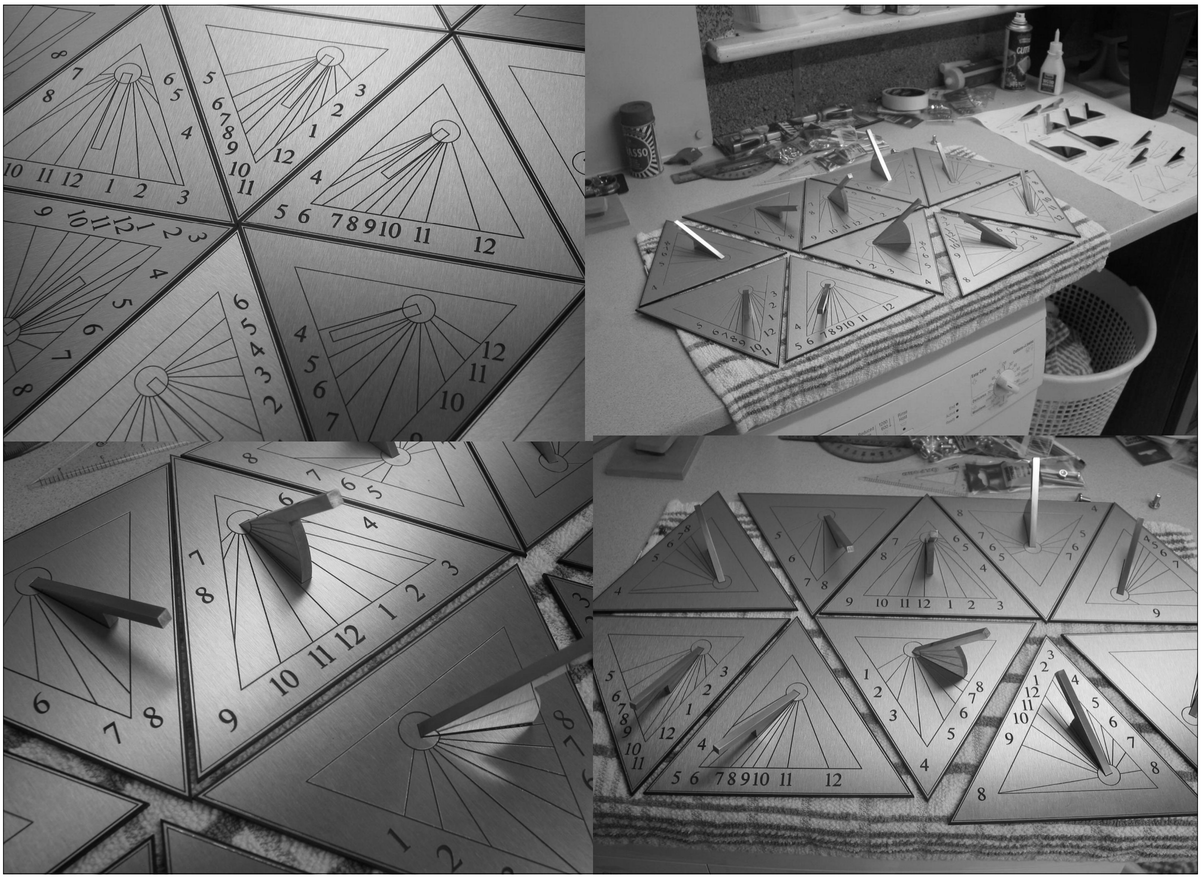


Fig. 13. Four views of some of the dialplates being assembled before fitting to the icosahedron.

The engraved dial plates complete with waterjet cut gnomons were then fixed to the stone faces of the dial with specialist adhesive which bonds them to the surface without any need for metal fixings or screws. The adhesive is a modern compound which forms a joint that is stronger than the stone itself. The adhesive is specially formulated for this purpose and can withstand extremes of temperature from –30°C to 100°C, with short term loads of 130°C possible. The adhesive is also resistant to ageing, corrosion and rotting.

The sun-dial head was then finally checked for due south orientation and the dial was finished. The photograph of Fig. 1 was taken on the day that the sun-dial was assembled and I think that you will agree that the overall effect of the finished sun-dial is quite striking.

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THE EQUATION OF TIME:
THE INVENTION OF THE ANALEMMA
A BRIEF HISTORY OF THE SUBJECT (Part II)

CHRISTOPHER St J.H. DANIEL

SUMMARY
In about the year 1730, the French astronomer Jean-Paul Grandjean de Fouchy invented the 'figure-of-eight' *analemma*, delineated on a meridian line, whereby a meridian sundial could directly indicate local *mean-time*. French gnomonical literature has always credited Grandjean de Fouchy with this invention and there can be no doubt that the many French mean-time sundials, as well as a number of other continental mean-time dials, owe their origin to him. However, there is evidence that suggests that the *analemma* was actually constructed some fifteen years earlier in Germany by Johann Philipp von Wurzelbau.

Referate der 34. Jahrestagung des AK Sonnenuhren 2005 - Sonnenuhren in Bonn und Umgebung

Die Zeitgleichung – die Erfindung des *Analemma*

Etwa im Jahr 1730 erfand der französische Astrom Jean-Paul Grandjean de Fouchy das "Achter-Schleifen" *Analemma*, dargestellt auf einer Meridian-Linie, womit eine Meridian-Sonnenuhr direct den Örtlichen Mittag anzeigen konnte. Die französische gnomonische Literatur schrieb diese Erfindung stets Grandjean de Fouchy zu, und es kann kein Zweifel daran bestehen, dass die zahlreichen französischen Mittagsuhren, wie auch eine Reihe anderer Mittagsuhren auf dem Kontinent ihm ihren Ursprung verdanken. Jedoch gibt es Hinweise, die darauf hindeuten, dass das Analemma tatsächlich schon etwa fünfzehn Jahre zuvor von dem Deutschen Johann Philipp von Wurzelbau konstruiert wurde.

THE EQUINOCTIAL MEAN-TIME SUNDIAL

The application of the analemma to the *equinoctial* sundial, specifically the 'universal' equinoctial *mean-time* sundial, takes a different form to that whereby it is applied to the 'universal' *mechanical* equinoctial mean-time sundial or heliochronometer; but it is no less significant. Indeed, as I shall endeavour to show, it is a fundamental factor in the history of the equation of time and the invention of the analemma.

In Great Britain, as with its earliest appearance in a printed English dialling work, of which I know, namely that of Mrs Gatty, published in 1889, it would also seem to have made its appearance in the very late 19th century. This came in the form of the invention, by Major-General John Ryder Oliver (1834-1909), of a 'universal' equinoctial dial, patented in 1892, which employed a solid *analemmic* style or gnomon, to compensate for the equation of time, in order to indicate local mean-time directly. (See Figure 17.) The sundial might be described as a semi-armillary dial, comprising a semi-circular meridian 'ring', supporting the gnomon, and a semi-circular equinoctial hour-'ring', which could be adjusted to correct for the longitude. When set for the latitude of the place of observation and aligned in the meridian, the gnomon would lie in the plane of the meridian, in alignment with the earth's polar axis. Thus, the shadow of the solid analemmic style, or rather the appropriate part of it, cast on the semi-circular hour-scale, would indicate standard mean-time, or *nearly* so. Since the solid body of the shaped analemmic style necessarily represents the *mean value* of the equation of time, rather than the true value, by virtue of its uniform construction, the time indi-

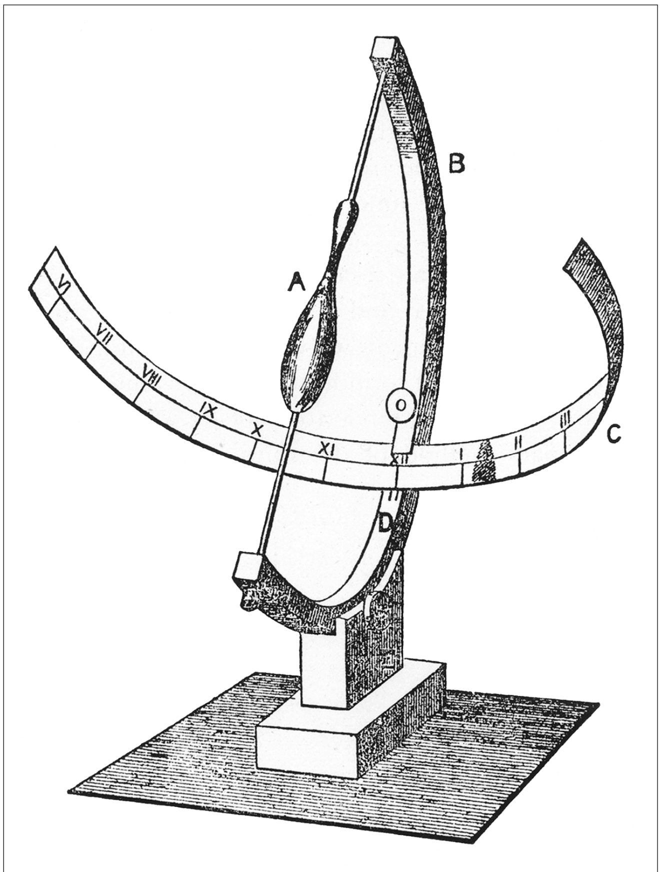


Fig. 17. Major-General Oliver's mean-time sundial, patented in 1892.

cated would not be consistently accurate; but, nevertheless, it would still provide a fairly reliable determination of the time for the everyday regulation of household clocks and watches.[48,49] John Oliver subsequently invented an 'improved' version of his equinoctial mean-time dial by the use of a cut-out analemmic aperture in a flat rectangular style-plate, in place of the solid analemmic body, (Figure 18) which achieved greater accuracy.[50,51] However, from an aesthetic point of view, the original instrument was a rather more elegant design.

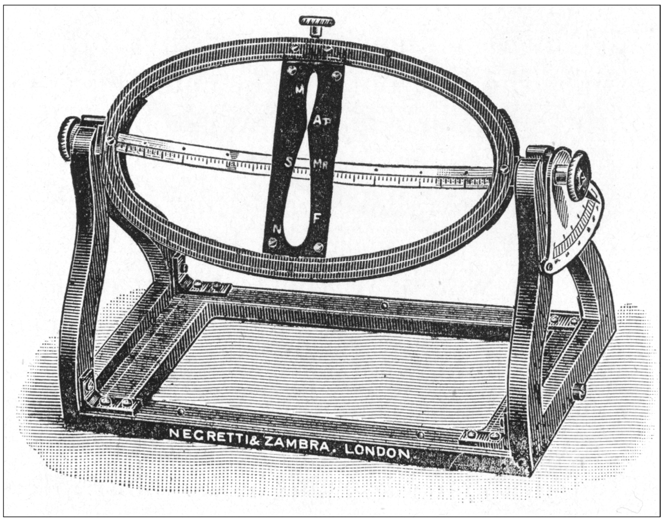


Fig. 18. Oliver's 'improved' model of his mean-time sundial, constructed by Negretti & Zambra.

William Pilkington, most likely the senior partner in the firm of Messrs Pilkington & Gibbs of Preston, also devised an equinoctial mean-time sundial, which made use of an alidade in the form of a box-like structure, which, when directed towards the sun, allowed a slit of light to be projected onto a meridian line. However, to correct for the equation of time, he used the clever device of a moving hour-ring, with a date-scale around the inner circumference,

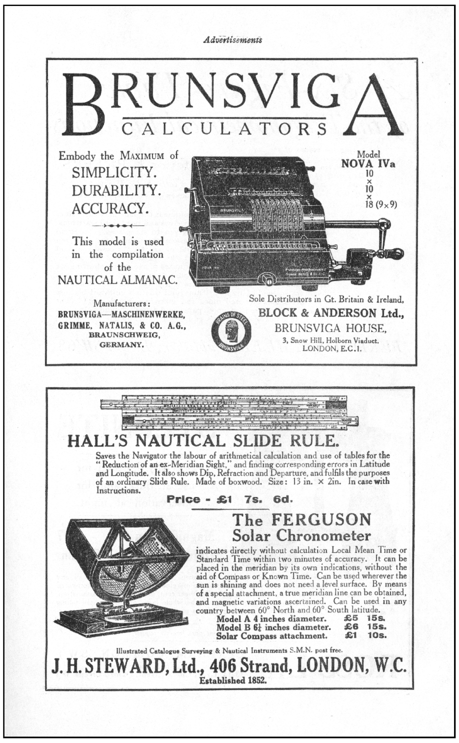
Fig. 19. Pilkington's mean-time sundial, the 'Sol Horometer', patented in 1911.

which could be turned so that it matched the same date on a similar date-scale on the fixed inner disc of the instrument. When the dates coincided, the hour-ring would be set for the correct value of the equation of time. It could also be set for the longitude correction, so that it would indicate standard time. Pilkington patented his sundial, which he called the 'Sol Horometer', in 1911. (See Figure 19.) Although it was a well-made precision instrument, with many of the same features and qualities of the heliochronometer, it lacked the style of the supreme invention of George Gibbs. Sadly, it seems to have been the product of professional rivalry![52]

Fig. 20. William Homan's hemispherical scaphe mean-time dial, c. 1912.

It is interesting to note that William Homan also invented an equinoctial mean-time sundial, in the form of a hemispherical *scaphe* dial, (Figure 20) at much the same time as Pilkington patented his 'Sol Horometer'. The gnomon consisted of a thin metal rod, which cast a shadow line onto a semi-circular brass hour-scale, which incorporated two date-scales, one fixed and the other movable, which, when matched for the date in question, corrected the instrument for the equation of time. It is a singular coincidence that the principle of this adjustment is the same as that used by William Pilkington.[53,54]

In the modern 'renaissance' of the sundial, in the latter half of the 20th century, many forms of equinoctial mean-time sundial, including heliochronometers, have been constructed as works of scientific art, several on a large scale. However, the last example of such an instrument, of which I know, made for the serious purpose of determining the



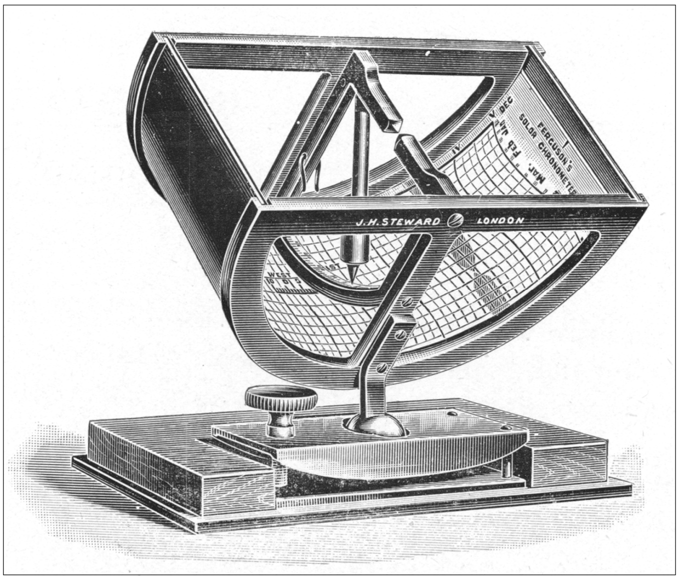


Fig. 22 (above). The 'Ferguson' universal equinoctial mean-time sundial, described as a 'solar chronometer'.

Fig. 21 (left). J. H. Steward's advertisement in H.M. Nautical Almanac for the year 1934, featuring 'The "Ferguson" Solar Chronometer and Astronomical Compass.'

time, as a matter of necessity, was Ferguson's small portable 'universal' equinoctial mean-time sundial, manufactured by J. H. Steward Ltd., which was advertised in H.M. *Nautical Almanac* (see Figure 21) in 1934.[55] Made of metal, it comprised a simple rectangular frame, fitted to a semi-circular equinoctial dial-plate. The gnomon consisted of two short pointed rods, lying in the polar axis, in the form of a transversal that almost bridged the centre of the rectangular frame. The gap between the shadows of the pointed rods, projected onto a flexible *analemmic* hour-scale, that compensated for the equation of time and which could be adjusted for longitude, indicated the time, i.e. standard 'clock' time. The flexible hour-scale also featured a scale of 'date-lines' or parallels of declination, by which the date could be determined, or, if the date were known, the instrument could be aligned in the meridian. A small vertical graduated quadrant, fitted with a plumb-bob, allowed the instrument to be set for the latitude of the place of observation. Thus, when set for the latitude and knowing the date, the sundial could be orientated by turning the instrument to bring the shadow gap onto the appropriate parallel of declination or 'date line', when it would indicate the correct time. (See Fig. 22.)

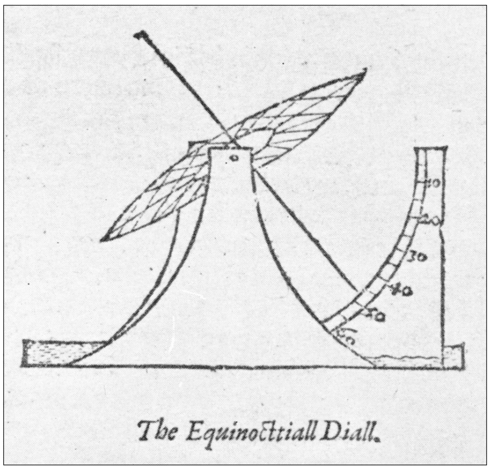


Fig. 23. 'The Equinocttiall Diall' featured in William Bourne's book A Regiment for the Sea, *1574. Initially, he suggested that it could be made from a discarded compass-card; but later advised on its construction in wood.*

THE EQUINOCTIAL SUNDIAL – The fundamental dial

Historically, the equinoctial sundial is the fundamental dial from which all others are derived, (Fig. 23) as ably expressed by Thomas Stirrup, the English 17th century mathematical practitioner and diallist, whose works had some influence on John Flamsteed in his youth.[56] Most examples are of the portable kind and are to be found in the collections of museums and in those of private individuals. The equinoctial dials which are set up in gardens usually take the form of the *armillary* sphere; but some feature as *scaphe* dials, cut into the stonework of large multiple sundials. Thus, unlike the great horizontal and vertical meridians, that perhaps inspired Grandjean de Fouchy to furnish them with the *analemma*, large equinoctial mean-time sundials, with possibly one exception (Fig. 24) in China,[57,58] are a product of the modern age. (See Fig. 25.)

THE ANALEMMA IN THE NETHERLANDS

It must be said that, at about the same time that Grandjean de Fouchy conceived the idea of the analemma, which previously I had considered to be around the year 1726, with his first construction being put into effect in about 1730, there is evidence that the analemma was not only known; but that it had been put to practical use elsewhere.[59] The most outstanding example is almost certainly the horizontal

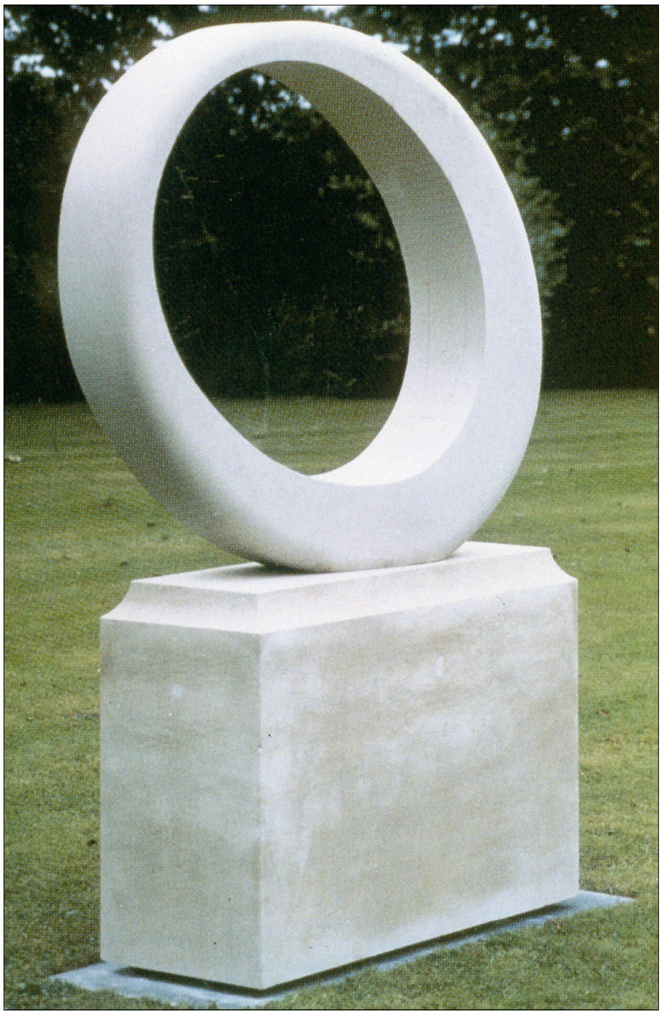


Fig. 24 (above left). A large 18th century equinoctial meridional stone quadrant, delineated with the analemma as a mean-time noon-mark, in the old Beijing observatory.

Fig. 25 (above right). A modern sundial sculpture, the 1.2m diameter 'Eye of Time' analemmatic noon-mark, designed by Dr Allan Mills and carved in Portland stone by Fairhaven of Anglesey Abbey Ltd., produced under licence by Garden of Art Ltd., Gestingthorpe, Essex in the year 2000. (Photograph © A. A. Mills 2000.)

Fig. 26 (left). The horizontal sundial, made by David Coster c. 1726, in the Rijksmuseum in Amsterdam. (Photograph © Rijksmuseum, Amsterdam.)

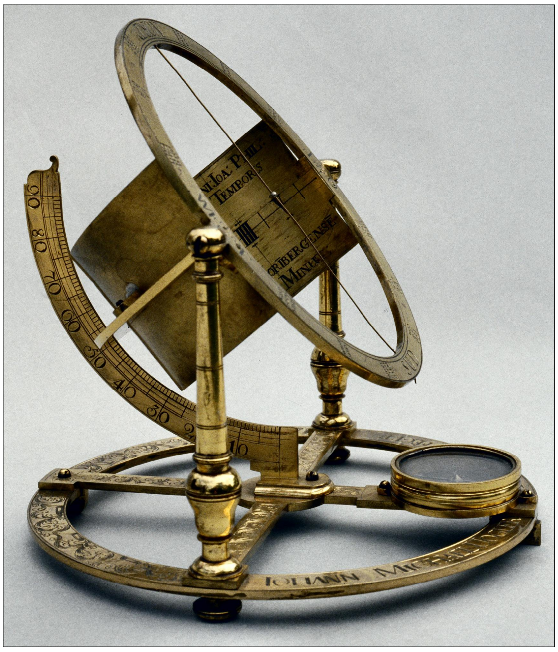


Fig. 29 (far left). The portable universal equinoctial mean-time sundial, made by Johann Michael Vogler for Johann Philipp von Wurzelbau c. 1716, in the gnomonical collection of the National Maritime Museum at Greenwich.

Fig. 30 (left). Side elevation of Vogler's sundial.

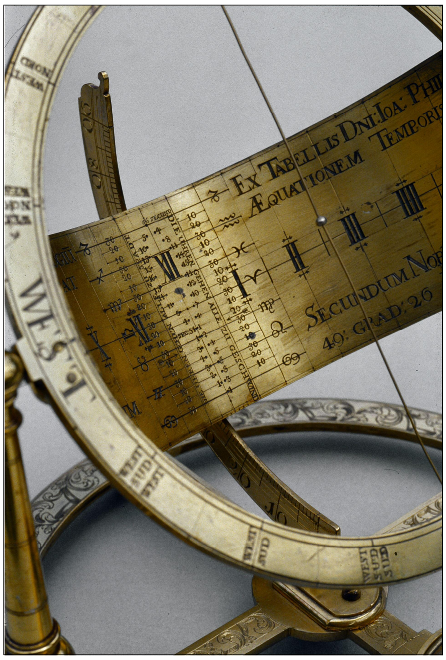


Fig. 31 (left). Detail of the dial-plate of Vogler's sundial, showing the analemma and the zodiacal date-scale. Part of the Latin inscription, proclaiming the new invention (of the analemma), for the correction of the equation of time, by Wurzelbau, is visible.

Fig. 27 (below). The oil painting by Nicolaas Verkolje of David van Mollem, a wealthy silk merchant, with his family, dated 1740.

Fig. 28 (below). A detail of Verkolje's painting, showing the armillary sphere with the mechanical device, in the form of the analemma, illustrating the apparent annual motion of the sun.

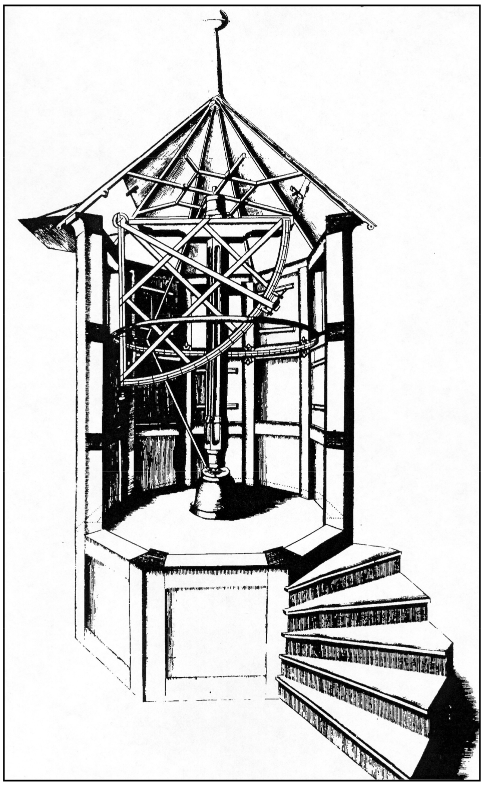


Fig. 32. Wurzelbau's observatory, on the roof of his house at No 4 Spitzenberg Place, in the city of Nuremberg, which he set up in 1692. (Photograph: H. Gaab.)

sundial, made by David Coster, (Fig. 26) to be found in the Rijksmuseum in Amsterdam. Unlike the meridian dials of Grandjean de Fouchy, this remarkable instrument is engraved with analemmic equation of time correction curves for *all* the hour-lines. It has been dated, from the coat of arms that it bears, as having been made between the years 1719 and 1733, possibly about 1726; but the author of the analemmic curves remains unknown.[60,61] Also, perhaps even more intriguing, is the detail shown in an oil painting of David van Mollem, a wealthy silk merchant, with his family, on the terrace of his country seat 'Zijdebalen-Lusthof'. (See Fig. 27.) The painting is signed by the artist Nicolaas Verkolje and dated 1740. In the bottom left hand corner of the painting there may be seen two scientific instruments, a dilatometer, used for measuring the expansion (dilation) of solid bodies when heated, and an armillary sphere (Fig. 28). The latter is clearly furnished with a mechanical device, in the form of the analemma, which contains a track along which a model of the sun may be moved, illustrating both the changing seasons and the equation of time.[62,63] It is evident that this painting portrays van Mollem, as no doubt he would have wished to have been portrayed, as a rich and powerful family man, with a cultured interest in the sciences and the arts. What remains unanswered, however, are the questions as to who made this mechanical armillary sphere and when was it made? The dilatometer was known to have been invented before 1731 by Petrus van Musschenbroek.[64] Since the inclusion of these instruments in the picture suggests that they are fairly new and perhaps much prized acquisitions, one might reasonably suppose that the armillary sphere was constructed some two or three years earlier, about 1737, if not before.

THE EQUINOCTIAL 'MEAN-TIME' SUNDIAL OF JOHANN MICHAEL VOGLER

There is another significant example of the *analemma* having been applied to a scientific instrument during this same period, which brings us back to the subject of the *equinoctial* sundial. (See Fig. 29.) This particular example is a portable universal equinoctial 'mean-time' sundial, made of brass, in the astronomical instrument collection of the National Maritime Museum at Greenwich.[65] It takes the form of a broad semi-circular equinoctial dial-plate engraved with an hour-scale, furnished with a linear zodiacal date-scale in the meridian, i.e. the 12 o'clock hour-line, which features the figure of the *analemma*, to correct for the equation of time. This piece is fixed perpendicularly to a narrow flat ring, lying in the plane of the polar axis of the sundial, (Fig. 30) which forms a frame to which a fine wire gnomon is attached in the meridian. At the centre of the wire, i.e. the centre of the polar ring, also being at the centre of curvature of the hour-scale, a small ball or bead is fixed as a *nodus*. The instrument is seated on a graduated quadrant, which allows it to be set for the latitude of the place of observation, and is supported on a stand, fitted with a small compass, with which it can be set in the meridian. At midday, the shadow of the bead or nodus will indicate the 'declination' of the sun, or rather its position in the zodiac, and the equation of time, i.e. local mean-time or 'clock' time, according to its position on the analemma. (See Fig. 31.)

The equinoctial dial-plate of this very fine instrument bears the inscription: *NOVUM INUENTUM HOROLOGIŪ EX TABELLIS DNI : IOA : PHIL : DE WURTZELBAU INDICAT AEQUATIONEM TEMPORIS DIERUM NATURALIUM SECUNDUM NORÏBERGENSĒ MERIDIANUM 49 : GRAD : 26 MINUT*, whilst around the ring of the base of the stand the maker's name is engraved: JOHANN MICHAEL VOGLER IN ELLINGEN FECIT. Johann Michael Vogler was a compass-maker and clock-maker in Ellingen, some 30 miles (50 km) due south of Nürnberg, who flourished about the year 1716, one of his most notable commissions being the construction of a clock for the town hall of Neustadt, then the capital of the Principality of Brandenburg.[66] However, the engraved legend on the dial-plate of the sundial credits the invention of the analemma to Johann Phillipp von Wurtzelbau of Nürnberg, who probably also designed and delineated the instrument, since this is evidently the very same sundial that Vogler was commissioned to make for him.[67]

VON WURZELBAU– inventor of the equinoctial mean-time dial

Johann Philipp von Wurzelbau (1651-1725) was born on 28th September 1651, the son of Johann and Dorothea Wurzelbau (whose surname has several variants), the owners of a well-established firm of brass-founders in Nuremberg. When he was only four years old, Johann Philipp's father died. Two years later, his mother married his godfather, Johann Philipp Kob, (after whom he appears to have been named), who had shared the management of a brass store in the city with his late father. His relationship with his step-father seems to have been a very good one, since, in later life, Wurzelbau praises him for the great care that he took in ensuring that he had a good education.[68]

Johann Philipp Wurzelbau, as he was then, received his first lessons from private tutors, who taught him Latin, music and the art of drawing. One of his tutors was Andreas Alexander, who came to Nuremberg in 1660, who taught him mathematics and stimulated the interest of young Wurzelbau in this subject. Furthermore, Alexander was noted as an artist in the construction of very precise instruments in brass, which may also have had some influence on Wurzelbau in later years. In 1662, at the age of 11, he attended the upper classes of the Aegydien Gymnasium, now described as the Egidiengymnasium or grammar school, with the intention of going to university; but the death of his step-grandfather in 1666 obliged him to give up his studies, at the request of his mother, to help his step-father in his business.[69]

In the 1670s, together with his step-father, Wurzelbau successfully managed the brass shop business in Nuremberg, to the extent that he had time to further his studies. He learnt French, Italian and Spanish, as well as Hebrew; but also he particularly occupied himself with mathematics. As was the custom at the time, it was common practice to travel through Europe to round off one's education; but Wurzelbau's plans, in 1673 and again in 1675, always seemed to be thwarted, not least by his later appointment in 1683 as "Genannter" of the Council of Nuremberg.[70] This appointment was in recognition of his status as a merchant and as a prosperous tradesman in the brass business; but Herr Wurzelbau found trade a tiresome duty. His interests lay elsewhere in the study of astronomy and geography. As it happened, in the autumn of the year 1678, Georg Christoph Eimmart (1638-1705) had established an observatory within the walls of Nuremberg castle, where he tutored aspiring astronomers. The year 1680 saw the appearance of a spectacular comet, which Eimmart observed for the first time on the night of 18th November. The comet was visible until the 3rd December, when it disappeared in its orbit around the sun, re-emerging and becoming visible again on the 26th December. Eimmart made his last observation of the comet on the 11th February 1681, as it moved away from the sun into deep space. Wurzelbau took part in these observations and there can be little doubt that his experiences encouraged his passion for astronomy.[71]

Fig. 33. Engraved portrait, dated 1716, of Johann Philipp von Wurzelbau, aged 65, held in much esteem as an eminent astronomer and scientist. (Photograph: H. Gaab.)

From the beginning of the 1680s, Wurzelbau was Eimmart's most important pupil, helping him with his researches into magnetic variation, which he had started investigating in 1677. A short report on this work was published in 1685 in the *Philosophical Transactions* of the Royal Society (of London), where, for the first time, Wurzelbau's name appears in a prestigious scientific journal.[72] On the 2nd July 1684, Eimmart and Wurzelbau observed the partial eclipse of the sun, whilst, just over a year later, on the 30th November 1685, Wurzelbau observed the lunar eclipse on his own. The published results came to the notice of the great Hevelius (1611-1687) of Gdansk, then the City of Danzig, where this celebrated German astronomer was born and where he died, who's *Selenographia*, his magnificent atlas of the moon's surface, and his exhaustive work on comets had made him famous. Evidently, Hevelius was so impressed with the meticulous work of Wurzelbau that he subsequently described his observations as "extremely excellent" and prayed that "God may give him a long life" so that he could long continue with his observations for the public good. However, his praise was not published until 1690, three years after his death.[73,74]

In 1686, Johann Jacob Zimmermann (1644-1693) of Wurttemberg stayed for a while in Nuremberg. During his visit, on the night of the 31st March 1686, he carried out observations, together with Eimmart and Wurzelbau, of the occultation of the planet Jupiter by the moon. He later published a paper on the results of his Nuremberg observations, in which he gave Wurzelbau equal credit for this work, referring to Wurzelbau as 'artibus egregium' – a glorious artist! [75] The following year, in 1687, Wurzelbau received an invitation from Edmund Halley (1656-1742), (later, in the year 1720, to become the Astronomer Royal of England) to be a correspondent of the Royal Society. As a result of this invitation, reports of Wurzelbau, principally concerning his observations of eclipses of the sun and moon, which were his primary interest, may be found in the *Philosophical Transactions* of the Royal Society for the next three or four years. Indeed, it was Wurzelbau's work on eclipses, particularly those of the total eclipses of the sun and his exact measurements of the totality, which really brought him to the attention of the astronomical world.[76] Furthermore, he is also noted for having recorded well over 4000 solar altitude [meridian altitude] observations between the years 1682 and 1718, which is quite an accomplishment by any standard! [77]

On the 14th May 1679, at the age of 28, Wurzelbau had married Magdalena Petz, the daughter of the banker Hieronymus Petz von Lichtenhof. Three years later, in July 1682, his mother, Dorothea died and it is possible that he inherited the house from her, for he started making astronomical observations from his own house in this same year, with a number of instruments that he had acquired. Amongst these was a gnomon, which took the form of a vertical wooden post, with which he recorded the meridian altitude of the sun during the years 1683 and 1684. In the year 1689, his step-father also died, at which time Wurzelbau slowly started to withdraw from commercial life, giving it up completely in 1691. The following year, in 1692, he established his own observatory, in the form of an observation turret, furnished with a fine brass azimuthal quadrant that could be rotated about the axis of an iron column, on the roof of his house at No 4 Spitzenberg place. (See Fig. 32.) It is also evident that he possessed a pendulum clock.[78] A few years later, probably before 1697, he appears to have acquired a larger quadrant, fitted with a telescope, which was fixed in the plane of the meridian; but, nevertheless, it seems that he preferred to use the smaller instrument for the majority of his observations. The year 1692 was also a significant one for Johann Philipp Wurzelbau, for, whilst he had married into the nobility, it was in this same year that he himself was ennobled, i.e. raised to the nobility, whereby he became Johann Philipp von Wurzelbau.[79]

Whilst, in the past ten years, Wurzelbau had already established his reputation as a scientist and had published the results of his researches, the first edition of his principal work, *Uranies Noricae basis Astronomico-Geographica*, which included a copperplate engraving of a drawing of his octagonal observatory turret, was published in Nuremberg in 1697.[80] Such was the acclaim for this work that the Council of the City of Nuremberg presented him with a large engraved glass cup, made by Paulus Edter, in recognition of his achievements.[81] Furthermore, in the year 1700, Wurzelbau was commissioned as the principal expert to resolve the problems arising from the reform of the calendar, which took place in that year, and in connection with the regulation of the Nuremberg clock, which governed official duties, which kept a complex count of equal hours, determined according to the length of the day (the hours of daylight) and the length of the night (the hours of darkness). This hybrid system, which basically measured equal hours from sunrise (h*orae ab* o*rtus*) and also from sunset (h*orae ab occasus*) gave rise to the recognition abroad of *Nuremberg* hours. Evidently, Wurzelbau's principal task, one

Fig. 34. Christiaan Huygens, the great Dutch mathematician, physicist and astronomer.

which he seems to have enjoyed, was to have provided accurate tables of the length of the day (*longitudo dierum*), i.e. the number of hours and minutes in the day, or in the required divisions of the period, such that the Nuremberg clock could be adjusted correctly.[82]

It was perhaps about this time, or somewhat later, that Wurzelbau acquired the assistance in his work of Johann Gabriel Doppelmayr (1671-1750), who had been appointed Professor of Mathematics in the Aegydien Gymnasium in Nuremberg in 1704. An astronomer with a reputation for important work in the construction of scientific instruments, especially the construction of sundials, Doppelmayr made a notable contribution to Wurzelbau's progress in astronomical-geography, one purpose of which was the determination of the geographical co-ordinates of Nuremberg, i.e. the latitude and the longitude in relation to other places. Between them, these two men did much to establish a singular tradition in this particular scientific field. In later years, Doppelmayr became Director of the Nuremberg Observatory and, in 1742, published his *Atlas Coelestis*.[83] However, in the context of the application of the *analemma* to an equinoctial sundial, as a means of directly correcting for the equation of time, in order to obtain mean-time, it is the statement that he made in his work *Neu-vermehrten Welperischen Gnomonica*, published in Nuremberg in 1719, that is particularly significant. He writes that "Wurzelbau calculated at first the course of the sun through the signs of the zodiac, determining the precise place (*Loca Eclipticae*) of the sun for the time of the 'Zu-und Abschlagen' [adjustments] of the clock".[84,85] The significance of this statement is that it suggests that, at this time, Wurzelbau had determined and delineated the course of the sun, through the signs of the zodiac, as engraved on the sundial, made for him by Johann Vogler. The sundial is delineated with the *analemma* against a linear *zodiacal* scale, as opposed to a tangential declination scale, which, whilst being of no significance in itself, supports this supposition.

There is a fine copperplate portrait engraving (Fig. 33) of Johann Philipp von Wurzelbau, dated 1716, at which time he would have been 65 years of age, a scientist and citizen of renown in Nuremberg, and highly regarded in scientific circles abroad. Indeed, as well as his exchanges with the Royal Society, he had been a corresponding member of both the French and the Prussian academies of science. His extensive correspondence with scholars from all over Europe included Jean-Dominique Cassini (1625-1712), John Flamsteed (1646-1719), and Joseph-Nicolas De Lisle (1688-1768), who sent Wurzelbau the results of his observations of the Transit of Mercury in 1723, and who, in the following year, became the tutor of Grandjean de Fouchy.[86] In all probability, the sundial would have been made for

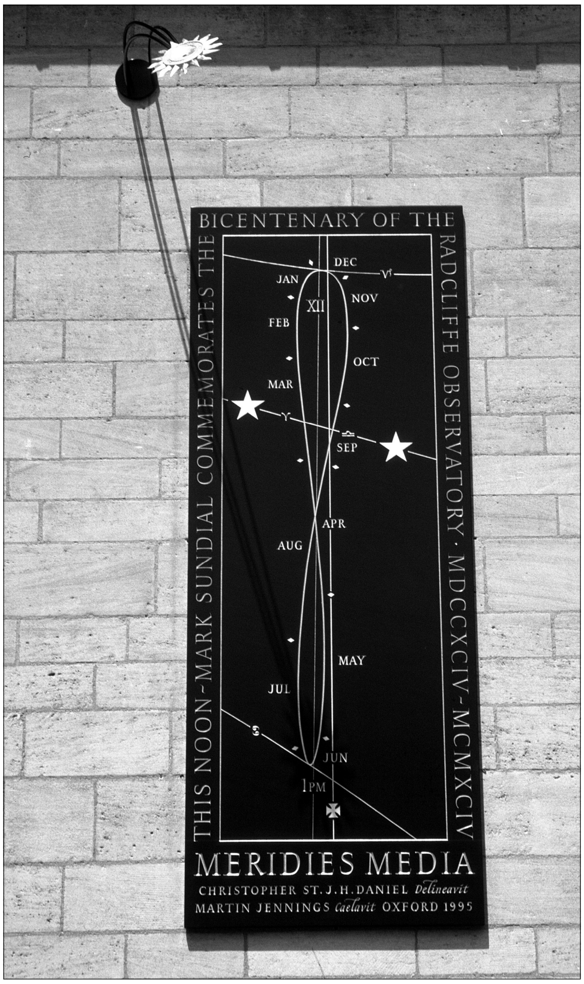


Fig. 35. The vertical mean-time meridian sundial at Green College, Oxford, designed by the author and executed by the Oxford sculptor Martin Jennings in 1995.

him at about this time, a symbolic but practical reminder of his discovery of the *analemma*.[87,88] After a long and distinguished career, this modest man, who had "an uncommon awe of God", and who is remembered for his many observations of the sun, particularly those of total eclipses, died of a fever on the 21st July 1725, in his 74th year.[89] His possessions were inherited by the Forster family and so passed down to Christoph von Forster (1766-1857); but in 1863, six years after von Forster's death, this collection, including his glass presentation cup and his sundial, were sold at auction.[90] Thus, in due course, the Wurzelbau sundial came to be in the astronomical instrument collection of the National Maritime Museum at Greenwich.

In 1964, I was appointed to the staff of the National Maritime Museum, Greenwich, as a Research Assistant I, in the Department of Navigation and Astronomy. I first became interested in sundials in 1967, when I was given direct curatorial responsibility for the sundial collection in the then Old Royal Observatory at Greenwich, which was an integral part of the National Maritime Museum. However, in 1968, a sundial in the form of a vertical mean-time noonmark, delineated with the analemma (*Meridies Media*),

Fig. 36. The 'Dolphin' equinoctial mean-time sundial at the National Maritime Museum, Greenwich, designed and delineated by the author, and executed in bronze by Edwin Russell, a leading British sculptor, of Brookbrae Ltd, to celebrate Her Majesty the Queen's Silver Jubilee in 1977.

designed by the late Dr Tadeusz Przypkowski, was set up on the south-facing wall of the Meridian Building. This unusual sundial required some investigation and it was through this study that I first discovered the elegant *analemma* of Monsieur Grandjean de Fouchy, in the delightful pages of *La Gnomonique Pratique* by Dom François Bedos de Celles. Prior to this, earlier in 1968, I had endeavoured to plot the equation of time myself against a linear scale, when the true form of the analemma, as yet, was unknown to me. This elementary exercise, as with my plotting of the equation of time about a circle (the secret cam of the Pilkington & Gibbs heliochronometer), was crude, to say the least; but a valuable lesson in my education. I later realised the historical significance of this simple act, since this must have been the basis of the discovery of the *analemma*. In due course, I also discovered the Wurzelbau sundial by Johann Michael Vogler; but it took time for me to appreciate the intrinsic value of this beautiful instrument.

On the question as to who was the first to invent the *analemma*, it must be said that, in some respects, it is surprising that it was not the invention of Christiaan Huygens (1629-1695), the great Dutch mathematician, physicist and astronomer (Fig. 34), who, in 1656, had invented the means by which a pendulum clock could be made to keep accurate

Fig. 37. Detail of the 'Dolphin' sundial at the National Maritime Museum at Greenwich. The gap between the shadows of the dolphins' tails, passing over the analemmic hour-lines, indicates the time to within some 30 seconds. The time indicated is 12:10 GMT.

time; and who also had produced a reliable table of corrections for the equation of time.[91] Huygens visited England in 1660-1661 and in 1663 was elected a Fellow of the Royal Society.[92] Then, of course, the idea could also have occurred to Jean-Dominique Cassini (1625-1712), who, according to the English astronomer Roger Long, referring to tables of the equation of time, "…made the first table of this sort in 1668…and did well enough for the rest of that century." [93]

Likewise, one may wonder whether or not John Flamsteed (1646-1719) had ever conceived such an idea, when he made his equation of time tables in 1665, although these were not published until 1672 -1673.[94,95] Bearing in mind the statement made in Flamsteed's letter of the 4th November 1669 to Lord Brouncker, the President of the Royal Society, and the praise bestowed on Flamsteed by William Molyneux (1656-1698), in his work *Sciothericum Telescopicum,* published in Dublin in 1686, for settling any controversy concerning the equation of time, John Flamsteed would seem to have been sufficiently acquainted with the subject as to have been close to such a discovery.[96,97] Nevertheless, the *analemma* seems to have remained a Continental inspiration, since it does not appear to have reached England until the latter half of the 19th century.

In the scientific climate of the time, despite wars and financial constraints, scientists managed to exchange a considerable amount of information. As has been mentioned, Johann von Wurzelbau had correspondence with Cassini, De Lisle, Flamsteed and Halley; but also with George Ashe (c1658-1718), the Irish astronomer, who was a friend of William Molyneux. Ashe visited Nuremberg in the autumn of 1689 and, whilst he was there, came to know both Eimmart and Wurzelbau personally. In a letter dated 27th January 1690, it was Molyneux who told Flamsteed of Ashe's meeting with Wurzelbau.[98] Incidentally, William Molyneux had journeyed to The Hague in the summer of 1685, where he had visited Christiaan Huygens, who showed him various instruments and telescopes in his garden.[99] He later went on to visit Cassini at the Paris Observatory.

Thus, it can be seen that there were exchanges between almost all of those astronomers who had determined and tabulated the values of the equation of time. Through the intermediary of De Lisle, there was even a link with Grandjean de Fouchy. Consequently, it would not be unreasonable to suppose that the projection of the *analemma*, as a means of correcting a sundial for this phenomenon, could well have been thought of by any of those who were closely concerned with this matter, who may, indeed, even have discussed the subject, before it was actually physically portrayed.

If one is really concerned as to who was the *first* to invent the *analemma*, the indications are that it was invented by Johann Philipp von Wurzelbau in Nuremberg in about the year 1716, if not earlier. However, the evidence suggests that it was also independently invented elsewhere in the Netherlands, sometime between 1719 and 1733, perhaps in about 1726; and certainly it would seem to have been independently invented by Jean-Paul Grandjean de Fouchy in or about 1730. Furthermore, there can be little doubt that Grandjean de Fouchy was the *first* to conceive the *analemma* as a device for determining mean-time on horizontal and vertical meridian dials or noon-marks. There can also be no doubt that it is primarily due to French gnomonical literature that the inheritance of this form of sundial still flourishes in modern dialling design and construction. The evidence of this historic inheritance is manifest throughout France today, where there are some 410 such dials.[100,101]

In conclusion, I believe that the indirect inspiration for my own sundial designs, including the vertical commemorative dial (Fig. 35) at Green College, Oxford,[102] and the 'Dolphin' equinoctial mean-time sundial at Greenwich (Figs. 36 & 37), celebrating H. M. the Queen's Silver Jubilee,[103] must surely have had their origins in the inventions of the two remarkable, but little known, early 18th century astronomers, Jean-Paul Grandjean de Fouchy and Johann Philipp von Wurzelbau, to whom I hope that I have here done some justice to their memory!

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NB. According to Madame Andrée Gotteland, other mean-time meridians have been found in Switzerland, in the convent of Bellelay at Porrentruy, some 42 km (27 miles) w.s.w. of Basel, that are dated 1591.

ACKNOWLEDGEMENTS

The author is much indebted to Madame Andrée Gotteland for information relating to Jean-Paul Grandjean de Fouchy; also to Herr Hans Gaab for the autobiographical material on Herr Johann Philipp von Wurzelbau; and especially to Günther and Christel (Christiane) Berger for providing a translation of this document from the German into English.

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'TIMEKUMPAS'
THE SMALLEST HELIOCHRONOMETER?

GRAHAM STAPLETON

In dialling, as in many other subjects, making any claim to the superlative regarding age, dimensions or geographical extremity tends quickly to elicit other examples that have a better claim. This equatorial dial - the size of a cigarette lighter - lacks precision, and so must be regarded more as a scientific toy. Nonetheless, I beg the reader's indulgence that it may be justly called the smallest of the heliochronometers. As its instructions and tables clearly indicate, it was intended for practical (if rather painstaking) use. Capable of allowing for latitude, longitude, equation of time and magnetic variation, this instrument can also measure azimuths. Such a level of sophistication presumably put the Timekumpas at a disadvantage when compared with simpler, cheaper devices. Patented on January 19th 1926 by James C. Doran & Sons of Providence, Rhode Island, U.S.A., I suspect that its manufacture may have been a fairly short-lived business.

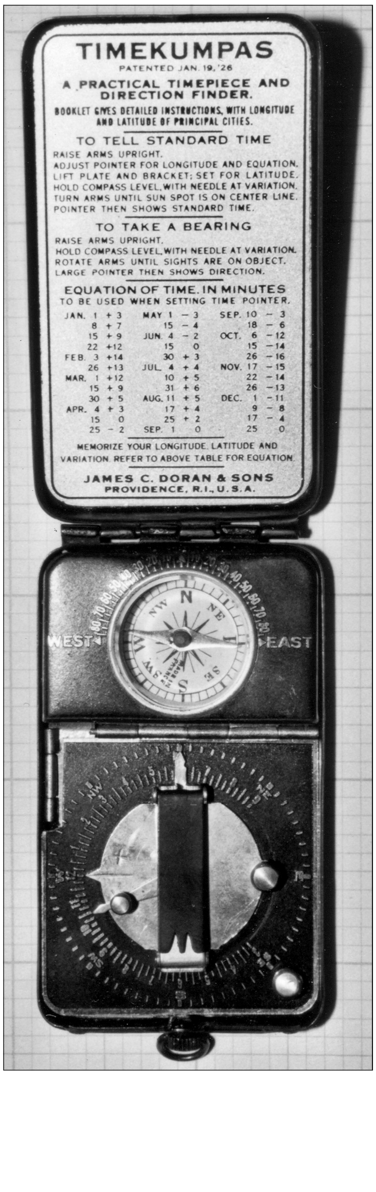


Fig. 1. The open Timekumpas with the equatorial dial folded flat and showing the instructions in the lid.

Inside the case, measuring 3"×1½"×⅜" overall, is a small compass and a hinged plate which is held at the required co-latitude by a toothed quadrant. Pivoted on the plate is the heart of the instrument - a ⅞" diameter disc, bearing the two hinged leaves of the alidade, two fixed pointers at right angles, and one pivoted pointer - called the 'adjusting pointer'. The pointer aligned with the alidade reads azimuths from the outer circular scale of compass points. The second pointer reads onto the inner scale of hours to show local apparent time; the adjusting pointer is moveable to show standard time. (Fig. 1)

Inside the lid are brief instructions for use and a limited table of the equation of time in whole minutes. Until the user has memorised - as the instructions suggest - the longitude, latitude and magnetic variation of their nearest city, the booklet needs to be referred to. (Fig. 2) This is assuming that they have first mastered the setting up, which is given as follows:-

STANDARD TIME

Refer to the table to learn details of the city nearest you. "L.D." is the minutes your city *is later (+) or earlier (-) than Sun Time. Combine these minutes with the minutes of "Equation of Time" and set the Adjusting Pointer accordingly.*

Raise the Sighting Arms to upright position.

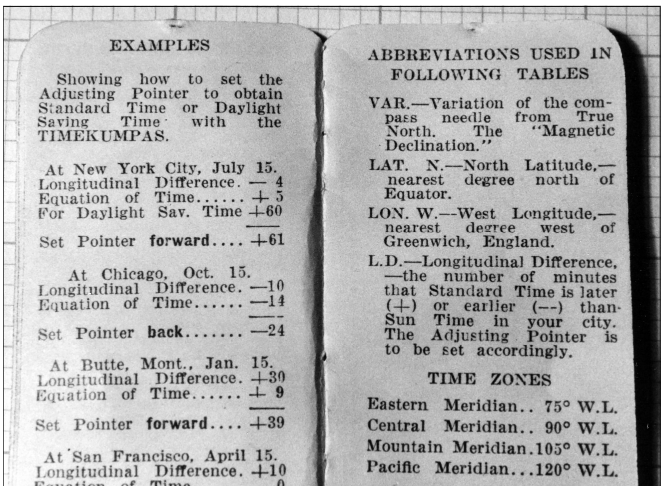
Make the adjustment for Latitude, by lifting the Hinged Plate and resting it in the Notched Bracket, at the point nearest your Latitude.

Hold the Compass level, with blue end of needle pointing to the variation, (east or west of "N") shown for your city in column "VAR". Then "N" points to the True Geographical North.

Rotate the Table until the sun ray coming through triangular hole is centered on the center (sic) line of the opposite Arm.

Then the Adjusting Pointer indicates Standard Time. (Fig. 3)

The Timekumpas is a universal instrument for the Northern Hemisphere, but the booklet concentrates solely on the United States, giving the setting values of four cities in nearly every State. However, its small size does preclude it from making any particular claim to precision. In the first place, the co-latitude can only be set to the nearest 5°. Next, it would normally be necessary to interpolate the day's value for the equation of time. The table has been pared down to whole-minute values; therefore it cannot be known with any greater precision. The most serious limitations however, are the small diameters of the magnetic compass and the hour scale. The compass, with its 5° gradations, makes hard work of finding true north. Similarly, setting the longitude and reading the time rely upon the hour scale, which is little more than an inch across, with fifteen minutes as the smallest division. In the light of these points, a user would certainly be fortunate to be less than ten minutes out.



EXAMPLES

Showing how to set the Adjusting Pointer to obtain Standard Time or Daylight Saving Time with the TIMEKUMPAS.

At New York City, July 15.
Longitudinal Difference. — 4
Equation of Time...... + 5
For Daylight Sav. Time +60
Set Pointer **forward**.... +61

At Chicago, Oct. 15.
Longitudinal Difference. —10
Equation of Time...... —14
Set Pointer **back**....... —24

At Butte, Mont., Jan. 15.
Longitudinal Difference. +30
Equation of Time...... + 9
Set Pointer **forward**.... +39

At San Francisco, April 15.
Longitudinal Difference. +10
Equation of Time...... 0
Set Pointer **forward**.... +10

ABBREVIATIONS USED IN FOLLOWING TABLES

VAR.—Variation of the compass needle from True North. The "Magnetic Declination."

LAT. N.—North Latitude,—nearest degree north of Equator.

LON. W.—West Longitude,—nearest degree west of Greenwich, England.

L.D.—Longitudinal Difference,—the number of minutes that Standard Time is later (+) or earlier (—) than Sun Time in your city. The Adjusting Pointer is to be set accordingly.

TIME ZONES

Eastern Meridian.. 75° W.L.
Central Meridian.. 90° W.L.
Mountain Meridian.105° W.L.
Pacific Meridian...120° W.L.

In all towns on these meridians, Sun Time and Standard Time are the same.

Fig. 2. Pages of the booklet giving examples of time adjustments.

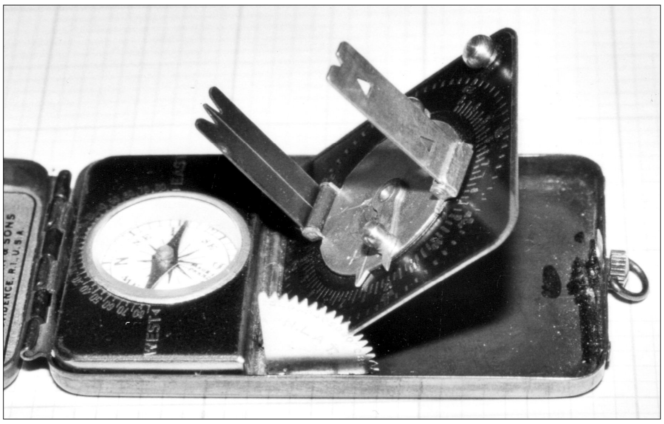


Fig. 3. The Timekumpas set up for use.

This admitted, the Timekumpas is nonetheless a noble effort to show that small sundials can be sophisticated. The owner of one should have little difficulty relating to a full size heliochronometer, such as a Pilkington & Gibbs. Although miniature equatorial dials were reasonably common - and in the case of Augsburg dials, more elegant - I cannot recall seeing one of this type that attempted Standard Time. The Timekumpas aimed for accuracy, even if it could not achieve it – not that accuracy has always been uppermost in the mind of buyers. The Butterfield type of dial enjoyed considerable popularity despite Bedos de Celles[1] castigation of their faults. We cannot disagree with him - but who of us wishes not to own one?

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READER'S LETTER

EARTH'S ROTATION

Eccentric I may be but I have often wondered what the consequences would be if the earth rotated on its axis in the opposite direction to the present norm; (for example – heaven forbid – if our planet were to be struck by a gigantic asteroid). An obvious consequence would be that instead of the sun rising in the east and setting in the west it would rise in the west and set in the east. This would have profound consequences for gnomonics since, inter alia, all sundial hour-line-numerals would have to be reversed. Alas, since I am by no means versed in mathematics, I am unable to list all the possible effects, but there must be many – some directly impinging on dialling and others less so. I therefore invite interested readers to submit their lists to me. Hopefully, our Editor will be persuaded to find space to publish the most comprehensive, and I will devise an appropriate reward for the 'winner'.

J Wall
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THE BRITISH ARE COMING

The North American Sundial Society Conference - Chicago, August 2005

J MIKE SHAW

Three of us, Tony Moss, Geoff Parsons and I, departed from Manchester early, to spend a few days exploring Chicago prior to the conference. Our first night was spent in a hotel near O'Hare airport in the quaintly named Elk Grove Village. Sadly, we saw no evidence of elks, groves or, for that matter, a village. However, we did have our first introduction to American portion control when we popped into a nearby Spaghetti Warehouse for a 'snack' - wow! The next morning, we used the excellent, clean and frequent Chicago Transit Authority Blue train for our 40 minute journey into Chicago - a two day travel pass for use on any train or bus was a mere $9 each - Ken Livingtone please note.

Fig. 1. The DuPage County Veterans' Memorial Dial.

Having deposited our luggage, we set out to explore the Windy City. A walk towards Lake Michigan (no, you can't see the other side, it's huge), revealed our first, gnomonless sundial at the entrance to Grant Park. We strolled in the sunshine past the Buckingham Fountain, and the amazing, polished steel, 'Cloud Gate' structure, towards Millennium Park where an orchestra was practising under an impressive steel sculptural proscenium arch. There were quite a number of Segway personal transporters weaving their way through the pedestrians on the wide walkways. We then boarded for a cruise up the Chicago river on an informative architectural tour - the buildings are stunning, so many innovatively designed skyscrapers, but they are not oppressive, letting in plenty of sunshine at ground level.

Over the next couple of days we did all the 'tourist' things. We rode on the 'El' - the ancient elevated railway that runs at first floor level round the city centre. We went up to the 96th floor of the Hancock Tower, in less than a minute, to see the amazing views of the city. We spent an afternoon at the Museum of Science and Industry - they had a Foucault pendulum, but we didn't find any sundials. We did a reconnoitre of the Adler Planetarium, from where there is probably the best view of the Chicago skyline. We sat out in the evening by the Buckingham fountain, where they did a 'sound and light' show, and watched the lights come on across the city - we had a great time. Chicago is quite a city, and well worth a visit.

The conference started on Thursday, in the midst of a torrential thunderstorm cloudburst. We arrived soaked to the skin, with our shoes full of water - our grateful thanks go to the Clothing Industry Development Council for drip dry trousers! This year, NASS decided to try out the idea of having a number of workshops, separate to the conference proper. On Thursday, our host, Steve Luecking, ran one on 'Rope Geometry' outdoors in Grant Park, and a second on an 'Introduction to CAD' at De Paul University, where the conference was held. Roger Bailey helped us with our mathematics in a session on 'Using a Programmable Scientific Calculator'. Following the conference, Steve ran a further '3D CAD' workshop, and Fred Sawyer held one on 'Spherical Trigonometry'.

Thursday evening was the formal registration, with a number of 'door prizes', including a copy of Mike Cowham's book *A Dial in your Poke*. It was good to meet up with old friends again, and to put faces to some more of the famous names from the sundial community. We met up here with Michael and Mary Isaacs, who were over visiting relatives, so the British contingent was swelled to five, out of a conference of around 46.

Fig. 2. The Henry Moore dial at the Adler piazza.

Friday morning, after a continental breakfast, which included some unusually coloured bagels, we set off on our usual bus tour. Sundials are widely spaced in the Chicago area, and the distance-to-sighting ratio was a lot different from what we British enthusiasts are accustomed to experiencing. However, the DuPage County Veterans' Memorial Dial (Fig. 1) was well worth the trip on its own. Set in a beautiful location, it showed Local Apparent Time, Standard Time via two analemmas per hour, Declination Lines and Italian Hours. The tour ended at the Adler Planetarium and Astronomy Museum, where we were given a behind-the-scenes tour, a look at some of the dials not normally on display and some free time to explore the museum.

The obligatory 'conference group photographs' were taken in front of the massive Henry Moore sundial which graces the Adler piazza (see Fig. 2).

The Sawyer Dialing Prize was then presented. This year it was awarded to our own Tony Moss. We all felt very proud as his citation was read:

"In recognition of his achievement in combining superb craftsmanship, a lifetime's teaching experience and a constant desire to share knowledge, methods and techniques in the practical art of dialing."

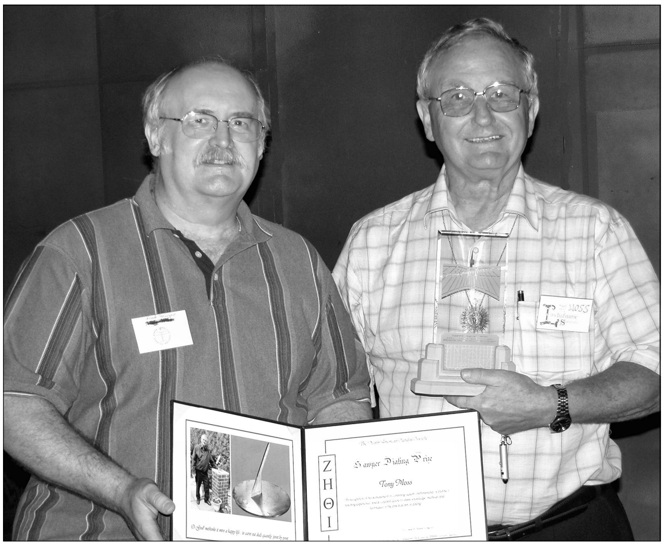

Fig. 3. The Fred Sawyer Prize is presented to Tony Moss (right) by the man himself.

Fred Sawyer presented Tony with his citation, and a specially commissioned Jim Tallman 'Spectra' glass sundial. (Fig. 3) Tony responded with an entertaining presentation about how he got into this sundial business in the first place!

Cocktails and the conference dinner followed in the Galileo restaurant of the Adler Planetarium, after which there was ample time for more photo opportunities, as the sun set over the Henry Moore dial and the Chicago skyline (Fig. 4). Tony, Geoff and I strolled back to our hotel, quite late, after a tiring, but very happy day indeed.

On Saturday and Sunday morning, the conference proper was held. This will be reported by NASS, so no great detail seems appropriate here. Fred Sawyer gave three talks; 'Conical Plinths and Boreals', 'A New Hectemoros Dial' and 'A.M.Earle on Sundials'. Roger Bailey talked on 'The Sundials of Francesco Zerbula' (this was similar to the talk given by Alain Ferreira at the last BSS conference) and 'Designing Sundials from Scratch'. Tony Moss introduced us to his new PowerPoint presentation 'Using and Understanding Sundials - Concepts for Students of Sundialing'. Don Petrie gave a talk about some of the dials that were seen on the BSS trip to Italy last October. Larry McDavid presented 'The Restoration of a Vandalised Dial' and 'The Ralph Larkin Memorial Dial'. Klaus Eichholz gave us an insight into the research he had done on a sundial by Francisco Xavier Josef Bovius, and even I did a short talk on 'The Analogue Dialist's Companion'. Following the formal presentations, there was a Topical Discussion Session, where we were all encouraged to participate, discussing a number of sundial related topics.

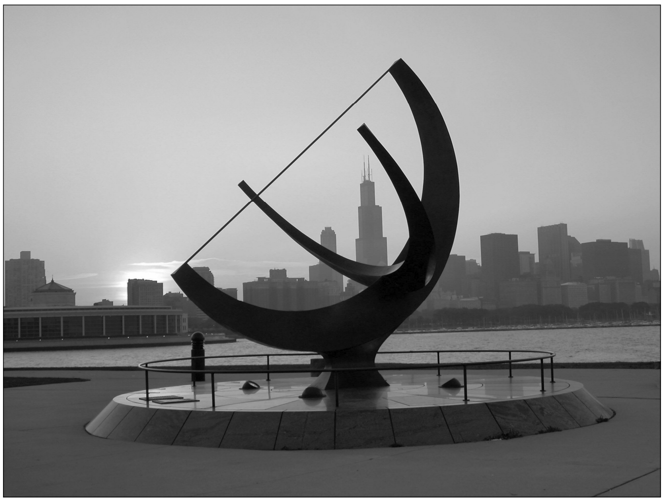

Fig. 4. The Henry Moore dial at the Adler in the Chicago sunset.

Speaking on behalf of the British participants, Chicago is a wonderful city (don't go in the winter though). The NASS conference is an event that you should try to go to at least once, both for the experience and to meet all those friendly, knowledgeable people that you have only heard about. Go early and do some touristy things as well. We had a great time - next year it's in Vancouver on 17th to 20th August.

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VECTOR DELINEATION - Part 2

TONY WOOD

VERTICAL DIAL, DECLINING

As we introduce declination (δ) and then inclination (γ) the equations become lengthier but involve merely numerical substitution and are relatively convenient for computer implementation. Only the functions sin, cos and tan are used as they are the ones which appear on calculators. For a vertical declining dial, where the dial plane is rotated δ about the vertical Oy_V axis, *δ is positive for east declining dials* (see Fig. 14). The shadow plane vector S_D components thus become:

$$x_D = p \cos\alpha \cos\delta - (-q \cos\lambda - p \sin\alpha \sin\lambda)\times\sin\delta$$

$$y_D = -p \sin\alpha \cos\lambda + q \sin\lambda$$

$$z_D = (-q \cos\lambda - p \sin\alpha \sin\lambda)\times\cos\delta + p \cos\alpha \sin\delta$$

and equating to the dial plate components $(x, y, z)_D$ of $(s, t, 0)_D$ as before and eliminating p and q we have, for the hour lines:

$$y_D = \frac{\sin\lambda \sin\delta \cos\alpha - \cos\delta \sin\alpha}{\cos\lambda \cos\alpha} \times x_D$$

with the lines being drawn, as before, in the lower quadrants.

The declination lines are derived similarly, the vector components of the ray line being:

$$x_D = p \cos\varepsilon \cos\alpha \cos\delta + (n - p \sin\varepsilon)\times\cos\lambda \sin\delta + p \cos\varepsilon \sin\alpha \sin\lambda \sin\delta$$

$$y_D = -p \cos\varepsilon \sin\alpha \cos\lambda + (n - p \sin\varepsilon)\times\sin\lambda$$

$$z_D = -(n - p \sin\varepsilon)\times\cos\lambda \cos\delta - p \cos\varepsilon \sin\alpha \sin\lambda \cos\delta + p \cos\varepsilon \cos\alpha \sin\delta$$

and, equating to the dial plate components $(x, y, z)_D = (s, t, 0)_D$ we have, in parametric form (parameter α):

$$x_D = \frac{n \cos\lambda \cos\varepsilon \cos\alpha}{\cos\lambda \cos\delta \sin\varepsilon - \sin\lambda \cos\delta \cos\varepsilon \sin\alpha + \sin\delta \cos\varepsilon \cos\alpha}$$

$$y_D = \frac{n \cos\varepsilon \times (\sin\lambda \sin\delta \cos\alpha - \cos\delta \sin\alpha)}{\cos\lambda \cos\delta \sin\varepsilon - \sin\lambda \cos\delta \cos\varepsilon \sin\alpha + \sin\delta \cos\varepsilon \cos\alpha}$$

The equinox (ε = 0) line being
$y_D = (-\sin\delta/\tan\lambda)\times x_D + n/\sin\lambda$.

The sub-style angle η_D is now derived from the gnomon's vector components after transformation into vertical declining axes

$$x_D = n \cos\lambda \sin\delta, \quad y_D = n \sin\lambda, \quad z_D = -n \cos\lambda \cos\delta$$

giving $\eta_D = \arctan(\tan\lambda/\sin\delta) - 180°$, the third and fourth quadrants being indicated as the parameter n (nodus distance along style) is taken as negative for vertical dials.

The hour line corresponding to this angle is obtained by referring back to the hour line delineation equation i.e. when $\tan\eta_D$ is equal to the gradient of the hour line:

$$y_D = \tan\lambda\times(\sin\delta - \tan\alpha_S \cos\delta/\sin\lambda)\times x_D$$

α_S being the requisite shadow angle and hence giving a corresponding time T_{24}.

Therefore, from

$$\tan\lambda/\sin\delta = \tan\lambda\times(\sin\delta - \tan\alpha_S \cos\delta/\sin\lambda)$$

We have $\alpha_S = \arctan(-\sin\lambda/\tan\delta)$ where α_S is in degrees. The corresponding T_{24} time is

$$T_{24} = 18 - (1/15)\times\arctan(-\sin\lambda/\tan\delta)$$

The angle of the gnomon to the dial plate (ζ_D) is given by

$$\zeta_D = \arcsin(z_D/n) \text{ or } \arcsin(-\cos\lambda \cos\delta)$$

The sub-nodus co-ordinates are:

$$(x_n, y_n)_D = (n \cos\lambda \sin\delta, n \sin\lambda)_D$$

and the height of the nodus above the dial plate is

$(z_n)_D = -n \cos\lambda \cos\delta$.

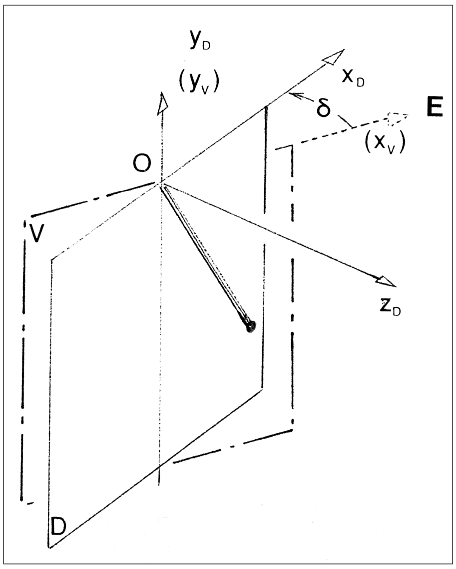


Fig. 14. Declining vertical dial. Axis system and declination angle.

Illumination Times

The horizon limit, L_H, is as defined in the section on horizontal dials.

The sun position limit, L_S, is found as above for vertical direct south dials, the z_D component of the ray line now being $z_D = -n \cos\lambda \cos\delta$ and the sun position limit is then

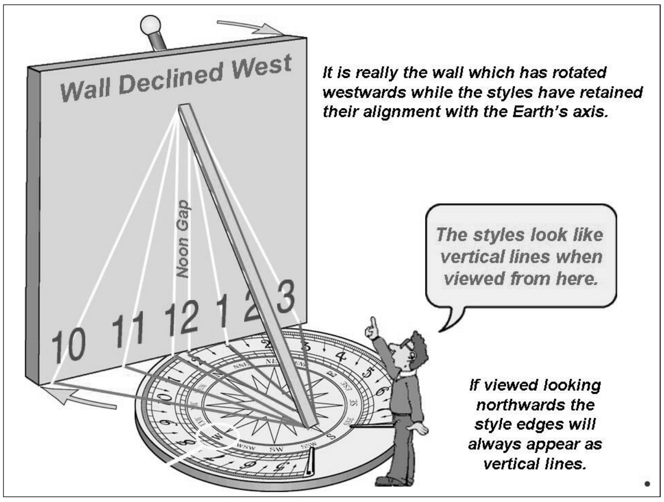
$$T_{24} = 18 - \alpha°/15 \quad \text{where}$$

$$\alpha = \arccos\left[\frac{-\cos\lambda \cos\delta \tan\varepsilon}{\sqrt{\sin^2\delta + \sin^2\lambda \cos^2\delta}}\right]_{PV,1} + \arctan\left(\frac{-\sin\lambda}{\tan\delta}\right)$$

To be continued

CD-ROM REVIEW

Sundial Presentations on PowerPoint by **Tony Moss**
CD-Rom with 150 animated slides for lecturers, teachers and students at many levels. *Published by The Lindisfarne Presse, 2005 (43 Windsor Gardens, Bedlington Northumberland) at £10 or $20, both inc. p&p.*
ISBN 0-9550828-0-3.

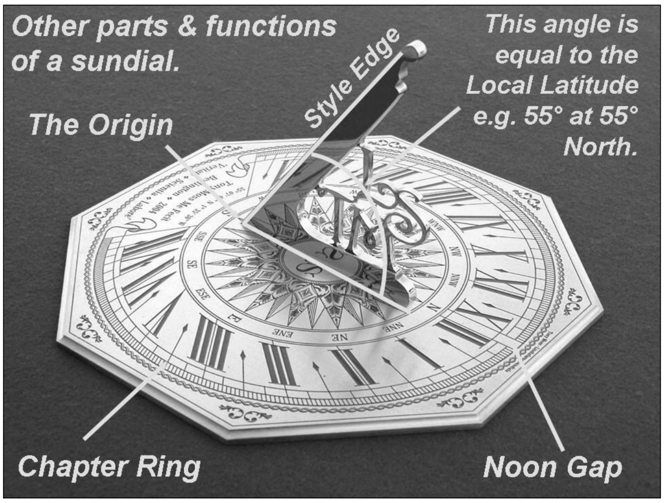


A sample slide from the 'Concepts' presentation, but without the benefits of colour or animation.

Being inexperienced in the use of PowerPoint™ for any purpose I was pleasantly surprised to find this CD extremely easy to open and use. The 'Read Me' instructions and information (available for both PC and Mac) are clear and can be followed without difficulty. 'The Notes for Presenters' on the disc are helpful.

Two presentations are included on the CD; 'Concepts for Students of Sundialling' and 'Using and Understanding Sundials'. Both provide a number of slides, most being animated, to illustrate a wide variety of aspects of sundials. The former consists of 54 slides, including the beginning and ending titles, and covers the theory of the scientific sundial. Topics covered explain the alignment of the gnomon with the Earth's axis starting with an equatorial dial and then deriving the horizontal and vertical dials for different latitudes. Detailed animated diagrams and actual sundials illustrate and explain the noon gap, the difference between clock and sun time, the analemma and the number of hours of sunshine falling on different dials throughout the year. I was particularly taken with the inclusion of a sundial made for use within the Arctic Circle and the consequential need to take account of the midnight sun! Having become familiar with the concepts in this section, even a beginner in gnomonics would have no difficulty in utilising the next.

The second presentation is longer, at 94 slides, again inclusive of the titles, but very sensibly it includes similar animated diagrams to some of those in the previous presentation where appropriate. Nine basic types of sundial are listed and the sequence of slides shows some examples beginning with the superb dial at All Souls College, Oxford, designed by Sir Christopher Wren. The illustrated vocabulary is a valuable resource. The explanation of the derivation of the sundial begins with the North Pole – striped like a barber's pole, and then shows a vertical view down onto the turning Earth. Local time and the history of the introduction of GMT in 1880 are dealt with as are the equation of time, solar time, longitude and the analemma. Worked examples transforming sundial time into clock time ensure that this aspect is thoroughly explained. The last picture shows the midnight sun north of the Arctic Circle at Spitzbergen.



An example from 'Using and Understanding Sundials'.

This disc contains a new (at least to me) approach to demonstrating the basic concepts and theoretical background to sundials. An experienced dial delineator might discover nothing new but would nevertheless enjoy the colourful and often amusing explanatory slides. For anyone with the slightest uncertainty as to why or how things are as they are or who needed to demonstrate these principles to a lay audience, this CD is likely to prove very helpful. Even though the elementary talks I occasionally give on sundials take place in village halls without the hi-tech capability of using PowerPoint, I consider that the way in which the ideas have been put across would be useful to me in preparation.

Jill Wilson

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BSS NEWBURY MEETING - 24 September 2005

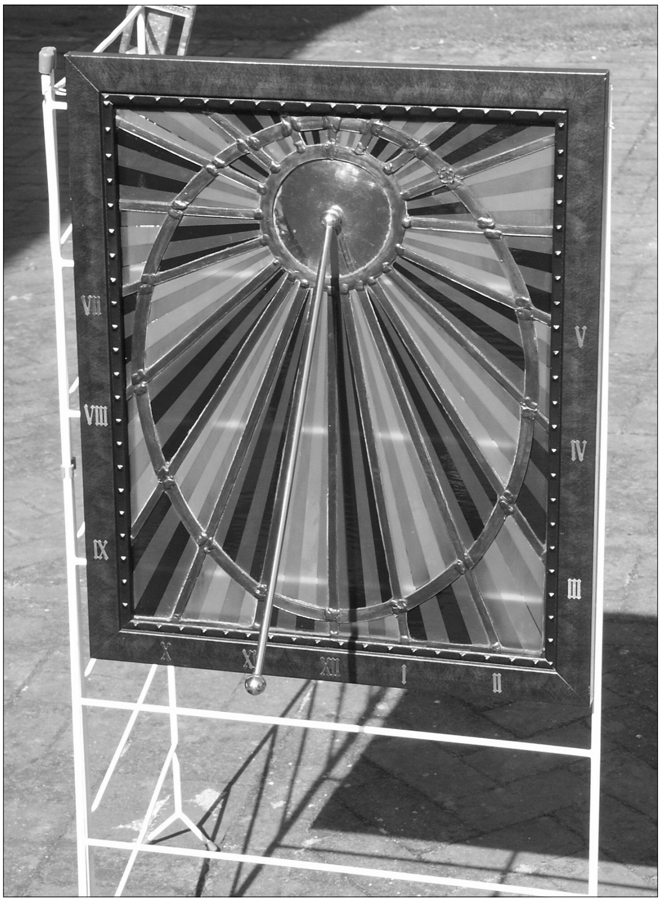
JOHN LESTER

Photo: M. Cowham

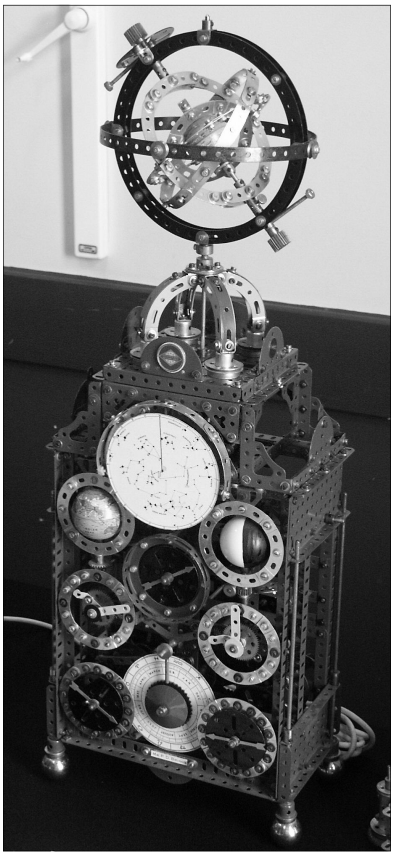
Bright sunshine welcomed 48 enthusiasts to the Mary Hare Grammar School for what was to prove one of the best ever Newbury meetings. Chairman Martin Jenkins kept the programme running smoothly and to time, introducing a varied and entertaining team of speakers. Geoffrey Lane began with a well researched account of the work of the 17th century maker of stained-glass sundials, Baptist Sutton, which added new information to the little that was previously known about him. He was followed by Mike Groom who explained for the computer literate how spreadsheets and CAD might be combined to facilitate the setting out of dials. Tony Wood then described some of the results of his museum survey which, in spite of the frequent difficulties in eliciting information, had unearthed some interesting discoveries. The morning ended with a change of key when Peter Ransom showed us how to construct our own origami equatorial sundial starting from a square sheet of paper. The ingenuity behind the design was impressive.

Peter Ransom and Martin Jenkins were stalwarts of the meeting.

Margaret Stanier, Bill May and David Young admire Heiner Thiessen's globe dial.



Alan Shuttleworth's colourful stained glass dial.



Patrick Brigg's amazing astronomical clock, all from Meccano.

After a break for lunch and a group photograph David Young took us on an illustrated tour of the Horniman Sundial Garden, describing not only the various dials to be found there but also the vicissitudes the project had undergone since it was first started. Dial recorders often meet the problem of estimating the declination of a dial and Patrick Powers explained how this might be calculated from the distance of the sub-style line from noon or the distance from six o'clock to the horizontal upper margin of the dial plate.

A collection of ornamental and desktop dials from Geoff Parsons.

Finally Peter Ransom took us to southern France where, in the village of St. Hippolyte du Fort, there had been an outbreak of sundial installation resulting in the construction of about 50 dials, of which 23 could be seen from the street.

The exhibits were as varied and interesting as the talks and following the formal programme 15 of the exhibitors described briefly what they had to show. Thanks to Bill Hitchings we had the opportunity of observing sunspots and prominences through telescopes equipped with Mylar and hydrogen-alpha filters. Mike Cowham had copies of his latest book, 'Sundials of the British Isles' which has been published as a limited edition of 600 copies, for sale to BSS members at a reduced price. Sundial makers had work of very high quality and restoration projects for us to examine, there was a collection of sundial ornaments (Geoff Parsons) and even some sundial embroideries (Peter Ransom). The mechanisms created from Meccano by Patrick Briggs were intricate and unforgettable. They included an orrery, timepieces which could show both solar and mean time as well as the length of daylight. One device had a dial which completed one revolution every 12.7 billion years ! Heiner Thiessen demonstrated his beautiful World Dial; Alan Shuttleworth showed us his carefully made stained-glass dial and there was much more which could be described if space permitted.

For all this feast of instruction and entertainment we were indebted, as ever, to David Pawley whose hard work and faultless organisation we acknowledged with gratitude.

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A SUNDIAL FOR A SCHOOL IN SOUTHERN SWEDEN

CURT ROSLUND and MARIE RÅDBO

How would you like to make your own metaphorical model of the evolution of cosmos that shows the sun parading on its daily path in the sky at all seasons of the year? The model could be either as a focal point of your garden, or in miniature on your sunlit writing desk. Here you can read how it can be done.

A SCHOOL FOR THE FUTURE

In the depths of the southern Swedish forests lies the small town of Hyltebruk where forest products are turned into manufactured goods. The pride of the town is its new school, Elias Fries School, built in anticipation of a low energy future with limited natural resources, but with more time for cultural activities. The school is small, built for 350 pupils between 6 and 12 years of age.

Great emphasis was placed on the question of how to fit the school into the landscape without spoiling the charm of the small country town. Elias Fries School does not look like any other school. There is no traditional, big building or asphalt schoolyard, just eight home-like schoolhouses set among trees, bushes and green grass. To one side, there is a pond full of goldfish with a little stream flowing through.

Science and art hold a particular standing at the school. One prominent work of art is a circle of tall standing stones, recalling a familiar type of prehistoric monument in this part of Sweden. By carving certain symbols and ideographs from science and culture into the stones, the artist Jörgen Frey has provided a link between past, present and future.

A SUNDIAL IS BORN

Another prominent work of art was to be a sundial built to harmonize with the ideals of the school. The chief architect of the school project, Birgitta Holmström, approached us to ask if we would be interested in designing the sundial. The task was an intellectual challenge. We were to be bound by strict stipulations. The design should be artistic and simple, of the right dimensions for school children and of a shape that would cause no risk to an adventurous pupil climbing on it. The sundial should be made from natural materials and with no need for daily attention. Moreover, its functioning should be so clear that most school children would understand it without special instruction but still be so intrigued that they would return on sunny days to watch the progress of the sun. The teachers should of course be able to conduct demonstrations with it of the movement of the sun in the sky. The sundial was not meant to be used as a clock or calendar but to show in a simple fashion how the sun moves during the day and with the seasons. Therefore, figures for neither time of day nor for time of year, were to be set out on the dial plate.

Sundials can be constructed in a number of ways depending on what is expected from them. After many lively and interesting discussions with teachers at the school and with Per Anders Lorick, the craftsman who was to build the sundial, we settled on a sundial with its shadow pin parallel to the earth's axis. It would have been natural to use the ground as dial plate but at the high northern latitude of 57 degrees for Hyltebruk, the shadow of a pin aligned with the polar axis would have been uncomfortably long in winter, when the sun at Christmas at midday only reaches an altitude of ten degrees above the horizon. We therefore decided to raise the dial plate twenty degrees up from the ground to face southwards forming an angle of 37 degrees with the polar axis.

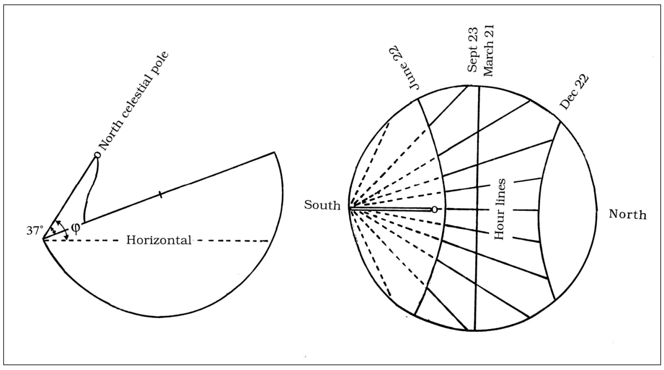

Fig. 1. Cross-section along the meridian (left) and drawing of the time network on the dial plate (right) of the sundial at Elias Fries School at latitude 57° N.

During the day, the sun moves along its daily path on the heavenly vault from the eastern to the western horizon, while the shadow of a polar-axis pin travels in the opposite direction on the dial plate. The sun's path in the sky changes slowly from day to day and the curve that the tip of the shadow pin traces on the dial plate alters accordingly. The sun repeats its behaviour year after year and returns on a particular date to the same path in the sky and the shadow of the polar-axis pin to the same day curve. On the equinoxes, about March 21 and September 23, when the sun crosses the celestial equator, the shadow path is a straight line at right angles to the meridian. In summer, the sun is seen high in the sky and the day curve on the dial plate lies south of the equinoctial line, and in winter north of it. The day curves for the summer and winter solstices, about June 22 and December 22, and for the equinoxes are shown in Figure 1.

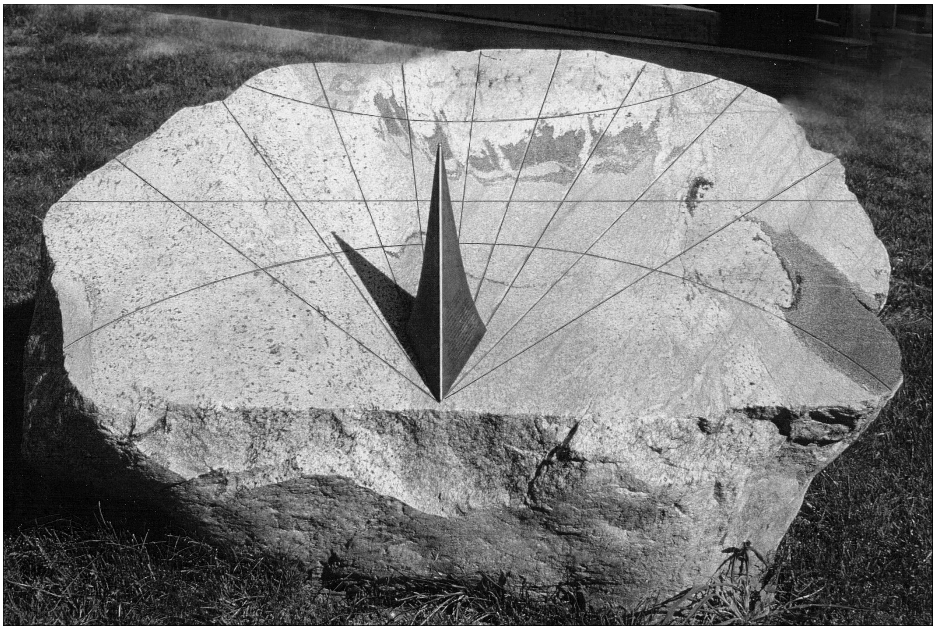

Fig. 2. The sundial at Elias Fries School photographed 10.26 am Swedish summer time on August 16 when the sundial showed 9.15 am true local time.

Next came the question of what material to use for the dial plate, which would occupy almost a whole square metre (1 square yard). Wood was thought to be too conventional and unimaginative. Then Lorick pointed out that there were plenty of big, almost round stones of the right size in the nearby forest. By cutting such a stone in two halves, the plane surface of either half would make an excellent dial plate with the rounded sides of the stone below the dial plate forming a firm stand for the sundial weighing about one tonne (1 ton).

An additional bonus would be the symbolic implications of working the stone into a sundial. The stone lying in the forest could be compared to a dormant cosmic embryo long before space and time existed. By cutting the stone in two halves, our universe would come into being with space created for matter to materialize and time to flow. By polishing the ragged, rough and uneven surface where the stone had been split, the grain of the stone would show forth and bring beauty and order to the surface, symbolizing the structure and harmony of the universe, that caused stars and planets to form and life to proliferate on earth. By engraving the time network on the stone's surface, man's determined and persistent ambition to explore and to map the universe is manifested. Finally, the surface of the stone will decay and crumble to dust, just as the universe will disintegrate and the light of the stars go out.

Due to the earth's daily rotation around its axis, the sun appears to go around the earth once every 24 hours. The position of the shadow of the polar-axis pin on the dial plate for all whole hours counted from the sun's meridian passage at midday are set out in Figure 1 as hour lines radiating from the base of the shadow pin rather like the spokes in a lady's fan. But remember that sundials never show clock time but true sun time at their location.

This model of a sundial with exactly the same pattern for the time network can be used all over the world as long as its shadow pin is properly aligned towards the celestial pole for that hemisphere where it is set up and its dial plate is mounted at an angle of 37 degrees to the polar axis. In the northern hemisphere, the dial plate would lie horizontally at a location 37 degrees north, facing south for a place north of this latitude and facing north south of it.

We decided to make the dial plate a circle with a radius of 500 mm (20 inches). The top end of a 400 mm (16 inches) long shadow pin fastened at the south point of the dial plate would then lie at a distance of 300 mm (12 inches) above the centre of the circular dial plate. These three simple measurements arise from the fact that the lengths of the three sides in a right-angled triangle with one angle 37 degrees are always related to each other in the ratio 3:4:5. This relationship can be used in constructing the sundial and for checking on its performance. With its help, it is not difficult to make the shadow of the top end of the polar-axis pin to fall right in the centre of the dial plate at midday on the days of spring and autumn equinoxes.

You yourself could make a sundial like the one described here at a size suiting either your garden or writing desk by rescaling the time network in Figure 1 to the dimensions you want. A stonemason would readily cut a plane surface on any stone you fancied, polish it and even engrave the time network on it. The polar-axis pin can be made from brass, tin or even wood and glued on to the stone. As long as the shadow on the dial plate is formed by the upper straight edge of the shadow pin, its base can be made quite broad to provide a firm connection with the dial plate. Next you place the stone so that the shadow pin points towards geographical north at an angle with the horizontal equal to the latitude of its location. Then you have a sundial of your own to enjoy at any sunny moment.

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THE CROSS DIAL BY C V BOYS
AT THE ROYAL BOTANIC GARDENS, KEW

D A BATEMAN

A subtitle for this note could be 'the wandering dial at Kew which has some mysterious errors'. The background is that during the 2005 conference at Egham, one of the coach parties visited the Royal Botanic Gardens to see the replica of the Tompion horizontal dial and the armillary sphere by Edwin Russell and Joanna Migdal. In the planning stages for the visit, it was hoped that we would also see the cross dial by C V Boys FRS. Unfortunately the Boys dial was in store, but investigations and more photography revealed that the dial had been set up in two locations, and that the engraved latitude and longitude on the dial has some surprising errors.

Fig. 1. The south side of the dial with the inscription recording the gift from C V Boys in 1929.

The dial is relatively well known as it appears in Cousins[1], one of the foremost books on sundials. The illustration used is given in Fig. 1 and the text commemorating the gift is in Fig. 2. The same photograph was used by Mills in his extensive article on the dials at Kew.[2] Mills included a photograph he had taken himself of a general three-quarter view of the north facing plane of the dial, and refers to the dial being in store. The same photograph as in Fig. 1 appears in Desmond's history of Kew.[3] The dial was erected in the Medicinal Garden in 1929, and Fig. 3 shows the dial in the formal beds.

The dial is a polar dial made from a series of bronze 'boxes' assembled in a cruciform and inclined so that edges are parallel to the earth's axis of rotation. Orthogonal edges act as gnomons and the hour markings are on a series of faces of the cubes. Being metal, it carries quite fine divisions of time down to 5 minute intervals. Unusually, the support of the cruciform is an inclined short pedestal, also in bronze. The more conventional arrangement of a cross dial is for one long arm to be the support and for the plane of the arm and cross to be inclined to the local latitude. Note also in the photograph that the dial seems to be rather oddly aligned on the capital.

THIS DIAL, DESIGNED,
CONSTRUCTED & ERECTED BY
C.V. BOYS, F.R.S.
WAS PRESENTED BY HIM TO
THE ROYAL BOTANIC
GARDENS, KEW

ENGRAVED BY H. ROUTLEDGE

THE STONE COLUMN TAKEN
FROM OLD KEW BRIDGE
WAS PRESENTED BY
GEORGE HUBBARD, F.S.A.

THE CAPITAL & BASE
WERE SUPPLIED BY
H.M. OFFICE OF WORKS
A. W. HILL, F.R.S. DIRECTOR
- 1929 -

Fig. 2. A copy of the text shown in the photograph in Fig.1.

It was reasonable to ask if the dial could be brought out of store for the occasion of the visit by Society members, but this was not practicable. However, not long after the initial enquiry, an unexpected letter said that the dial had been set up temporarily as a centre of a 'winter scene' at one of the entrances to the Princess of Wales Conservatory. This gave the opportunity to re-photograph the dial as in Figs. 4 & 5.

Although Mills and Desmond recorded the dial as having been set up in the medicinal gardens of Cambridge Cottage, these locations are not shown on the simple maps available to visitors. For a while Cambridge Cottage became the Wood Museum and is now called the Kew Gardens Gallery. Given that the latitude and longitude are on the dial to a precision of seconds of arc, it should be a simple matter to work back and pinpoint the location on a map - see Fig 6. However, it became obvious that both of the coordinates

Fig. 3. The dial on its pedestal in the old medicinal garden. Cambridge Cottage is on the right.

The Garden staff searched in their map records and produced a large scale plan that shows a formal garden surrounded by the boundary wall on the north side. This is the wall that can be seen in the background of Fig. 1: the other side of wall is Kew Green. To the west is Cambridge Cottage and to the east private property called Kings Lodge. The plan explains the first oddity about the dial. The plinth and pedestal capital are shown as diagonally aligned with the formal borders and the wall and to bring the dial to the north-south axis needed a rotation of 28º relative to the sides of the capital.

The full grid reference of the dial in this garden is 518935E and 177436N, and converted, gives 51º 28' 58.33" N and 00º 17' 12.95" E on the OSGB36 datum. From a mapping point of view it should be noted that OSGB36 came into use for all national mapping after 1936, but before then any discrepancies relative to the Greenwich Meridian will have been no more than a few metres. It is hard to explain the differences between the engraved values on the dial. They appeared to be in error, at least in respect of the medicinal garden. The longitude engraved on the dial would have placed it some 1.3km west of Greenwich, whereas the Gardens are actually 20km west, and the latitude is about 250m south of the correct location. This is very surprising.

Fig 4. The dial on temporary display for a 'winter scene' in the Princess of Wales Conservatory during December 2004.

Fig. 5. The north facing side with the tabular equation of time and instructions.

KEW
LAT 51° 28^{m} 50^{s} N
LONG 1^{m} 9^{s} W

TO FIND GREENWICH MEAN TIME
FROM THE SUN AT KEW
ADD(+) OR SUBTRACT(-)
THE NUMBER OF MINUTES IN
THE FOLLOWING TABLE
SUMMER TIME IS ONE HOUR MORE

Fig. 6. Transcription of the instruction for finding mean-time. Note the ligature (combining) of the M and E, and the engraving seems rather 'tentative' for minutes and seconds of the latitude compared with the clear engraving of the same for the longitude.

do not appear to contain any hint of a typographical error such as a transposition of numbers, or obvious mistake. If they were intended as a generalised latitude and longitude of the gardens, then why give them to such precision?

The gardens around Cambridge Cottage have undergone a number of changes, but from a sundial point of view, it was not a good location, with buildings close by to the east and

Fig. 7. The dial set up in 1972 in a location near to an area then known as the Ferneries.

west. The dial was moved in about 1972 to a location south west of the then Ferneries. The maps of the time enable the grid reference to be determined as 518754 E and 177332 N, but the best local landmark is opposite the rare tree, the 1761 *Ginkgo biloba*. Figure 7 shows another photograph from the archives of the dial in this location, dating from about 1975. It would appear that the plinth was moved as well! It looks very similar to the one in the medicinal garden, and there is a telltale mark below the pedestal which suggests it has been turned through about 45º to suit the new position. The pedestal appears to have been cleaned. Advice from the Gardens is that the dial was removed in 1985 and put in store. The site around the area has been considerably altered, partly in association with the building of the nearby Princess of Wales Conservatory.

An interesting footnote concerns the pedestal. One of the most prolific sundial makers in the period 1848 to the 1930s, Francis Barker & Sons, featured Kew Bridge Pedestals and replica Kew Bridge Pedestals in one of their catalogues of about 1910. The second bridge over the river Thames at Kew was demolished and the third bridge opened in 1903 by Edward VII and Queen Alexandria. One assumes that perhaps 100 or so balustrades became available to be re-used in various applications, including pedestals for sundials. It is interesting that the demand must have been sufficient for Barkers to have had replicas made at half the price of the bridge balustrades. The price of a "Kew Pedestal in old stone with 8 inch horizontal dial: £10 10s", and a 'facsimile' was half the price. The company is still in existence making prismatic compasses for military and civilian applications.

Cambridge Cottage features in the early history of Kew, with the following taken from Desmond's comprehensive history.[3] Formerly the home of the Lord Bute, Princes William and Edward moved into the west wing in 1772, and in 1801 Frederick, the son of George III was created Duke of Cambridge, and he received Cambridge Cottage as a residence in 1806. There had always been a strong royal connection with the gardens, and on the Duke's death, the King agreed in 1904 that this royal property could be used as "a Museum of Forestry, quarters for staff...". In 1907 work was started on altering the gardens into a geometrical medicinal herb garden. In 1967 the garden was changed again to give larger beds for herbaceous plants. In 1992 changes continued and now the former formal beds have given way to lawns and Cambridge Cottage, and its pleasant garden, is available for hire for events such as wedding receptions.

Professor Sir Charles Vernon Boys FRS (1855 - 1944) was one of the leading experimental scientists of his time. He wrote a book on soap bubbles as a means of illustrating the effects of surface tension, and achieved fame with his applications of very fine quartz fibres to measure extremely small forces and the gravitational constant.[4] He also pioneered high speed photography of lightning flashes and rapidly moving objects. In his later years he became interested in eradicating broad leaved weeds from his lawn, and published *Weeds, weeds and weeds* in 1937. One assumes that this may have led to a close association with Kew, either for botanical reasons or acquaintance with the then Director of Kew, Sir Arthur William Hill, FRS, who was Director for the period, 1922-41.

In conclusion, it is unlikely that the mystery of the engraving error will be solved. Even so, the origins, workmanship, and rarity of cross dials make this a fine example of its type, and it is likely that the dial will be put on permanent display in the not-too-distant future.

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All the staff in the following departments - Horticulture and Public Education; Archives; and Building and Maintenance - have been extremely helpful. Figures 1, 3 and 7 are official photographs. Also to Allan Mills for additional biographical details of C V Boys.

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SUNDIALS AT THE UNIVERSITY OF LEICESTER

ALLAN MILLS

An 'Eye of Time' noon mark has now joined three other unusual dials on the campus of the University of Leicester. Two metres high, with a shape defined by two offset ellipses, its hollow structure gives a modern sculptural appearance reminiscent of some of the works of Barbara Hepworth and Henry Moore (see Fig. 1). It is set facing south, so that a midday sunlight enters through a small hole to form an image of the solar disc upon and analemma incised within the interior (see Fig. 2). Time of year as well as time of day is therefore indicated. Theory has already been covered,[1] and an earlier example illustrated.[2] This work complements John Davis' figurative 'Newton' dial in bronze, set in the courtyard of the Space Research Centre. John has already described this dial, the result of a collaboration with the sculptor Vanessa Stollery.[3]

Two matching vertical declining dials in Westmoreland slate may be seen above the entrance to the Bennett Building of the Department of Geology. One indicates equal hours; the other, the less familiar seasonal hours.[4]

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Fig. 1. 'Eye of Time' noon mark at Leicester University. In Portland limestone on a base of Clipsham stone.

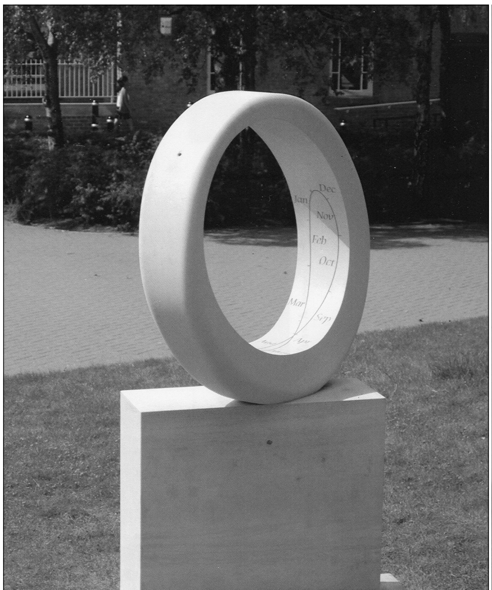

Fig. 2. Analemma incised within the sculpture. All carving was accomplished by Fairhaven of Anglesey Abbey Ltd.

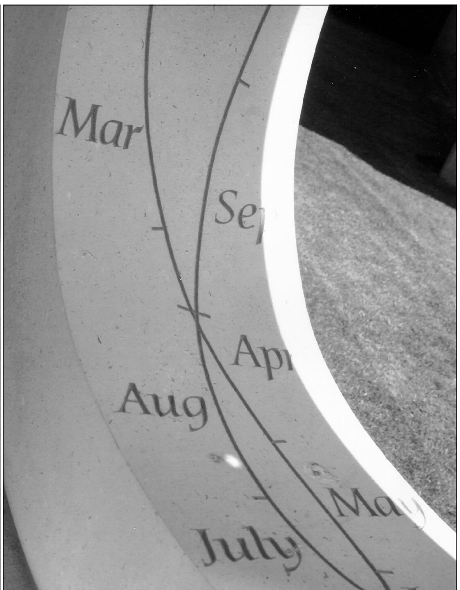

Fig. 3. The sunspot on the analemma.

BSS GRANTS POLICY

INTRODUCTION

The BSS Council has approved the following policy on grants for sundial projects, with immediate effect. The total amount of money likely to be available for grants is around £500 p.a. Members are invited to submit proposals for projects to the Council.

POLICY

1. All grants will come from the BSS Andrew Somerville Memorial Fund (ASMF). This (virtual) account receives all donations made to the Society in the form of gifts, legacies, proceeds of auctions etc. The first call on the ASMF is to fund the annual Andrew Somerville Memorial Lecture and grants will only be given if there is a sufficient reserve in the fund for this purpose.

2. In addition to receiving donations to the BSS, the ASMF can also receive an annual transfer of up to 25% of the amount the Society receives in Gift Aid from the Inland Revenue in that year. The transfer will only occur if there are suitable projects approved for grants.

3. Requests for grants from the ASMF must be made in writing, via a BSS member, to the Treasurer. Decisions on whether to make a donation, and how much, will be made by the BSS Council. The decisions will normally be made as part of the normal tri-annual Council Meetings but, exceptionally, urgent requests can be dealt with by correspondence.

4. Donations may be made towards the cost of:

i) Educational activities. This may include the costs of leaflets and signage to accompany public collections of dials. It may also cover expenses of exhibitions and presentations on dialling to groups of the public. The request must document:

a) details of the event, display etc.

b) the proposed items to be funded, including total costs, sources etc.

c) the amount requested from the BSS and details of other sources of funding.

ii) Restoration of significant sundials which are publicly owned or are owned by non-profit-making organisations and are on public display. The request must document:

a) details of the dial, its ownership and history.

b) the proposed work to be performed, costing details, and who will perform the work

c) the amount requested from the BSS and details of other sources of funding.

5. Donations will not normally be made for:

i) The purchase of new sundials. An exception to this is replacement of stolen dials which would be covered by 4(ii), or to allow such dials at risk to be removed to a place of safety.

ii) Restoration of privately owned sundials.

6. The Council may defer a request to a subsequent year if sufficient funds are not currently available in the ASMF.

7. The size of any grant should generally not exceed 50% of the cost of the work/item.

8. It is a condition of making a grant that the proposer will provide full details of the finished project for publication in the BSS Bulletin and elsewhere, and will record any fixed dial in the BSS Register.

Approved by .... BSS Chairman. Dated 13/10/05

(C. St. J. H. Daniel)

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