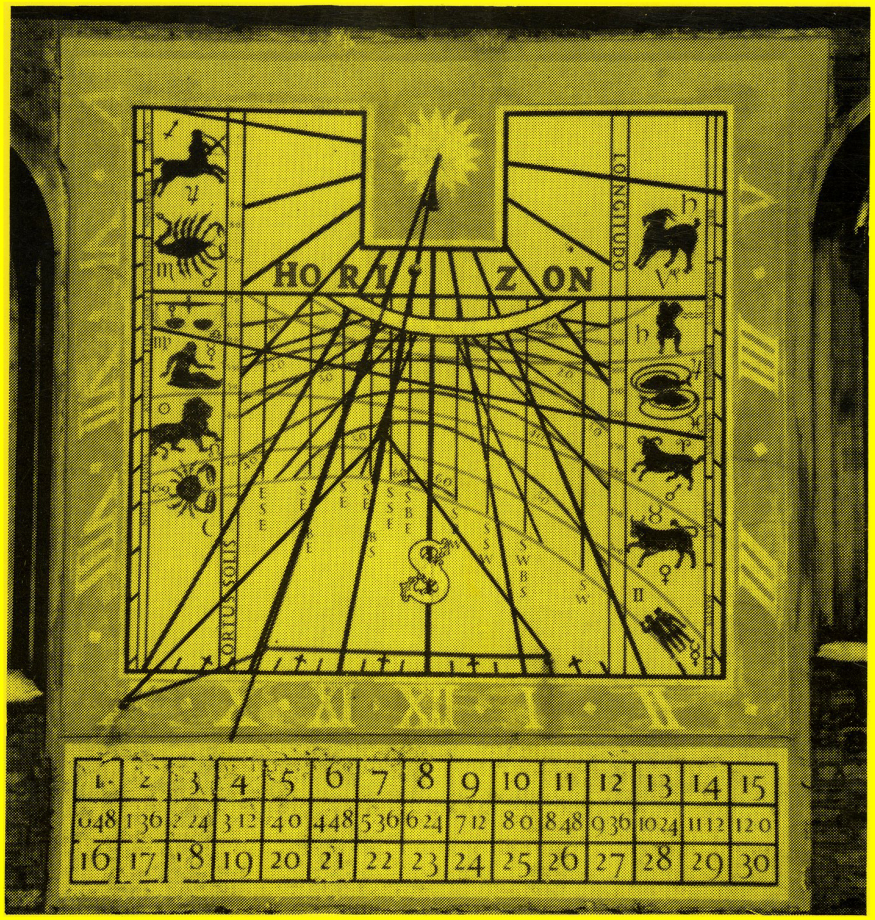
The British Sundial Society



BULLETIN

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Cover Illustration - The Queens' College Dial, Cambridge. See page 2 for details of this world-famous dial, with the lunar table to enable the time by the moon's shadows to be ascertained.

DIALOGUE

DE ZONNEWIJZERKRING

There are only 14 pages of editorial text in Issue 94.2, in which the main article deals with the Little Shop of Venice dial, and in particular the two which have special scales on the back of the instrument for indicating unequal hours. One is made for latitude 48·5°, perhaps Tübingen in Germany where Oronce Finé studied. The other is in Florence and made for latitude 52°, possibly made in Oxford, England, to the instructions given in MS Bodley 68. It is strange that the indication of unequal hours should be deemed desirable at this late period.

However there are another forty pages devoted to a three-part presentation of the contents of De Zonnewijzerkring from its inception (Bulletin 78.1) to the present penultimate issue (Bulletin 94.1). It commences with a listing of all the Bulletins and the outstanding area in each, followed by a page listing the authors (82 in all). Next is a 14 page listing of the main contents of each Bulletin. It is interesting to see that until November 1983 the pages ran on consecutively until reaching 930, in the February 1984 issue it restarted at 101. But by the June 1984 issue, reason prevailed and since then each De Zonnewijzerkring Bulletin has commenced at page 01. The number of issues in a year can vary, for example 1982 was a bumper year with five Bulletins.

The next listing is that by subject. This will probably be of the greatest utility for those carrying our research. However, the listing of authors, each with a list of the articles by the author, is most useful. The very great contribution made by M. J. Hagen immediately springs into view with two full pages of his listed articles. J. A. F. de Rijk requires only slightly less space for his listing. F. J. de Vries and H. W. van der Wyck have also made magnificent contributions. Only one British author is shown, our late Chairman, A. R. Somerville, with four articles to his credit.

One can only express amazement at the amount of dialling knowledge which is deposited in past issues of De Zonnewijzerkring, and the great erudition displayed by the many authors. What a great pity to BSS members that all this is expressed in the Dutch language and inaccessible to the great majority. Let us look forward to the day when English summaries to the articles are included as the norm instead of the exception. Also it would be a great improvement if De Zonnewijzerkring could be produced in a similar style to that of the BSS Bulletin, that is, printed and not photocopied. The quality of the written material deserves better support in the form of better quality illustrations.

CHARLES AKED

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LA BUSCA DE PAPER

Issues No 15 and 16 for 1983 were received too late for reviews to be included in BSS Bulletin No. 94.2. They are each double numbers since each contains another section of the continuing list of dialling terms in eight languages.

Issue No 15 is devoted to one main article entitled "A Reliquary Sundial". This was originally published in Spanish in the journal *Revista General de Marina*, Volume 157, September 1954. This is a small reliquary in the form of a *crux immissa* or Latin cross. This was placed in the Naval Museum of Madrid and was the gift of the Spanish ambassador in the Vatican, Mr. Ponca de León. The cross has numerals and hour curves on all the outer surfaces. The article goes into detail about all these.

The inside of the cover bears the inscription "A. Zeelft, 1572". A ring on the upper part allows the device to be hung from the neck of the owner. What relics were held in the cross is now unknown, possibly something from a loved one such as a lock of hair. It may have had some religious relic since the cross came from Vatican, but such items are generally kept by the church.

Issue No 16 has more articles, the first being about the sundials at La Savina on the island of Formentera (Balearic Isles). This is in the form of a Tower of the Winds, the sundial on each face being 2·5 metres high by 1·2 metres wide. Apart from the north dial, the gnomons are vertical to the dial planes. The dials were installed in 1992 on a small traffic island just off La Savina.

On page 3 is an article on a book, *Sonne, Zeit und Ewigkeit - Alte Sonnenuhren* by Heiner Sadler, Dortmund, 1983. (Sun, Time and Eternity - Old Sundials). This is a pocket book of 104 pages containing 69 dials, mostly German. The oldest is dated 822 on the church of Saint Michael in Fuida. The English translator did not think it worthwhile to translate the title of the book.

Next is an article on the restoration of two sundials in the cloister of the Minim Convent at Muro (Majorca). They are thought to be dated 1779 but fell into disrepair when abandoned by the Minim Order. They have now been restored by the Muro Town Council.

This issue ends on a sad note addressed to English speaking readers. From issue No 4, three languages were published in *La Busca de Paper*, including English. Only six English readers subscribed, and so reluctantly, from 1994, there will be no more English translations included. This is a great shame since these translations had improved out of all proportion with the translations of William Bain. The earliest English translations were often useless. The BSS Editor's offer to correct these before publication was never taken up.

If the same argument was used with the BSS *Bulletin*, many articles from overseas authors could not be printed, but the cost of the resumés in the BSS *Bulletin* in even one language would be intolerable and could not be sustained.

The index of dialling terms has got as far as CY. At this rate the present Editor of the BSS *Bulletin* is unlikely ever to see the last entries in the listing, but it is a magnificent attempt to make all these terms available to the major countries in Europe. Perhaps these will be published as a separate book at some time in the future.

If any BSS member feels that he or she could review this publication, (translating from Catalan or Spanish, the Editor would be pleased to have this assistance. It generally has eight pages, so it is not an arduous task.

* * * * * * * *

Please see pages 43 and 49 for details of the North American Sundial Society's Bulletin.

THE QUEENS' COLLEGE DIAL, CAMBRIDGE

CHARLES K. AKED

No one who visits Queens' College, Cambridge, can fail to be impressed by the large painted sundial in the Old Court as shown in Figure 1. It is not the first dial installed in the College, however little is known of the earlier examples except that these were not as elaborate. All the dials installed on this wall appear to have been painted on the surface, ie. there are no incised lines to guide the restorer when correcting the ravages of time.

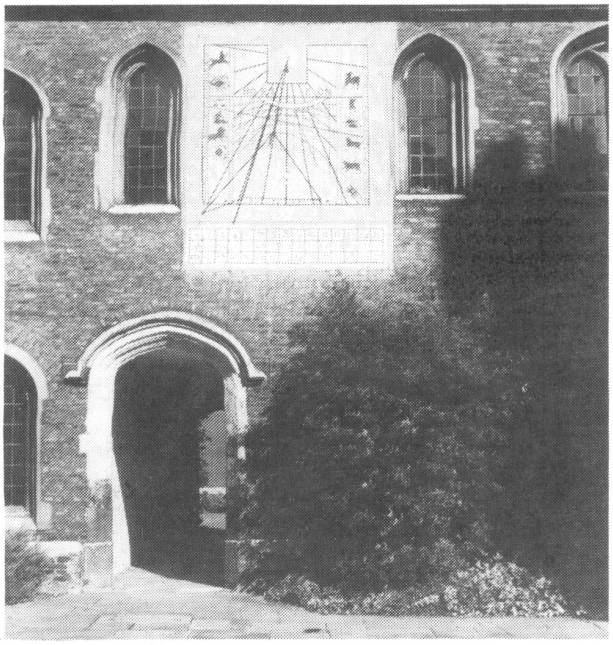

FIGURE 1: The Queens' College dial in the Old Court.

The first illustration of a sundial on this site is found in *Views of Cambridge*, Loggan, 1675, whilst the earliest records in the college about a dial on the chapel wall occur in the Bursar's accounts for the year 1642. This account is a little ambiguous although the details appear to be the expenses for the refurbishment of an existing dial:

For stone and work about the chapel dial.....	£1 14s 6d
For gilt for the dial	£0 4s 6d
To the painter for the dial	£0 5s 4d
For the cock of the dial	£0 18s 0d
For the oil, white lead and hire of hair cloths	£0 6s 0d

According to M.M. Scarr in his pamphlet - "The Dial in Old Court, Queens' College", this was for constructing a new sundial, the first item being for providing a flat stone surface for the painting of the dial. As the total cost for the dial would only have been £3 8s 0d, this seems too small for an entirely new dial, and it would have cost much more than 5s to set out an entirely new dial, even in those far off days. As the area covered by the dial is about 7 x 6 feet, £1 14s 6d for suitable stone and fixing it in place seems insufficient, for the outer bricks of the building had to be removed to allow this layer of stone to be inserted. The expenses were probably no more than for repairs and restoration of an existing dial. In 1968 the surface of the stone was no longer smooth enough to take the painting of the dial and it was rendered with a layer of cement mortar. This of course destroyed the painting of the previous dial, the present dial is an reproduction made from the measurements taken of the old dial before its destruction. This is not quite so bad as it may seem because by 1860 the sundial had been so badly looked after that it was derelict, with its iron gnomon rusted away almost completely. The present gnomon is replacement and is a rather ungainly piece of ironwork which casts a multitude of misleading shadows. On the active portion of the gnomon is a small wooden ball painted gilt, to which reference will be made again later in this account.

Mrs. Gatty puts the date of the dial at 1733, for the college records show that the dial was repainted in that year, but it may have been more than a straightforward repainting because the dial was expecially admired by those who saw it on completion. Since the dial existed in this place before painting, the restored dial could hardly be considered new even if greatly altered.

Old records abound with the details of the repainting of sundials but it is rare to find any continuous sequence of this continuing process. The gilt ornamentation might last twenty or more years in outside conditions, whereas the linseed oil and lead pigments of the old paints could not last above ten years without serious deterioration and loss of protection to the surface beneath, hence the frequent necessity for repainting. Even with more modern paints, the dial has been repainted six or seven times in the present century, and modern synthetic paints have much more staying power than the old. Of course some colours are more fugitive than others.

Tradition would have it that Sir Isaac Newton designed this dial. Obviously the dial existed much earlier than him and like many of the Newton attributions, it is completely without foundation. If Mrs. Gatty's statement is true, then the dial was after Newton. It is true that many college undergraduates amused themselves by applying their mathematical knowledge and skills to the art of dialling and often presented a dial of their own particular design to their college. Newton does not appear to have been one of these. Besides Newton was a Trinity College man and would not have contributed to a rival Cambridge college. Perhaps Newton's studies to discover the laws governing the motion of the moon have given rise to this erroneous tradition. In the Great Court of Trinity College is a rather superior type of garden horizontal dial near the College chapel, the pedestal of which was built in 1704, the dial plate on it was made by Troughton of London circa 1750. So Newton did not even choose to embellish his own college with a sundial of his own design.

DESCRIPTION OF THE DIAL

Within the confines of the Old Court, one is in the oldest part of Queens' Collge where the ambience of tradition and age can almost be felt as a physical force. The large sundial (about 7 x 6 feet) dominates this small area, see Figure 2. The overwhelming impression is that of the pale blue border rather than the greatest extent of the central white area, mainly because of the jumble of lines delineated upon it and the shadows cast by the black-painted gnomon and its two supporting struts. The root of the gnomon originates in a gilt sun-burst, as do the hour lines for the Roman numerals painted gilt on the blue border. The subdivision into quarter hours is by short black strokes, with a short cross stroke to distinguish the half-hours but only along the

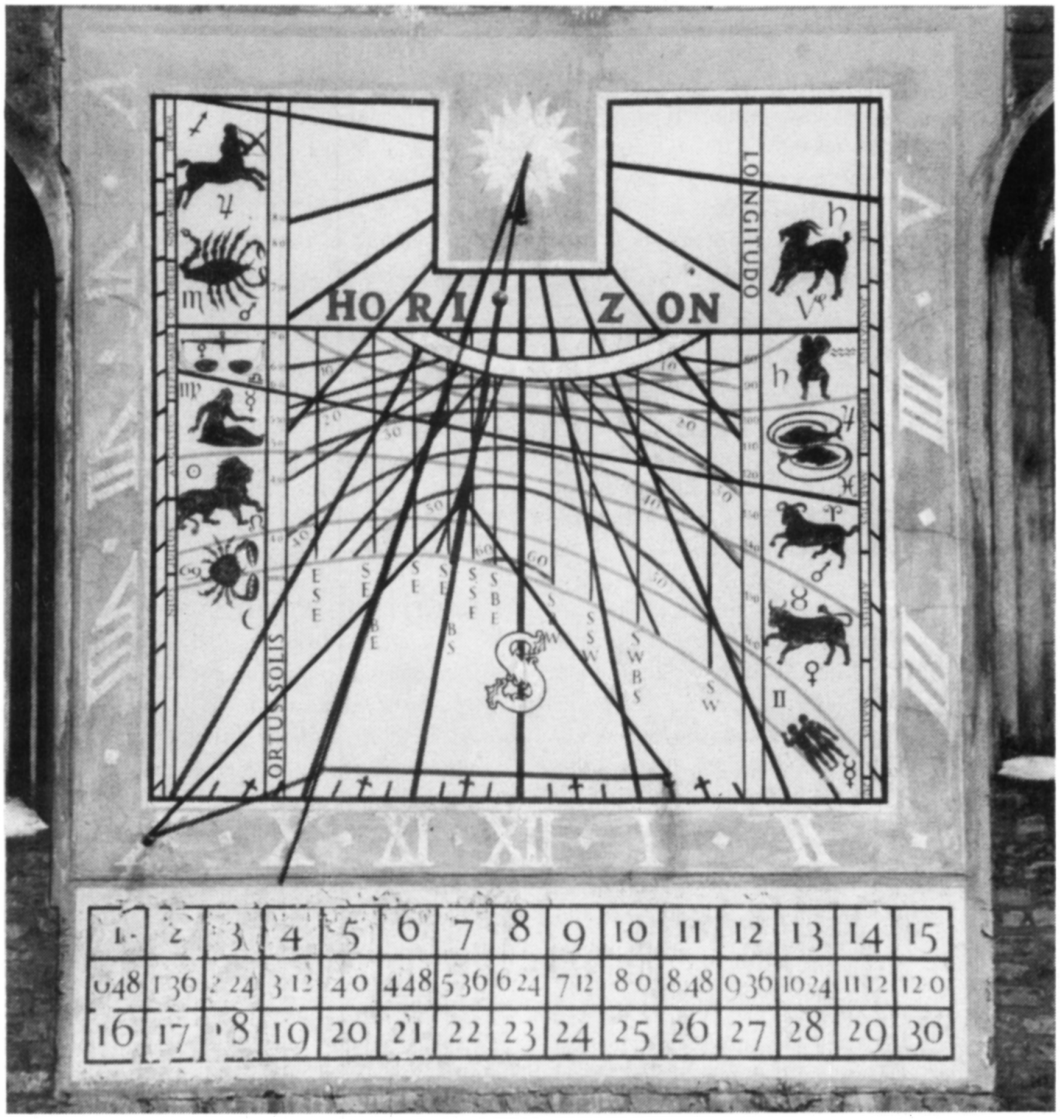

FIGURE 2: A closer view of the Queens' College dial

horizontal scale. Gilt lozenges emphasize the half hours between the hour numerals.

Of course the indication on the dial is true solar time for Cambridge. As Cambridge is almost on the zero line of longitude of Greenwich, no correction for longitude is required, however to convert Cambridge solar time to the more prosaic Greenwich mean time, the Equation of Time correction needs to be applied to the dial indications. Additionally, as the dial is consulted mostly in the summer period, an hour has to be added to the dial indication and equation correction to determine the appropriate British Summer Time. It is better to look at your quartz crystal watch, which will take only a second or so, because there is no table for the Equation of Time corrections placed near the dial. This would have been a much more useful addition than a moon table of dubious value, of which more anon.

The months of the year (delineated in Latin) are contained within a very narrow border between the hour subdivisions and the zodiacal signs in a vertical strip on each side near to the numerals. There is conjecture that the months were designed around the Julian and not the Gregorian calendar, however the dial is not so closely laid out that it makes much difference in spite of the present discrepancy of about 16 days between the two calendars. The date is read on the dial by the shadow of the gilt ball on the gnomon on the green lines extended to the month signs. It is of dubious accuracy for the curves are not quite correct, it is almost impossible to arrive at the correct calendrical date from the dial indication.

THE ZODIACAL SIGNS

The zodiacal signs are painted in red in clockwise rotation from upper right:

Capricornis, Aries, Aquarius, Pisces, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius.

Each zodiacal sign has its associated symbol and planetary symbol in close proximity. Before 1968 some of these details were missing and were replaced in the restoration of that year.

The zodical signs, essential for astrological purposes and given prominence here, have become frozen in time because the star constellations giving rise to these signs are rotating slowly around the earth with a period of about

26,000 years because of the phenomenon known as precession which affects rotating bodies. The signs were drawn up when Aries was the constellation when the sun crossed the equator at the time of the equinoxes in ancient times, ie. about 200 BC, it is known as the "First point of Aries". Since then precession has moved through about 30° of its cycle and so the same occurrence is now in the constellation Pisces. The astrologers continue to prognosticate on the planetary positions as though no change has taken place; the resulting inaccuracy is not of the slightest inconvenience.

The sign of the zodiac is read from the dial by considering the shadow of the gilt ball and the green curves, of which the inclined black line from Libra to Virgo is to be considered as a green line. (The fact that this black line is almost parallel to the V-V of the hour lines is merely a fluke, it is not of significance). One must also know the time of the year since from 21 December to 21st June the days are growing longer and the astrological signs on the right are to be consulted. From 21st June to 21st December the days grow shorter again and the signs on the left are then used. Hence the splitting of the month December at the top, and the corresponding division of June at the bottom of the scale of months.

One has to remember that the signs are for astrological purposes only, it does not correspond to the actual position of the constellations in the night sky. These signs are still of importance to those who believe in astrological predictions, ie. those who read the daily prognostications to be found in most daily newspapers. If the signs are favourable, by all means believe them; if they are gloomy, then regard these as mere superstition for the weak-minded.

The black lines emanating from the point of crossing of the horizontal line and the vertical line indicate the old temporary hours which lingered on even after mechanical clocks were introduced and became common. The daylight period was divided into twelve equal parts, the length of these varying with the season. This system was quite unsuitable for use in northern climes which have such a large variation in the length of daylight throughout the year, it fails completey near to and beyond the Arctic Circle. The transition from one time measuring system to another would take a very long time since older people find it very hard to assimilate something which is replacing a very familiar method. No one has ever managed to persuade the British nation to accept the twenty-four hour clock, for example.

To prevent what would become an utter confusion of black lines, the temporary hour lines are terminated at the golden arc below the horizon line. This area is of no purpose for indications in any case except that it obliterates the line which could have indicated winter solstice.

Two narrower bands on the inside of the zodiacal bands carry "LONGITUDO" on the upper right and "ORTUS SOLIS" on the lower left. The Longitude scale is supposed to give the duration of the day in hours and minutes between sunrise and sunset. The "Ortus Solis" scale indicates the time of sunrise and is read by use of the green lines and the shadow cast by the gilt ball on the gnomon.

The horizontal black line about a quarter of the way down the dial is the "HORIZON", whilst the inclination of the gnomon from the vertical indicates that the dial is a declining one, ie. the wall on which it is delineated is not facing south but is inclined towards the East by about 15°. As a result the dial is arranged to show the hours from 5 in the morning until 5 in the evening (it will do this only at the equinoxes and a lesser range during the rest of the year) instead of the normal 6 in the morning to 6 in the evening of the true south-facing vertical sundial.

The writer has not been able to check the restrictions on the dial indications imposed by the surrounding buildings but the dial is fixed fairly high and only the morning and evening limits of the sundial should be affected, much depending of course upon the season of the year, see the dark shadow to the left of Figure 1 at 10 a.m.

AZIMUTH OF THE SUN

Ther is a set of vertical black lines dropping down from the horizon line which have letters at the lower end which correspond to the reading on a magnetic compass scale. The shadow of the gilt ball on the gnomon falling on these lines gives the bearing or azimuth of the sun at any particular time of day. Between the lines one has to make an estimate of the position.

ALTITUDE OF THE SUN

This is read from the dial with the help of the red curves and the shadow of the gilt ball on the gnomon. The curves have the values ten to sixty degrees indicated by numerals at both ends of the angular height curves. The lines for seventy and eighty degrees are too short to be worthwhile including.

There is a large "S" below these curves to indicate South, merely as an added embellishment, it should not have been placed on the dial but does help to fill up an otherwise vacant space in the centre of the dial. The dial painter made a real effort to make it decorative but did not quite succeed.

THE "MOON DIAL"

The Queens' College dial is often referred to as a "Moon dial" but this is quite misleading, it merely has a table below the main dial to help in the converting of any shadows made at night by the light of the moon into meaningful hours. The table is more to impress than for utility since the moon cannot cast a shadow which can be distinguished until about the time of the first quarter, and similarly after the third quarter when the light is insufficient again. In fact, in the Old Court as it is at the present time, even in the most favourable conditions of atmospheric conditions and phase of the moon, the artificial illumination quite obscures any indication made by the moon. On Friday 24th September, 1991, when the moon was at its most brilliant (being the Hunter's Moon), the illumination inside the Old Court had to be extinguished for the members of the British Sundial Society to be able to see any shadow cast by the moon on the dial, and it also required a dark adapted eye.

THE "MOON TABLE"

The table is based on the fact that the moon completes its monthly cycle on 30 days (actually about 29½ days) and rises about 48 minutes later each night. Commencing at zero error on the first day of the full moon, the figures below the days have to be added to the indication of the dial given by the moon. Since the moon's cycle is very complex as a result of it being the lighest component of the Sun/Earth/Moon system, the resulting accuracy is very poor, thus it gives a guidance rather than a time indication.

One has to know the basis on which this table is drawn

up and how it is to be applied. At full moon the error is taken to be zero, seven days before full moon the moon gives an indication on the dial which is 5 hours 36 minutes fast, therefore this must be deducted from the dial reading to obtain the time. Seven days after the full moon, the same amount must be deducted from the reading on the dial. The varying errors of the moon cycle are ignored.

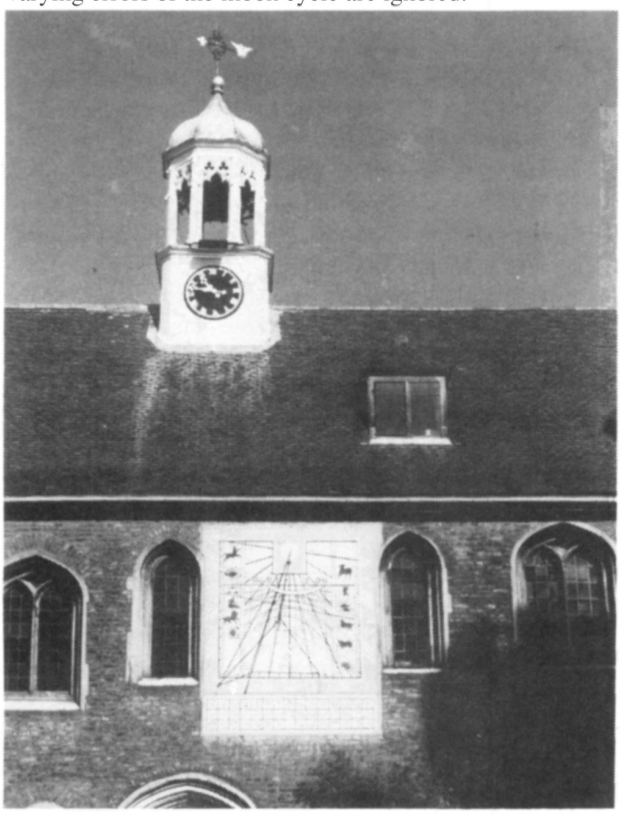

FIGURE 3: The Queens' College dial with the clock cupola above.

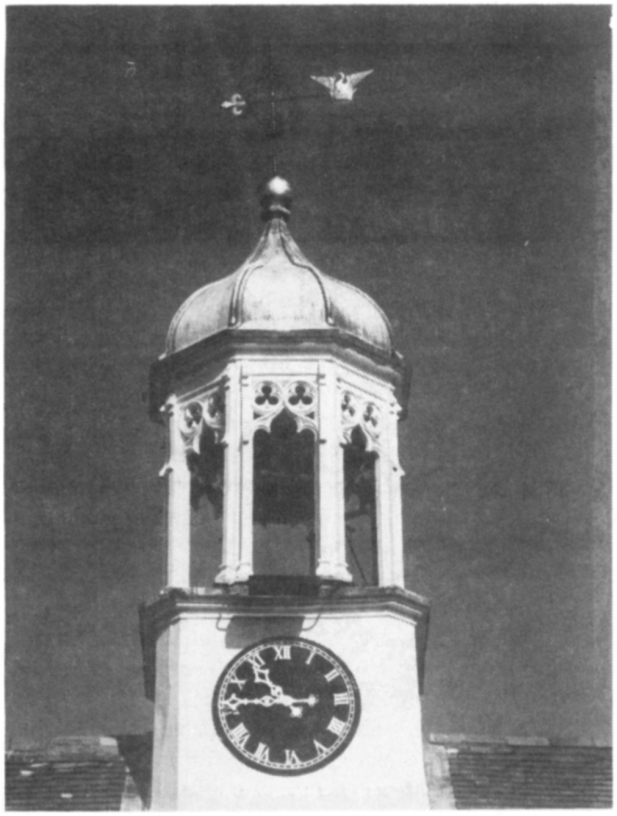

FIGURE 4: The clock cupola in Old Court, the dark shape under the dome is the clock bell for sounding the hours.

In the pamphlet by M.M. Scarr, the explanation of the moon table is not really made clear. For a time the writer thought the order of the figures for the table was incorrect, especially as he had received some queries about the moon table. The apparent jump from the 15th to the 16th day is caused by the division of the day into two x 12 hours. Nevertheless the table appears to be in error because the sequence should be the full moon at zero with a diminishing series of values before the full moon, and a set of increasing values after the full moon. If day one in the table was the date of the full moon the table commences quite correctly with 48 minutes on the day after the full moon and increased up to 5h 35m on the 7th day after the full moon; these values to be added, after which the moon's light becomes insufficient. The 30th day should be zero which it is in the actual table because it has gone through twelve hours. However to make sense the value of time shown in the centre row has to be deducted from 12 hours and this answer deducted from the indication on the actual dial by moonlight for days 23 to 30. A better way would be to insert 0 on the left of the upper row and place the 30 of the lower row under this and reverse the sequence until day 16 comes under the column headed by 14. The same values for the seven days after the full moon would then apply to the seven days before the full moon but with negative values.

The table is actually arranged to indicate from new moon to new moon, and the zero position occurs on the fifteenth day when the full moon shines, so the cycle would cover from day 8 to day 22. Hence the confusion in the table as painted on the dial without some guidance given to the observer. M.M. Scarr in his pamphlet treats the full moon as being on day 15, which makes the lower row in the table correct but this then apparently transfers the errors to the top row. In actual fact if the values shown are added to the reading on the dial, for example on day 14, the day before the full moon where the figure is 11h 12m, this is like subtracting 48 minutes from the dial reading and thus the table is absolutely correct as shown. On day 8 the value is 6h 24m, which when added is equivalent to subtracting 5h 36m. One of course discards every block of twelve hours from the additions made. Adding is a much simpler operation than subtraction.

By the time the average gnomonist has worked out the hour from the moon table and dial indication by moonlight, providing he has not left his calculator at home, it is more than likely that dawn will have broken and the shadow of the moon replaced by one from the sun. About half of the figures in the moon table have no significance at all since the moon is never bright enough to make a useful sahdow on those nights. F.W. Cousins refers to the table as supervacaneous (get your dictionary out). Because there is no hint on the dial itself on how to obtain lunar time, the best that can be said about the "moon table" is that it adds at little extra decoration to the dial and no doubt impresses the gullible. Unless the observer knows exactly how to arrive at the solution and has knowledge of the moon's age plus an ability to perform mental arithmetic, he will be wasting his time in trying to work it out. The moon table is of little use at night because it is hard to read the figures in the dim light of the moon. In any case, there is a clock dial on the roof just above the dial which is illuminated at night for those who do not have the necessary expertise, and for those nights of the month when there is no moon available to illuminate the sundial, see Figures 3 and 4.

Perhaps it might be worthwhile to mention why the error is zero at full moon. Disregarding the error of the moon indications in losing about two minutes an hour, at full moon the moon is situated on the far side of the earth from the sun and is directly opposite the sun, it is precisely twelve hours out of phase with the sun and receives the full illumination as seen from earth. As the moon is turning around the earth in almost twenty-four hours, it is a near enough substitute for the sun when full if the night sky is clear. At new moon it is between the earth and the sun and runs almost in phase with it, with the dark unlit side facing the earth and nothing can be seen. (The moon's orbit is inclined at about 5° to that of the earth's and because the moon is so small, it does not cause an eclipse to be seen on earth except on rare occasions). At new moon the error is also zero but the daily extra time of about 48 minutes to reach the same point after 24 hours time gradually adds up to 24 hours falling behind in about 30 days to complete the Moon's cycle. So there is no real mystery about why an ordinary sundial can be utilised to interpret the time from moonlight. The fact is that with the severe light pollution of the present time, not many of us today can witness the night sky clearly enough to distinguish the natural phenomena once taken for granted by our forbears.

In September 1991 the colours of the dial were beginning to become wishy-washy through deterioration of the paint and in fact the brickwork below the dial was stained with colour leached out from the dial surface. The same effect can be seen on the roof of the building where paint from the clock cupola on the ridge has stained the tiles immediately below. The dial thus has a rather faded look about it a few years after being repainted and many of its features recounted here are scarcely visible to the ordinary viewer without a pair of binoculars.

THE MECHANICAL CLOCK

It has been suggested that this dial may have been erected as a check on the mechanical clock installed in a cupola on the roof almost directly above the dial, see Figures 3 and 4. There is a bell dated 1633 in the cupola which is struck hourly, this is earlier than the clock movement below the cupola. It is quite a large bell and must have disturbed the sleep of countless undergraduates during its lifetime. The dial is just about good enough to set a clock by although any clock installed before the end of the seventeenth century would have been of debatable accuracy of going. Once the long pendulum clock was put into use, an accuracy to within a minute or less a day could be expected, and the dial can be read to within a minute. Had the dial been intended for this purpose, one would have expected to find an Equation of Time table installed nearby, for a correction of the clock by the solar noon indication will lead to errors of up to almost 17 minutes from mean time in the course of the year. Of course it must be remembered that the absolute accuracy of a clock governing an establishment does not matter a great deal if everyone is synchronised to its indications. A few minutes more or less in the seventeenth century would have been of little consequence. It is most likely that the clock was installed so that an acoustic signal would inform everyone of the progress of the hours, the sundial having been installed long before the iron autocrat aloft usurped its principal function. If the dial was used to correct the clock, then it was the last useful function allocated to it.

SUMMARY

There is a good description of the Queens' College dial in *Cambridge Sundials* by Alexis Brookes and Margaret Stanier with a closeup view of the dial and a general view of the dial in the Old Court. As is stated in this little work, the dial is not the most beautiful of the Cambridge sundials, but it is one of the most arresting examples. Without knowledge of the structure of the dial, the average observer would take much time to unravel the apparent spider's web of criss-crossing lines, and it must be regarded as a tour de force of dialling art rather than as a utilitarian device. The actual presentation of the hour indication leaves much to be desired outside the range of nine in the morning to two in the afternoon because of the zodiacal signs. A large dial such as this should be more concerned with accuracy of time indication than showing those of dubious value. These complex dials serve as a reminder that clarity and simplicity lead to excellence of presentation and improved accuracy.

Perhaps at the next repainting the dial can be restored by a more competent artist for the present execution is not as good as it should be. The layout should be altered to restore the winter solstice line, and the word "HORIZON" displayed more artistically. The off-centre golden arc makes the dial appear lopsided and perhaps should be removed, as also all lines immediately above the horizon line which have no part to play in the dial's functioning. This would help to clear up the eyecatching clutter in the centre of the dial. A more elegant gnomon casting only the required indicating shadow would also be a great improvement. This gnomon should be painted in the ground colour of the dial to make it blend into the background, it is only its shadow that should appear black to the observer's eyes.

* * * * * *

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Views of Cambridge, Loggan, 1675.

The Book of Sundials, H.K.F. Eden and Eleanor Lloyd, George Bell, 1900.

Sundials, F.W. Cousins, 1969. Page 114 gives an illustration of the Queens' College sundial and a brief explanation. He quotes 1727 as the date of the dial, and that Sir Isaac Newton had no association with it.

Sundials, Their Theory and Construction, A.E. Waugh, Dover Publications, 1973. The use of a sundial to interpret the shadows cast on it by moonlight is briefly presented as a rule of thumb for practical use.

The Dial in Old Court, Queens' College, M.M. Scarr, 1988. This is based upon the booklet first compiled by Professor G.C. Shephard when an undergraduate of the College in 1948. This is the most authoritative treatment of the Queens' College Dial presently available although now out of date and in need of revision.

Cambridge Sundials, Alexis Brookes and Margaret Stanier, Pendragon Press, 1991. Condenses the information of the 1948 Shephard compilation into two pages of text.

The pamphlet by M.M. Scarr is available at the Porter's Lodge, Queens' College, Cambridge, it is a revision of Shephard's compilation. There is also an excellent postcard illustration of the dial. A calendar in 1991 featured the Queens' College dial in a large coloured illustration.

THE GATE OF HONOUR, CAMBRIDGE

BY CHARLES K. AKED

Those attending the BSS Conference held at Cambridge in September, 1991, and who commenced dial hunting in the city, may have been somewhat surprised to see the Gate of Honour of Gonville and Caius College, wreathed in scaffolding which almost obscured a view of the dials. The writer certainly was surprised since he had no prior notice of such work being carried out and the gateway had been restored as recently as 1958-9 to commemorate the quatercentenary of the refounding of the college by Dr. Caius.

The gateway was actually built after the death of Dr. Caius although he had laid the foundation of Caius Court at 4am on 5th May, 1563, a time determined by casting a horoscope. This court was completed before his death in 1573. Dr. Caius left a considerable sum of money for building the gate, which was completed by 1575. The exact cost of the gate is difficult to disentangle from that of building Dr. Caius's tomb and work on the Chapel Tower undertaken at the same time, from 27th June, 1573 to the finishing of the work in 1575. This brief extract from the records may be of interest:

For ffree stone from Kings Clyffe and white stone from Hasingfeild, digging and carriage	£18	9s	4d
To ffree masons and rough masons for Porta Honoris and the Tower	£73	7s	4d
For lyme from Hinton	£8	18s	0d
For sande	£1	19s	6d
Iron work for Porta Honoris	£1	7s	0d
To labourers	£24	8s	3d

The rest of the record deals with the details of the tomb, for Dr. Caius.

The Gate of Honour (Porta Honoris) must therefore have cost less than £100, including the six dials delineated upon it.

THE GATE OF HONOUR

Dr. Caius himself sketched the outline of the building, and records show that the gate was built ". . . of squared hard stone wrought according to the very form and figure which Dr. Caius in his lifetime had himself traced out for the Architect, and had its apex a weather-cock in the form of a serpent and a dove". It would seem Dr. Caius just indicated the general form and left the details to another designer, possibly Theodorus Haveus who was the designer of Caius's tomb and of an elaborate column on which was placed a stone with 60 sundials with a weather cock in the shape of Pegasus, set up in Caius Court.

The Gate of Honour was designed in a variety of styles characteristic of the Elizabethan era, it was exceedingly complicated. Figure 1 shows an illustration taken from *Regola generali di architettura sopra le cinque maniere degli edifici* written by Sebastiano Serlio and published 1537-47, which was taken as the model, see Figure 1. The upper part of the structure was hexagonal and on this six dials with iron gnomons were placed, on on each face. The dome above this also had an hexagonal column surmounted by a ball finial carrying a gilded weathercock. See Figure 2 which is an old engraving of the Gate of Honour, the dials may just be distinguished. Four of the dials can be seen outside the College from Senate House Passage, (E, SE, SW and W), the NE and NW are only visible from within Caius Court. (Do not stand on the lawn or some College official is likely to administer an unwelcome rebuke). In spite of the presence of nearby tall buildings, all the present sundials receive some sun during the course of the year. The hexagonal sides of the tower above the gate are not precisely aligned with the meridian owing to the limitations of the College site and adjoining buildings.

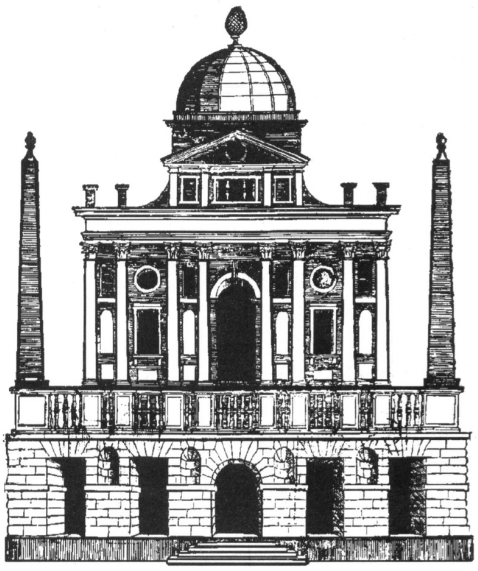

FIGURE 1: Serlio's design for a Corinthian Temple on which the Gate of Honour is loosely based.

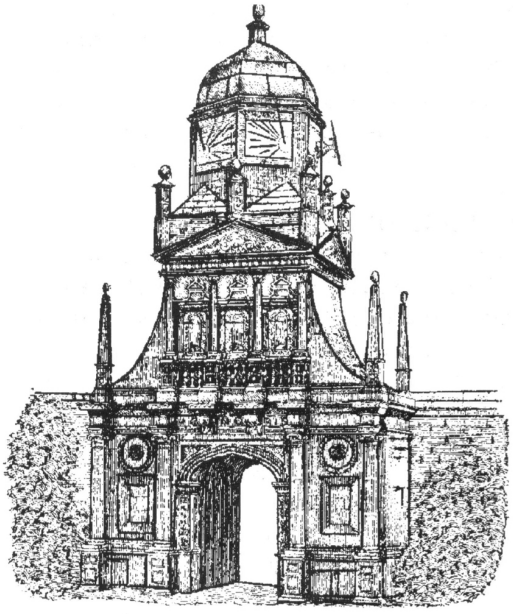

FIGURE 2: An engraving of the Gate of Honour, drawn by Rodney Shackell (Courtesy of W. Heffer & Sons Ltd, Cambridge).

RESTORATIONS AND REPAINTING

When King James I decided to visit the University in 1614, preparations were made to renovate the premises. The sundials were not in a very good state of repair and a

student of the College called Oliver Grene undertook the task of repairing the sundials on the Gate of Honour, plus those on the column within Caius Court, and several others. His name is commemorated in nearby Green Street. It must be remembered that at this age, sundials were mainly executed by painting upon stone, gnomons were of iron which soon rusted, and the dial ensemble deteriorated rapidly if not constantly maintained.

Only eleven years following King James's visit, all the dials were again being repainted as is detailed in the College Bursar's book of 1625:

Item: Paid to Russell the painter:

For gilding and working ye Great Mural Diall £4
For gilding and working the sixe dialls on Hon. gate £3
For gilding and working ye globe dialls £3
For gilding ye pegasus, gilding and working the concave diall and colouring all the rest with the rundles there 20s
Ye free mason for his worke there and at ye top of the globe dialls, sundry ingredients to make cement to fill and square ye moulded and decayed sydes of ye globe dial £1 2s 6d
4 pounds of lead to fix the basis to the pegasus, the concave diall stone, etc.

Similar records show the sundials were repaired in 1658 and again in 1662, whilst there is a reference to painting and gilding the six dials over Honoris Gate in 1969. No doubt a thorough search of the College archives would uncover more such records of the repainting of the dials. Loggan who recorded the Oxford scene in many engravings, shows the Gate of Honour complete in all details in 1688, including the sundials. Whilst the column in the centre of the Court is shown, none of its 60 dials had survived. In Mrs. Gatty's *The Book of Sundials* she mentions that Loggan's view in his *View of Cambridge* shows "a cube of dials", she does not include an illustration of the dials themselves. Perhaps it is because only four dials are visible in any view of the Gate of Honour.

There are many drawings of the Gate of Honour in the following years, not all entirely accurate as the interpretation depended upon the individual artist. As the years went by pieces fell off as stonework decayed, or were removed by vandals, such as the finals and weathercock, obelisks and pedestals. The dials eventually became obscured as ivy was allowed to creep over the whole structure.

By 1866 it was reported that the whole structure was in a very poor condition because of the porous nature of the stone employed to build the gate. The surface had peeled to such an extent that the carvings were no longer distinguishable. The cornice was broken and several of the interesting features had vanished altogether. The report by Willis and Clark in 1866 spurred the College into some slight action and in 1889 Dr. J. H. Middleton, of King's College, recommended that a set of measured drawings of the Gate of Honour should be made. These drawings were made between 1890-1900 and, probably to make the measurements possible, the covering of ivy was removed at this time. Progress was very slow because the architect T.D. Atkinson of Cambridge recommended that plaster copies of certain parts be made in 1900, and had to repeat his recommendation again in 1921. After the second report casts were taken and copies were deposited in the Victoria and Albert Museum, London, and the Cambridge University of Architecture.

By 1937 the Gate of Honour had had the stonework cleaned and some repairs carried out. The cleaning removed all the paint from the stonework, although it was though that the "white paint" used on the outside was merely limewash which was then commonly used to preserve stonework. Repairs to the stonework were carried out by means of "reconstituted stone" made from powdered natural stone. The restoration was very successful except that the renewed parts only served to accentuate the poor condition of the remaining untouched stonework. In spite of the earliest records of the work showing that only two kinds of stone were quarried for the earliest records of the Gate of Honour, the cleaning revealed that much of the base was of a third type of stone.

THE QUATERCENTENARY RESTORATION

Since the quatercentenary of the refounding of the College by Dr. Caius was approaching, it was decided to refurbish the Gate of Honour and replace the badly decayed and missing parts by Clipsham stone. This work commenced in 1958, upon which it was discovered that the worst affected stone at the base was actually stone which had been used previously, since there were many carvings on the inner surfaces. Such stone, even when reworked, carries the memory of its previous service and decays much more rapidly than new.

This work was finished by 1959 and the question of the dials now became of some importance. Careful examination by the Building Research Station using ultraviolet and infrared tests failed to reveal any signs of paint, the cleaning of the stonework had been efficacious in removing all such traces. A few incised lines remained and the holes for the brackets supporting the gnomons. The stonework, although now made sound, was much too rough to take painted hour lines and so some other method of providing dials was sought.

After much debate it was decided to have dial plates of bronze with coloured fillings of enamel. The exact orientation of the hexagonal sides of the tower were determined by Dr. P.J. Message. Fellow of Caius College, who also carried out the computation of the hour lines for each of the six dials. From these calculations and the sketches made by the Junior Bursar, Dr. Frank Powell, from Loggan's engraving of 1688 (although Loggan's sketch is crude), drawings and specifications were prepared by the Ancient Monuments Branch of the Ministry of Works under the supervision of the architect T. A. Bailey. The dials were then made by Birmingham Guild Ltd. and fixed in position in March 1963. The dials were an expensive addition to the tower as is revealed by the record of the expenditure: Stonework - £4334, Sundials - £1124 plus painting and gilding - £58. These dials are clear and plain with very little embellishment, see *Cambridge Sundials* by Alexis Brookes and Margaret Stanier, where three of the six dials are shown on the cover, and two more inside.

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There is a plaque affixed to the Gate of Honour relating to this restoration of 1958-1959, alas the dials were not fixed in place in time for Dr. Caius's quatercentenary of the refounding of the college.

It is pleasant to relate that the master craftsman who restored the Gate of Honour, Mr. W. H. Topper, Master Mason, was awarded an honorary degree of Master Arts in 1960 in recognition of his excellent restoration work.

Amazingly Mr. Topper was 78 years of age when he commenced the work, his assistant Mr. C. J. Whittaker who carried out the carving was 85 years young, whilst the boy helping Mr. Topper, Mr. A.G. Whitmore, was a mere 45 years of age.

At the ceremony awarding Mr. Topper his M.A., the public orator Professor Guthrie gave an adulatory speech in Latin, which he drew to a close with a Latin quotation from the earliest Latin poet, Livius Andronicus:

Topper facit homines ut prius fuerent.
[Topper remakes men as they were before.]

FIGURE 3: Scaffolding enveloping the Gate of Honour in September, 1991. Seen from outside the college.

Professor Guthrie (in Latin) went on to say, "put stones for men and you have our friend [Mr. Topper]. I present to you a man worthy of his Cambridge".

Thus Mr. Topper is one of the few men honoured by an M.A. degree from a university after submitting his examination responses on tablets of stone!

The accompanying photograph shows the Gate of Honour as it was at the time of the British Sundial Society Conference in Cambridge, September 1991. The writer has not yet obtained a report of the latest restoration work but this does not affect the actual dials since they require minimal maintenance, the materials used are permanent apart from occasional regilding of the bronze.

ACKNOWLEDGEMENT

The author of this article must express his indebtedness to the article by F. C. Powell in *Biographical History Gonville and Caius College*. Volume VII, 1978. This contains additional detail, comment and references about the Gate of Honour which is not strictly relevant to diallists.

CAIUS COURT PILLAR

Although not directly associated with the Gate of Honour, the pillar of Caius Court might as well be mentioned further here. It is recorded in the College books of 1576 - "A stone of marvellous workmanship, containing in itself sixty dials, made by Mr. Theodorus Haveus of Cleves, a famous artist and a notable exponent of architecture, blazoned with the arms of the nobles who then dined in the college and dedicated by him to the college as a token of goodwill. On the summit of this stone is placed a winnowing fan like a Pegasus". Theodorus Haveus settled in Kings Lynn, Norfolk, with his family.

So many dials in one college can only have been to demonstrate the skill of the diallist and to serve as decorative features. Most would have been of limited utility because of the high walls surrounding Caius Court. By 1675 there was nothing remaining of these for Loggan to sketch although the column itself was still standing. The column vanished without trace at a later date, suffering the fate common to all these painted dialling follies.

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Views of Cambridge, Loggan, 1675.

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NOTE

The little booklet *Cambridge Sundials* is still available from Dr. Margaret Stanier, 70 High Street, Swaffham Prior, Cambridge CV5 0LD, price £5.50 which includes postage. All the dial illustrations are in colour. This was reviewed in BSS *Bulletin* 91.3, page 27, and remains the definitive outline of the sundials to be found in the City of Cambridge. The price given in the review is incorrect.

THE AUGSBURG DIALS

JOHN MOORE

Augsburg is a relatively small town in the centre of southern Germany. Its position, to the south of Nuremberg put it in an ideal position for trade, not only with Germany but also the surrounding countries of Bohemia, (now part of the Czech Republic), Austria, Switzerland and consequent links to Italy. It was one of the most famous metalworking towns of Europe and became well known for its quality goods, particularly in gold and silver. Many of the items produced were very ornate reflecting the exceptional craftsmanship that was to be found there. In the 16th and 17th Centuries it built up a reputation for its finely decorated and often complicated clocks. Many of the clock dials carried astronomical information, sometimes in the form of an astrolabe. It was not until the 17th Century that sundials were made there in any quantity. It is probably from the earlier clockmakers and their descendants that the art of sundial making was developed.

The earliest dials produced there were of high quality, often somewhat complicated and usually quite ornate, somewhat like the clocks of the period. As dialmaking became well established, it became necessary to make dials at relatively low cost to sell them in any quantity. From around 1700 onwards, the majority of the dials produced in Augsburg were of a common pattern with only minor stylistic differences between them. They were mass produced, often quite simply, by a small number of workshops. There were, however, a few makers that specialised in the finer type of dial, often using silver as their main material and with parts of their dials beautifully gilt.

AUGSBURG STYLE DIALS

The commonest form of dial produced, and produced in considerable quantities, was a universal equinoctial dial. In fact, it is this type of dial that is most commonly found by those scouring antique shops or fairs for portable dials. It is universal because it could be used in most parts of the Northern Hemisphere, covering a range of latitudes from as low as 10° to 85° or more, and equinoctial, because the hour divisions were of equal length, both summer and winter. One of the simpler of these dials by Lorenz Grässl is shown in Fig. 1. As with most other portable dials, a compass was always incorporated to enable the dial to be correctly aligned. Their compass bowls were normally marked with a line showing the local magnetic declination. This, as has been explained in previous articles, is a valuable guide to dating these dials, by checking the variation of compass declination as it varied over the years. (Ref. 1). The dials were usually supplied in small leather cases for carrying safely in the pocket. Luckily, many of these have survived and still protect the dials within them. To enable the dials to fit properly into their case, they were made so that each part could be folded flat against its body. For the travelling gentleman, the underside of the compass bowl was normally engraved with a short list of European towns with their latitudes. (Fig. 2.) In addition to this list engraved on the dial, many dialmakers provided within the dial's case, a printed paper sheet containing details of many more towns and instructions for using the dial. This was much more comprehensive, giving the latitudes for many of the larger towns of Europe. (Fig. 3.) On the reverse of the sheet were the instructions for use of the dial, usually in three different languages, German, French and Italian. (Fig. 4.) Virtually identically printed sheets were supplied by most of Augsburg's dial makers, the only real difference between them being the makers' name.

FIG. 1: Typical Augsburg style dial by Lorenz Grässl.

FIG. 2: List of European towns and signature engraved on the underside of the compass bowl.

An interesting and attractive variant on the 'standard' Augsburg dial was made by Andreas Vogler. Instead of using the commoner round chapter ring, he favoured a lyre shaped design. (Fig. 5.)

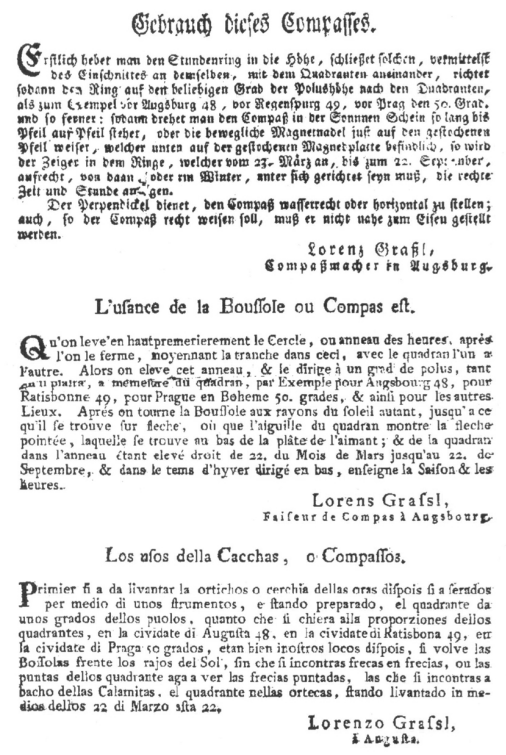
Many of the Augsburg dials incorporate a simple plumb bob to aid precise levelling. This is suspended by a small folding frame at one end. Its small size precludes accurate alignment but it did provide some assistance to the owner when setting it up. Three screw feet were fitted to enable these dials to be correctly levelled for use, two of which could be unscrewed by a small amount so that a precise setting could be made. In most instances, these dials would have simply been held in the hand giving their owners merely a rough indication of the time.

The main plate of most dials was made from a brass casting. It was then further decorated by engraving and sometimes by fretting. The compass bowl, the chapter ring, the latitude arc and the pin-like gnomon were usually

ELEVATIO POLI.

Achen	51	Feldkirch	47	Lisabon	39	Petersburg	60
Adrianopel	42	Florenz	43	London	52	Pisa	42
Antibes	44	Franckfurt am Mayn	50	Lübeck	53	Presburg	48
Arles	43	Frankfurt an der Oder	52	Lucern	46	Ravenna	44
Amsterdam	52	Friburg Brisg.	48	Lüneburg	54	Reval	61
Andernach	50	S. Gallen	47	Magdeburg	52	Reims	47
Augspurg	48	Genev	45	Majorca	39	Rom	42
Anspach	49	Gent	51	Malacca	37	Rouen	48
Antorf	51	Genua	44	Mantua	44	Rostock	54
Avignon	43	Grenoble	45	Marienburg	53	Salzburg	48
Boucaieu	45	Görlitz	51	Marpurg	51	Savion	43
Basel	47	Gräz	47	Marseille	43	Speyer	59
Berlin	53	Gröningen	53	Mazuz	59	Stettin	54
Bersalon	41	Gülch	51	Mecheln	51	Stockholm	60
Besançon	45	Hagenau	49	Memmingen	46	Stuttgardt	49
Braunschweig	52	Halberstadt	52	Messina	38	Strasburg	48
Bremen	43	Hall im Inthal	48	Mez sen Lorraine	47	Tarent	41
Breslau	51	Hall in Sachsen		Meyland	44	Tibur	42
Brüssel	51	Hamburg	54	Minorca	40	Toloto	39
Bourdeaux	47	Hatsfurt	40	Monaco	45	Torne	51
Camin	54	Heidelberg	59	Montpelieur	45	Toulon	43
Canteiberg	52	Heilbronn	43	Moscau	58	Trient	45
Carlstadt	50	Hildesheim	59	Nantes	48	Trier	49
Cassel	51	Hoff	50	Narbon	46	Triest	45
Clauffenburg	47	Jena	51	Neapolis	40	Turin	44
Coblenz	50	Ingolstadt	48	Nice	47	Venedig	45
Cölln	51	Inspruck	46	Nismes	47	Verona	45
Constantinopel	43	Kämpten	47	Nördlingen	49	Vienne en Dauphiné	47
Coppenhagen	50	Kempten	52	Nürnberg	49	Uolence	45
Coitanz	47	Kizingen	50	Ochsenfürt	52	Ulm	48
Cracau	50	Königsberg	54	Ofen	47	Upsal	61
Culmbach	50	Krems	48	Olmüz	49	Utrecht	52
Danzig	54	Landau	49	Orange	47	Weisenburg	49
Digne	45	Langres	47	Orleans	47	Wien	48
Dresden	51	Leiden	52	Osnabrug	52	Wittenberg	53
Dünckelspiel	48	Leipzig	51	Padua	45	Worms	49
Edenburg	57	Ligniz	51	Palermo	30	Würzburg	49
Eisenach	51	Linz	48	Paris	48	Zeiz	51
Emden	53	Lzon	45	Parma	43	Zürich	46
Erfurt	51			Pavia	44	Zwickau	50
Eslingen	48						

FIG. 3: Printed list of towns provided by Grässl.



Gebrauch dieses Compasses.

Erstlich hebet man den Stundenring in die Höhe, schließet solchen, vermittelst des Einschnittes an demselben, mit dem Quadranten aneinander, richtet sodann den Ring auf den beliebigen Grad der Polushöhe nach den Quadranten, als zum Exempel vor Augsburg 48, vor Regenspurg 49, vor Prag den 50. Grad. und so ferner: sodann drehet man den Compaß in der Sonnen Schein so lang bis Pfeil auf Pfeil stehet, oder die bewegliche Magnetnadel just auf den gestechenen Pfeil weiset, welcher unten auf der gestochenen Magnetplatte befindlich, so wird der Zeiger in dem Ringe, welcher vom 23. März an, bis zum 22. September, aufrecht, von daan, oder im Winter, unter sich gerichtet seyn muß, die rechte Zeit und Stunde anzeigen.

Der Perpendickel dienet, den Compaß wasserrecht oder horizontal zu stellen; auch, so der Compaß recht weisen soll, muß er nicht nahe zum Eisen gestellt werden.

Lorenz Graßl,
Compaßmacher in Augsburg.

L'usance de la Boussole ou Compas est.

Qu'on leve'en hautpremierierement le Cercle, ou anneau des heures, aprés l'on le ferme, moyennant la tranche dans ceci, avec le quadran l'un a l'autre. Alors on eleve cet anneau, & le dirige à un grad de polus, tant qu'il plaira, a memesure du quadran, par Exemple pour Augsbourg 48, pour Ratisbonne 49, pour Prague en Boheme 50. grades, & ainsi pour les autres Lieux. Aprés on tourne la Boussole aux rayons du soleil autant, jusqu'a ce qu'il se trouve sur fleche, où que l'aiguille du quadran montre la fleche pointée, laquelle se trouve au bas de la plâte de l'aimant; & de la quadran dans l'anneau étant elevé droit de 22. du Mois de Mars jusqu'au 22. de Septembre, & dans le tems d'hyver dirigé en bas, enseigne la Saison & les heures.

Lorens Grafsl,
Faiseur de Compas à Augsbourg.

Los usos della Cacchas, o Compassos.

Primier si a da livantar la ortichos o cerchia dellas oras dispois si a ferados per medio di unos strumentos, e stando preparado, el quadrante da unos grados dellos puolos, quanto che si chiera alla proporzione dellos quadrantes, en la cividate di Augusta 48. en la cividate di Ratisbona 49, en la cividate di Praga 50 grados, etan bien inostros locos dispois, si volve las Bossolas frente los rajos del Sol, sin che si incontras frecas en frecias, ou las puntas dellos quadrante aga a ver las frecias puntadas, las che si incontras a bacho dellas Calamitas. el quadrante nellas ortecas, stando livantado in medios dellos 22 di Marzo asta 22.

Lorenzo Grafsl,
Augusta.

FIG. 4: Instructions for use in three languages.

silvered. This was a matt silvered finish that made the dials easier to read, being a good surface for showing the contrast of the shadow.

All of these later Augsburg style dials were relatively simple and were only intended to display the hours, unlike dials from many other parts of Europe that would often include both astronomical and astrological information.

The dials were prepared for use by unfolding the chapter ring, gnomon and latitude arc. The chapter ring would then be set to the correct angle for the place which would be found from one of the lists. They would be placed on a solid surface, being levelled by the screw feet with reference to the plumb bob and would be aligned North - South with respect to the compass. The reading would then be taken from the position of the gnomon's shadow on the chapter ring. For a few days on either side of each of the equinoxes this type of dial is difficult to read because the front edge of the chapter ring hides the sun's rays from the gnomon. During the winter months when the sun is low in the sky the shadow can only fall beneath the chapter ring. Consequently the gnomon is erected in reverse so that it points downwards, although in practice this is not always possible with low latitudes.

The finer versions of these dials were made by just two makers, Johann Martin and Johann Willebrand. Their dials were normally made in solid silver with some of the parts being mercurial gilt. (Fig. 6.) The process of mercurial gilding was particularly dangerous and many workers employed to do this lived very short lives. The process involved mixing one part of gold to eight parts of mercury, that would be heated until they united. The amalgam was then put into a chamois leather bag and the surplus mercury was squeezed out. The brass, copper or silver article to be coated, would then be rubbed with the amalgam until it adhered. It was then was placed in a charcoal fire to evaporate the mercury. This left a thin layer of gold on the

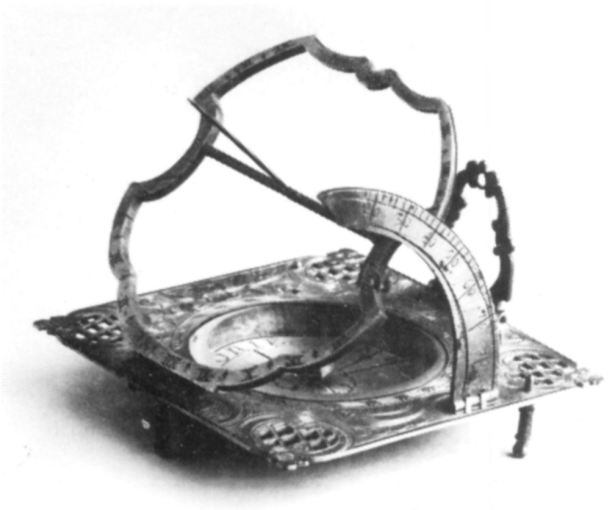


FIG. 5: Dial by Andreas Vogler with a lyre shaped chapter ring.

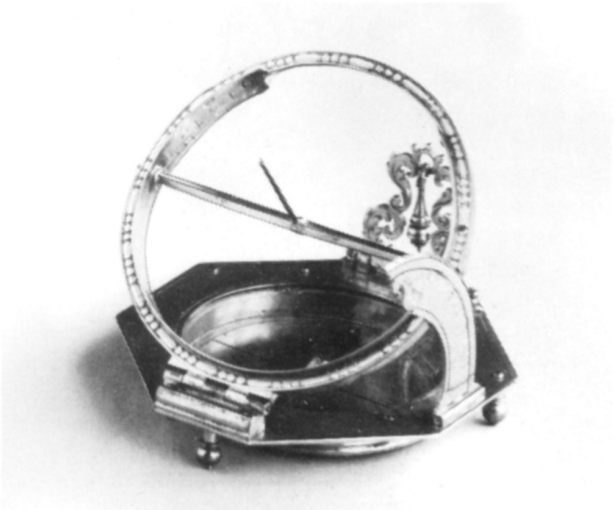


FIG. 6: Silver and gilt dial by Johann Willebrand.

FIG. 7: Crescent dial by Johann Martin.

FIG. 8: String gnomon dial by Johann Martin.

surface that would then be burnished and polished. The gilding process was used quite commonly throughout Europe. Augsburg was a centre famous for its many finely gilt products. The cases for these higher quality dials were again, normally made from leather, but sometimes a silver or silvered brass disk will be found attached inside the lid carrying an expanded list of towns and latitudes.

THE CRESCENT DIAL

A very interesting form of dial was originated by Martin and Willebrand in Augsburg that utilised two back-to-back crescents (Fig. 7), although rarely one single crescent may be found. The silvered double crescent arrangement is particularly attractive, the space between being filled with ornate gilt scrolls. The easterly crescent was employed to show the scale of hours before noon and the westerly one for the afternoon. The gnomon is in the form of another crescent with sharp tips. It is of minimum thickness to throw a fine shadow at the 6am and 6pm points. It can moved up and down along its polar axis against a date scale so that the shadows produced by the fine tips of the gnomon would fall at the correct position. In use, once the date has been set, the dial would be rotated until the tip of one gnomon coincided exactly with the equatorial line of the hour scale. This is another form of dial that does not use a compass for alignment and in consequence it is possible to take a reading from the wrong scale, especially around noon.

These dials are not a commonly found and most of those extant are mainly to found in museums. The pattern was occasionally copied by other dialmakers and examples are known from other areas of Europe, particularly France.

STRING GNOMON DIAL

This is another rarer form that was occasionally produced in Augsburg. Its style was quite individual and unlike other string gnomon or diptych dials made in France or other parts of Europe. The string is attached to a folding arm, such that when erected the gnomon is taut and at the correct angle for the latitude. Unfortunately the string gnomon dial cannot be made truly universal, and in these Augsburg models there are several anchoring holes on the folding arm to allow for a selection of closely related latitudes. In the silver and gilt example illustrated by Johann Martin (Fig. 8), there is only one hour scale incised, and this is for 48°, being the mid point of the range of string positions. This dial by Martin is housed in an octagonal metal case that is thought to be original. It is made of a non magnetic metal, so that it does not affect the compass. The narrow range of latitudes provided on this dial were hardly sufficient for the travelling gentleman and dials such as this were probably made for the more static members of the community. Unusually for Augsburg, these dials also included a lunar volvelle. The inner ring of the dial scale may be rotated to line up the figure taken from the moon's shadow with that of the day of the moon. The solar time is then read against the **XII** position on the time scale. As with most types of lunar dial, readings would only be possible in the bright moonlight produced a few days either side of full moon.

THEIR MAKERS

As already stated, there were only a few dialmakers recorded as working in Augsburg. Those producing the finest work were Johann Martin and Johann Willebrand. Dials of a similar quality and identical in style are sometimes found with the name Masig on them. This was not another Augsburg maker, but was a retailer of their products in London. Martin and Willebrand were obviously making their dials without signature or with that of Masig. It is noteworthy that virtually all Augsburg dials are signed. For this reason we may be reasonably certain that we know all of the Augsburg makers. The same is not true of dials from many other parts of Europe.

According to Zinner, (Ref. 2) Lienhart Miller worked in Augsburg, apparently making Ivory Diptych Dials in the style of Nuremberg. Gouk (Ref. 3), believes this to be a mistake, as his work is obviously that of a Nuremberg man. His name has therefore been omitted from the following list.

THE AUGSBURG SUNDIAL MAKERS

BERGAUER Michael. Worked in Augsburg in 1671. Formerly from Innsbruck.

BUSCHMANN Kaspar. 1512 - 1589. Local family of clock makers. Had sons Johann I, 1592 - 1662, David, 1626 - 1701, Johann II, 1632 - 1662. All are known to have made dials.

GRUÄSSL Lorenz. (Lor Gresl, Grassl, Gräsl, Grasl.) Worked in Augsburg 1767. Born in Ingoldstadt.

HAUSER

HÖLDERICH J.N. 18th Century.

KLIEBER Tobias. (T.K.) 1545 - 1620. Compass and sundial maker.

KLIEBER Ulrich. 1554 - 1608. From a clock making family in Augsburg. Ulrich III believed to have made most of the sundials.

MARTIN Johann. 1642 - 1721. Worked in Augsburg from around 1669. Son of clock maker Marx Martin of Frankfurt am Main. Joined by his stepbrother Johann Willebrand (q.v.) in 1682.

MASIG The name, Masig London, appears on some dials obviously made by Martin and/or Willebrand. Probably London agent for them.

MÜLLER Ludwig Theodatus. (L.T.M.) 1710 - 1770. Active in Augsburg around 1760. Originally from Saxony.

PEFFENHAUSER Philipp Heinrich. (Pepfenhauser) c1657 - 1733. Active in Augsburg in 1683.

RUGENDAS Nicolaus. 1665 - 1745. Two other members of the family, also Nicolaus, were clock and watchmakers.

SCHEGA Jo. Antonius. Worked in Augsburg and Munich around 1700.

SCHISSLER Christoph. 1530/32 - 1608. Active in Augsburg around 1554. Died 1609. He made some of the finest instruments of the period.

SCHÖNER Christoph. (Schener). Married 1683, worked until 1700.

SCHRETTEGER Johann Nepomuk. 1764 - 1843. Married daughter of Andreas Vogler (q.v.) in 1797.

SOMMER Johann. Augsburg in the 18th century.

VOGLER Andreas. c1730 - 1808. Miller's son. Active 1766. Brother of Johann Georg Vogler. (q.v.)

VOGLER Johann Georg. c1720 - 1765. Compass maker in Augsburg 1745. Brother of Andreas Vogler. (q.v.)

L.G.V. On an Augsburg style dial made by Halderich. (Hölderich).

WILLEBRAND Johann (Mathias). c1658 - 1726. Born in Frankfurt am Main. Worked in Augsburg around 1682 where he joined his stepbrother Johann Martin (q.v.).

His style, and that of Martin are generally indistinguishable.

WILLEBRAND Johann Martin. 1714 - 1742. Son of Johann. His signature appears on only a few dials.

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Ref. 2. Deutsche und Niederländische Astronomische Instrumente des 11 - 18 Jahrhunderts, Ernst Zinner.

Ref. 3. The Ivory Sundials of Nuremberg, Penelope Gouk.

ACKNOWLEDGEMENTS

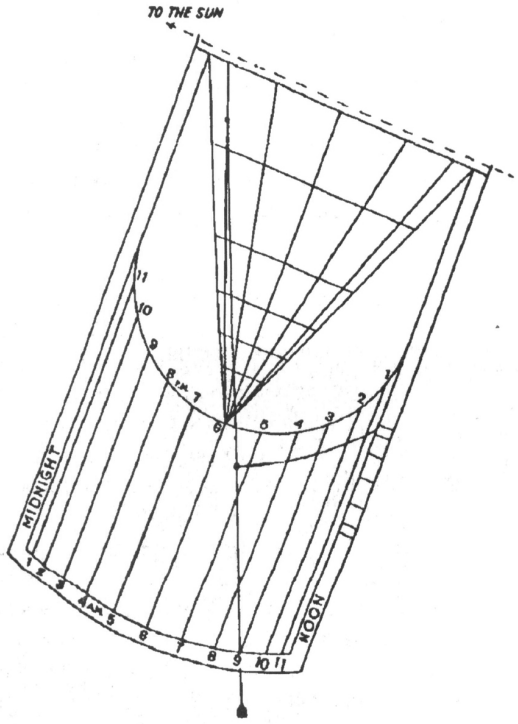
The author would like to thank Christies of South Kensington for the photograph of the Crescent Dial, Fig. 7.

Saxon Sundial Safari - Delegates at St. Gregory's Minster, Kirkdale, North Yorkshire - Saturday 25th June, 1994

A UNIVERSAL NOMOGRAPHIC SUNDIAL

FREDERICK W. SAYWER III

The Capuchin dial is a type of altitude sundial usually constructed out of a card, a bead, a weight and a length of string. It is relatively easy to make, and when made well, it can be an interesting device that registers local apparent time and gives its user some understanding of the way in which the length of daylight varies with the seasons. The traditional Capuchin dial is designed so that it functions well only at the one particular latitude for which it is constructed. More general forms of dial, including the so-called Regiomontanus,[1] may be used in different latitudes, but they are correspondingly more difficult to construct.[2] The Regiomontanus dial introduces a two-dimensional trigon which must be used to prepare the instrument for a given latitude and date (*see figure: The Regiomontanus dial as presented by A.W. Fuller*).



Regiomontanus Sundial

The sundial to be developed here is a compromise between the simplicity of a Capuchin dial and the universality of a Regiomontanus dial. As is the case with the Capuchin, the proper alignment of the thread which registers the time is an easy task, requiring the diallist only to draw two lines and to slide the thread along a straight slot cut in the card on which the dial is drawn. However, nomograms will be introduced into this dial in such a way that it will be as universal as a Regiomontanus. The dial will not require a two-dimensional field for the suspension of the string; the motion of the plumb-line will be restricted to a one-dimensional slot.

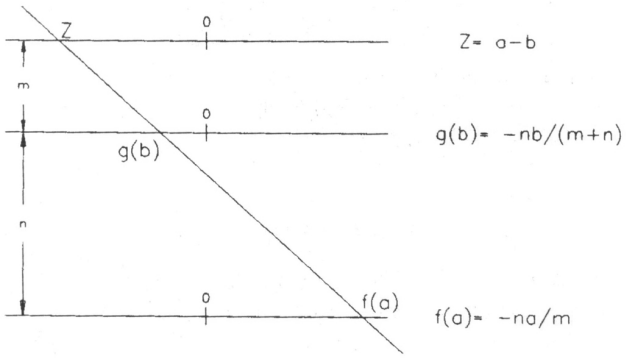
The field of nomography was created a century ago by the mathematician Maurice d'Ocagne.[3] For decades it provided a practical means for quick calculation; however, with the advent of electronic computing, nomography has quickly gone the way of the slide rule and, some would argue, of the sundial.[4]

A simple nomogram, or alignment chart, consists of three lines or curves, each graduated for a different variable in some formula; the curves are places such that a line drawn along a straight edge cutting them gives the values of the three variables as they are related by the formula. Thus, on a simple addition nomogram, a straight edge laid across two of the scales curves so that it intersected the *A* and *B* scales at points corresponding to *a* and *b*, would intersect the scale of the third curve at the point corresponding to the value $a + b$.

Of course, more complex nomograms can be built out of simple elements, and the combinations can yield graphic calculations to provide acceptably accurate solutions for many practical problems which posed more of a challenge before the electronic age began. However, the two nomograms to be incorporated into this new dial are simple adaptions of the most basic subtraction and multiplication nomograms. The demonstration will rely only on the properties of similar triangles.

SUBTRACTION NOMOGRAM

Begin by drawing three parallel lines with the distances of the centre line from the other two being *m* and *n*, respectively. Mark a zero-point on each of the lines; these points should all lie on a single perpendicular through the given lines. About each of the zero-points, construct a scale: On the centre line the scale for variable *b* is graduated according to the formula $g(b)$ where $g(b) = -nb/(m + n)$. On the line at distance *n* from the centre, the scale for *a* is graduated to the formula $f(a)$, where $f(a) = -na/m$. Finally, the scale on the remaining line has a simple linear graduation (*i.e.* $h(z) = z$).



Subtraction Nomogram

The result is a subtraction nomogram. If a straight-edge is laid across the two non-linear scales so that it cuts them at points corresponding to *a* and *b*, then it will also cut the linear scale at the point *Z* corresponding to $a - b$.

To demonstrate that this is in fact the case, draw a perpendicular through *Z*, cutting all three scaled lines. This perpendicular then forms the base of similar right triangles with the straight-edge providing the hypotenuse. By virtue of the properties of similar triangles, we therefore have:

$$\frac{f(a) - Z}{g(b) - Z} = \frac{m + n}{n}$$

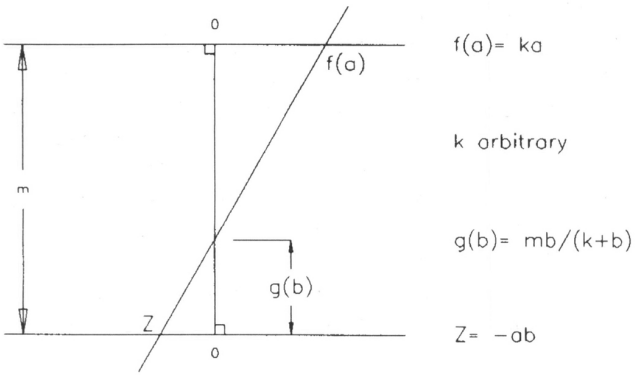
Solving for Z and substituting the graduation formulas for $f(a)$ and $g(b)$ yields:

$$Z = \frac{(m+n)g(b) - mf(a)}{n} = a - b$$

We thus have two scales, one independent of a and the other independent of b, which are nonetheless so graduated and positioned that they combine with the third scale to yield a graphic calculator of a-b.

MULTIPLICATION NOMOGRAM

Much the same principles are at work in the multiplication nomogram. Drawn two parallel lines separated by distance m. Draw a third line, perpendicular to the first two, and cut by them at their respective zero-points. On one of the parallels, construct a scale for a with graduation given by $f(a) = ka$, where k is any positive, fixed value (*e.g.* $k = 1$). Finally, construct a scale on the perpendicular with graduation $g(b) = mb/k+b$, and with a zero-point shared with the linear-scaled parallel. Now, a straight-edge cutting the a and b scales will also cut the linear scale at the point Z corresponding to $-ab$.



Multiplication Nomogram

For justification, turn again to the properties of the similar right triangles formed by the three scales and the straight-edge. We have:

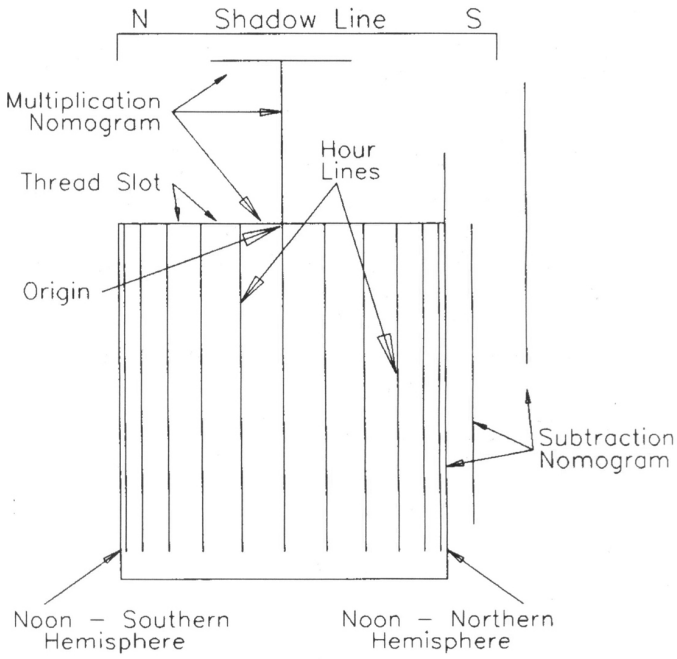
$$\frac{Z}{g(b)} = \frac{f(a)}{m\text{-}g(b)}$$

Substituting the graduation formulas yields the interim result $Z = ab$. Note however that this reading would require the a and Z scales to have opposite senses, *i.e.* one would increase to the right and the other to the left. In order to keep both scales increasing to the right, we place a negative sign on the interim value for Z, thus yielding $Z=-ab$.

NOMOGRAPHIC SUNDIAL

Begin with a coordinate system (x,y) and draw the hour-lines familiar from the Regiomontanus dial: the line for hour arc t is $x = \cos t$, $y < 0$. A slot must be cut in the x-axis so that the thread with attached bead and weight can be moved back and forth.

Lay the multiplication nomogram over this coordinate system, placing the Z scale on the x-axis with the zero-point on the origin. The scales of the nomogram are to be drawn by substituting for a and b the values $\tan\delta$ and $\tan\varphi$, respectively, where δ is the solar declination and φ is the geographic latitude. Thus, a straight-edge laid across the δ and φ scales will also cross the point A: $(-\tan\varphi \tan\delta, 0)$, which is the point from which we suspend the thread and bead.



The Nomographic Sundial

Now note that the noon[5] line ($t = 0$) is the line $x = 1$. Lay the Z scale of the subtraction nomogram along this line (rotate the nomogram 90° counterclockwise, keeping the positive sense of the linear scale and the y-axis together). Keep the zero-point on (1,0). Substitute for a and b in the nomogram scales the values $\tan\delta$ and $\tan\varphi$, so that the nomogram will select the point B: $(1, \tan\delta - \tan\varphi)$ in the coordinate system.

To complete the dial, we need to specify a line parallel to the x-axis as the shadow-line. Affix a gnomon perpendicular to the plane of the card at the left end of the shadow-line for northern latitudes and the right end for southern. The gnomon can be a small pin or even the edge of a portion of the card, cut and folded back at a 90° angle.

READING THE TIME

To use this sundial, begin by laying it flat and drawing the thread taut so that it forms a straight line joining the points corresponding to your latitude, whether above or below the equator, and the current date on the two perpendicular scales at the top of the dial. Note where this straight line intersects the thread slot and place the knotted end of the thread at the point of intersection. Next, without disturbing the knotted end of the thread, draw the other end taut between the appropriate latitude and date points on the scales to the far right of the dial. Note where this line intersects the linear nomogram scale (*i.e.* the northern noon-line); place the bead at the point of intersection and draw the thread taut between the bead and the knotted end which has already been placed in position.

Now hold the dial up vertically with its edge towards the sun - the left edge in northern latitudes and the right in southern. Tilt it until the edge of the gnomon's shadow falls along the shadow-line. The thread, whose weighted end now hangs freely, will fall among the hour-lines. If the knotted end has not been allowed to change its position in the slot and if the bead has not slipped, then the position of

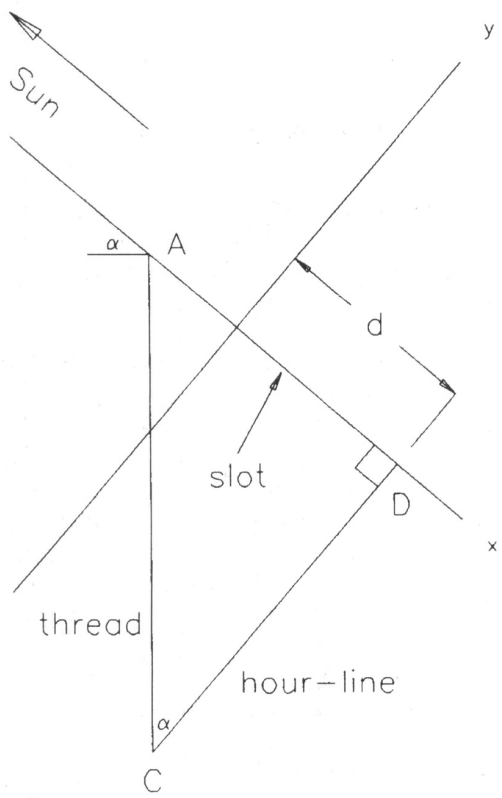
the bead will correspond to the current local apparent time. For northern latitudes, noon is to the right side of the dial; for southern latitudes, it is to the left.

If the dial is to be used in only one latitude, it may be convenient to draw in a series of lines corresponding to several dates, or more simply to mark the thread slot and the noon-line with the appropriate date points determined by using a straight-edge passing through the latitude points corresponding to your location. By noting that the location of the knotted end of the thread in the slot corresponds to the times of sunrise and sunset for the given date and latitude, it is possible to see at a glance how the length of the day varies throughout the year.

JUSTIFICATION

Assume for the moment that we are dealing only with northern latitudes. Given the construction and placement of the nomograms, operation of the dial selects the points A: $(-\tan\varphi \ \tan\delta, 0)$ and B: $(1, \tan\delta - \tan\varphi)$. The distance AB between these points is:

$$AB = \sqrt{(\tan\delta - \tan\varphi)^2 + (1 + \tan\varphi\tan\delta)^2} = \sec\varphi\sec\delta$$



Let the line AC represent the section of the thread between the suspension point A in the slot and the bead, which covers the point C. From the setup of the dial, we know that $AC = AB$. When the dial is in use, the bead falls among the hour-lines and rests on the line $x = d$ for some value d, which we need to determine. Let D be the point $(d, 0)$ on the x-axis. Given that the card is inclined at the angle α, equal to the altitude of the sun, we now have a right triangle ADC with angle $ACD = \alpha$, hypotenuse $AC = \sec\varphi \sec\delta$, and side $AD = \sin\alpha\sec\varphi\sec\delta$.

Given the location of point A, and the length AD, we know that: $d = \sin\alpha\sec\varphi\sec\delta - \tan\varphi\tan\delta$.

Now, the standard solar altitude formula which underlies all altitude dials is: $\sin\alpha = \sin\varphi\sin\delta + \cos\varphi\cos\delta\cos t$.

Rearranging this equation to solve for $\cos t$ yields:

$$\cos t = \sin\alpha\sec\varphi\sec\delta - \tan\varphi\ \tan\delta = d.$$

Thus, the bead has fallen among the hour-lines ($x = \cos t$) and has come to rest on the line corresponding to the correct current time t. We have a functioning sundial.

It would of course be possible to construct an analogous dial for southern latitudes by rearranging the nomogram scales; however, it is not necessary to do so. This dial will work without modification if we follow the directions to point the right side of the dial to the sun in southern latitudes and use the left 12 o'clock line as the noon-mark.[6]

COMPARISON TO THE REGIOMONTANUS

If we examine the Regiomontanus sundial, assuming the origin of the coordinate system to rest at the apex of the trigon, we find that the Regiomontanus is designed to select the points A_R and B_R as follows:

A_R : $(-\tan\varphi\tan\delta, \tan\varphi)$ $\qquad$ B_R : $(1, \tan\delta)$

A : $(-\tan\varphi\tan\delta, 0)$ $\qquad$ B : $(1, \tan\delta - \tan\varphi)$

Thus, the nomographic A and B are simply Regiomontanus points A_R and B_R "lowered" on the dial by a distance equal to $\tan\varphi$, so that the thread suspension points all lie on a single straight line.

Note that the justification given for the nomographic dial works with little modification for the Regiomontanus. The only characteristics of the points A and B essential to the proof are: *1.*) the x-coordinate of AB is $-\tan\varphi\tan\delta$, and *2.*) the distance AB is $\sec\varphi\sec\delta$. Both pairs of points satisfy these criteria.

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1. Descriptions and derivations of these dials may be found in Godfray 1911 and Fuller 1957. The latter works seeks to discover the geometric method by which dials of this type were originally conceived, perhaps by the ancient Greeks.
2. The additional complication admittedly is not great, but Regiomontanus dials tend to use a linkage arrangement to facilitate placement of the thread on the right point in the trigon field. For a diallist not prepared to deal with linkages or to develop another method for suspending the thread, the Regiomontanus usually collapses to a simple Capuchin.
3. d'Ocagne 1920. A more recent elementary and practical text is Epstein 1958.
4. One is reminded of an observation by essayist Hilaire Belloc:

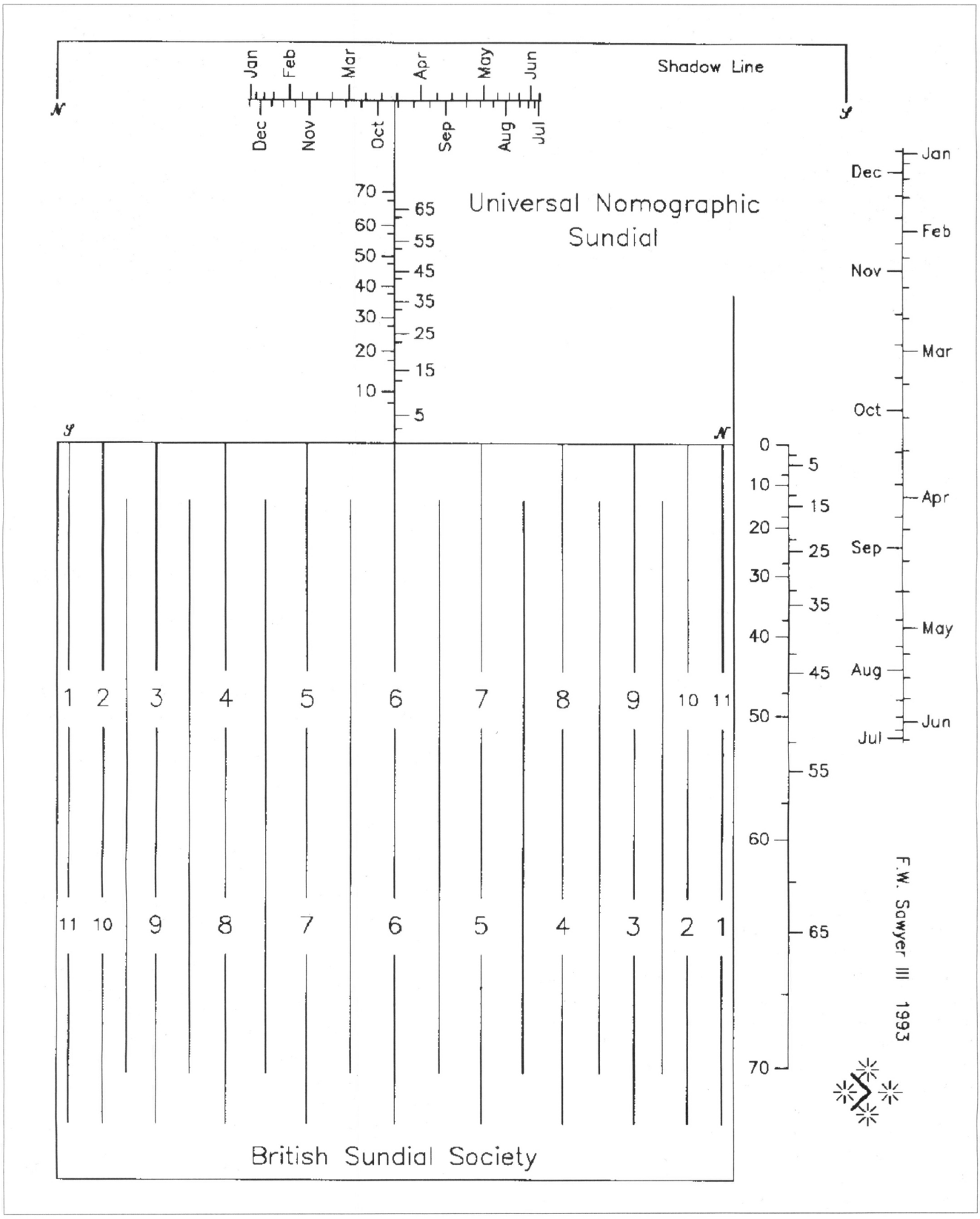
   > Civilisation loses its treasures by an unconscious process. It has lost them before it has appreciated that

they were in the way of being lost; and when I say "its treasures" I mean the special discoveries and crafts of mankind. (Belloc 1940).

5. As will be seen, this is the noon-line assuming a northern latitude. For southern latitudes, it becomes the line of midnight.
6. This adjustment amounts to recognizing that the dial also implements the following form of the altitude formula:

$$\sin(-\alpha) = \sin(-\varphi)\sin\delta + \cos(-\varphi)\cos\delta\cos(180°-t).$$

* * * * * * * *



The Universal Nomographic Sundial

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

GIOVANNI PALTRINIERI (ITALY)

Photo 1: The obverse of the bronze medallion of 1695, showing the meridian line of San Petronio

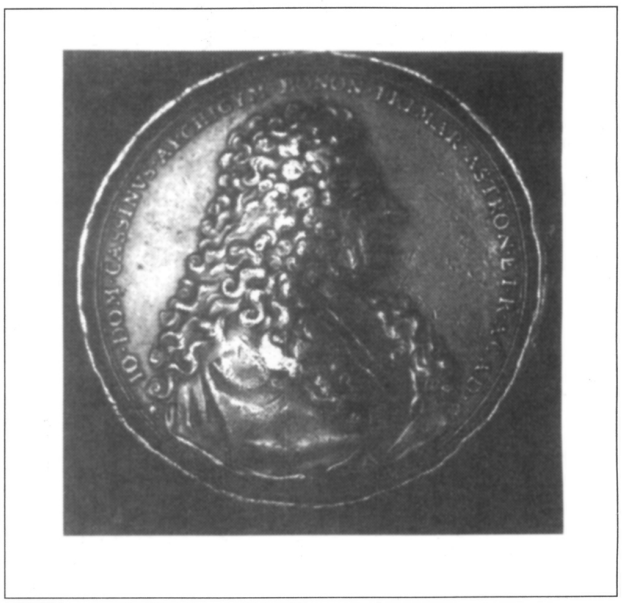


Photo 2: Bust of Gian Domenico Cassini on bronze medallion of 1695.

THE RESTORATION BY EUSTACHIO ZANNOTTI, 1776

In 1776 the Senate of Bologna decided on the restoration of the meridian line once more as it had deteriorated so that observations were not as accurate as formerly. The person charged with the superintendence of the delicate work was the astronomer Eustachio Zanotti.

In reconstructing the instrument anew, Zanotti wished to retain unchanged the fundamental dimensions such as the gnomon height, the solstice projections and the marble slabs with the zodiacal signs as arranged by Cassini. Measuring the points on the line and expressing these in parts (1 part = 1 module/1000 = 0·27068849mm) as recorded in the book published on completion of the restoration, he states in the text:

In replacing the signs of the zodiac as first positioned by Cassini, we noted the measurement of the distance of each sign from the vertical point, which enabled the new marble slabs to be positioned exactly as before thus giving to posterity the indication of inclination which occurs at the time of the ecliptic with the equator.

A marble slab is engraved with an ellipse corresponding to the solar image for the year 1656. At the present time because of the variation in the obliquity of the ecliptic, the solar image of neither of the two solstices exactly fits the ellipses engraved on the marble slab but they intersect it. However the two ellipses were replaced in the same place, the intention being to note the distances of the extreme points of the principal axis from the vertical point.

DETAILS OF MEASUREMENTS

Nearest point on principal axis at Summer Solstice	37825	(10·239m)
Furthest point on principal axis at Summer Solstice	38960	(10·546m)
Gemini and Leo	45145	(12·220m)
Taurus and Virgo	64953	(17·582m)
Aries and Libra	98308	(26·611m)
Pisces and Scorpio	148170	(40·109m)
Aquarius and Sagittarius	211125	(57·151m)
Nearest point on principal axis at Winter Solstice	243379	(65·882m)
Furthest point on principal axis at Winter Solstice	250135	(67·711m)
Minor axis of ellipse at Summer Solstice	1132	(0·306m)
Minor axis of ellipse at Winter Solstice	2630	(0·711m)

Many other tests were carried out on the old meridian line, which by this time was in a completely ruinous state. On the 24 May 1776 the work of the reconstruction of the whole instrument was commenced.

Finding that the wooden chain originally used by Cassini was in good condition, it was again employed to measure exactly 100 modules and to obtain the correct height of the plate containing the gnomon aperture. A line was stretched from the vertical point under the gnomon up to the winter solstice, the marble slabs were removed and a layer of bricks put down to form a more solid foundation for the meridian line. In order that the new meridian line would be more stable than the old, the system of separate marble slabs on each side was not used, instead a single series of slabs into the groove of which was inserted a metal bar in the shape of a swallow's tail. The slabs were laid with great care so that each was aligned with the line, and adjusted horizontally by employing a water channel at the side. The slabs carrying the signs of the zodiac were made of larger dimensions and inserted between the marble slabs of the

Photo 3: The Vertical Point and the start of the Meridian Line. The end of the brass and copper strip marks the exact vertical point under the gnomon.

The far tablet carries the Latin words: "LINÆ MERIDIANA CONSTRVCTA ANNO MDCLVI. AMPLIORI FORMA RENOVATA ANNO MDCCLXXVI" - Meridian Line constructed Anno 1656. Enlarged and renovated Anno 1776. The nearer tablet is engraved:

Left: HORÆ ITALICÆ MERIDIEI - PERPENDICVLA PARTES CENTESIMÆ - SIGNA ZODIACI DESCENDENTIA - Meridian Italian Hours - 1/100th perpendicular parts - Descending Zodiac Signs. Right: - SIGNA ZODIACI ASCENDENTIA - Ascending Zodiac Signs. Nearest of all is: LIGNVM VERTICALE - Vertical Line.

Photo 4: The Summer Solstice position. The engraved circle inside the sign for Cancer is the exact size of the projected image of the Sun on the floor at this date. It is rounder because the sun is almost overhead in summer

line. (See photo 4 for the sign of the Crab.)

Finally the meridian line consisting of three strips running side by side, the middle one of copper, the two outer of brass; were inserted into the groove and secured by hammering into the grooves, no cleats were used. These strips were made to an exact length of four modules, and in this way the junction between the strips gave the modular reference. On the eastern side of the meridian line was engraved, as before, the modular units with a two by two progression; on the western side the numbers of the zenith degrees, more of ornament than for true use, the hour and minute of midday according to the system of Italian hours measured on a mechanical clock. This allowed a direct reading on the line itself of the exact instant in time when the luminous ellipse was central, providing the simple and precise "reference point" for the correction of mechanical clocks, see photo 5.

Zanotti, with the help of the new meridian line of San Petronio, was then able to carry out many interesting observations of the sun's movements, to draw up a new accurate calendar. bequeathing to posterity this exceptional instrument. On the 4th of October 1776, the festival day of San Petronio, the renovated meridian line was inaugurated officially, being attended by a gathering of the faithful without precedent.

Among the curiosities mentioned in the book published at the completion of the work, is recorded the comparison made by Zanotti between the meridian line of San Petronio and that constructed at the Observatory of Bologna situated at via Zamboni 33. Wishing to ascertain the difference (in seconds) between the two instruments, Zanotti first calculated the difference in longitude, and then placed a pendulum clock at each of the meridian lines; the one at San Petronio was synchronised with the last chime of the bell at the Communal Palace, this being close enough to avoid any acoustic error. The clock at the Observatory was further away and so could not use the same bell because of the low velocity of sound in air, so it was done by a visual signal. It was noted that on looking from the Observatory tower it was possible to see the hammer which struck the bell of the tower of the Comune quite clearly with the aid of a telescope, in this somewhat original fashion it was possible to synchronise the pendulum clocks at the two meridians; by observing the passage of the sun at the meridian, and taking into account the difference in longitude between the two meridians, it was found that the meridian line at San Petronio anticipated the Observatory meridian by 1·5 seconds.

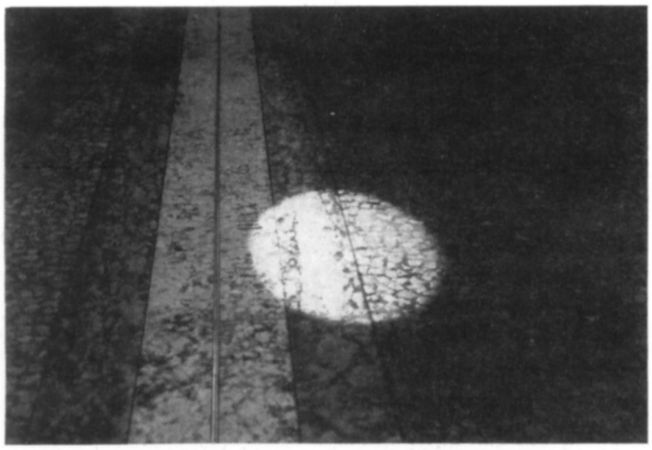


Photo 5: The Solar Image has just traversed the Meridian Line (it is some minutes past noon.

Photo 6: The end of the line, and the engraved image of the sun at the Winter Solstice on the floor. It is elongated because of the lower angle of the sun in winter. The vertical marble panel carries the words (in Latin):

"MERIDIANÆ HVIVS LINÆ TOTA LONGITVDO INTRA VERTICALEM ET CENTRALEM SOLIS RADIVM IN HYBERNO SOLSTITIO EST SEXCENTIMILLESIMA PARS CIRCVITVS UNIVERSÆ TERRÆ".

(The meridian line from the vertical point to the centre of the sun's rays at Winter Solstice is 1/600,000 of the earth's circumference).

Since then the meridian line has not been submitted to any changes or special restorations, apart from some slight adjustment to the plate carrying the gnomon hole, made necessary by the natural settlement of the building. Today, more than two centuries distant from the restoration, the instrument can be considered as being in an excellent state of preservation and still good enough to indicate midday accurately to the faithful and the tourists who gather there for their daily appointment with the sun.

INSPECTION OF FEDERIGO GUARDUCCI, 1904

In 1903 Professor Federigo Guarducci was nominated to occupy the chair of Geodesy at the University of Bologna. The following year, in consideration of his scientific merit, the Academy of Science nominated him as an honorary Academician. By the rules of the Academy he had to submit a thesis of some scientific merit, his choice of subject fell upon the state of the meridian of San Petronio. The thesis was read at the Academy's session of 28th May 1905 and was entitled "The Meridian Line of the Basilica of San Petronio of Bologna revised in 1904".

In order to carry out the necessary survey, Guarducci employed the more modern and accurate instruments then available at that time; and with his consummate experience in trigonometrical surveys he made a complete and most exhaustive investigation which constitutes a very reliable guide to the state of the San Petronio meridian line at the beginning of the twentieth century.

The thorough analysis of Guarducci made the following points:

a The centre of the gnomon aperture has not suffered an appreciable displacement from the vertical point.

b The gnomon height still corresponds to that fixed by Zanotti; and probably neither Matteucci, nor his successor or the others who followed, had to carry out corrective action. The actual height found was 27·0699 metres.

c The meridian line was found to be displaced towards the east by 1′ 36·6″; retarding the indication of midday by 2·5 seconds at the summer solstice.

d The level of the line was almost perfect considering the state of the instrument. Using the height of the vertical point, the greatest subsidence was found on the equinoctial slab - 0·008m, that of the winter solstice - 0·007m; those of the remaining points all were somewhat less.

e The arrangement of the solstice ellipses remained acceptable limits considering the wear of the lines and the dimensions of the instrument. Such projected images tend to a slow change as a result of the constant diminution of the obliquity of the ecliptic, the following tables show the variation of the projected image for the years 1655 and 1904.

	Summer Solstice		Winter Solstice	
	Centre	Major Axis	Centre	Major Axis
Engraved on	m	m	m	m
the marble	10·398	0·312	66·803	1·829
Calculated	10·396	0·310	66·836	1·849
Guarducci	10.419	0.313	66.709	1.811
Calculated	10.431	0.311	66.710	1.842

f The latitude of the vertical point, checked by the most

modern instruments available gave results of 44° 29′ 37·6″; and the obliquity of the line with respect to the plane geometry of the basilica was 9° 59′ 03″.

Guarducci's memorandum concluded with a positive judgement on the state of preservation of the instrument and the stability of the building and the meridian, which on the whole has been maintained almost unchanged.

1925 was the occasion of the third centenary of the birth of the Gian Domenico Cassini and a second and more up to date edition of the interesting research of Guarducci was published in commemoration of this event.

THE MECHANICAL CLOCK OF FORNASINI, 1758

Between the third and fourth chapels of the north nave of the cathedral of San Petronio exists one of the first Italian examples of equation clocks. Below the two clock dials is an engraved tablet (in Latin) which explains the function and the relation which exists between the hands of the clock face and the meridian line, see photo 7. The creation of this instrument was motivated during the period in which Francesco Zambeccari was Primate of the Basilica of San Petronio. He commissioned Domenico Maria Fornasini, to carry out the work with the aid of his son Cristino in 1758.

It was in these years that there was a transition between the two different systems of the subdivision of time, Italian hours which made the 24th hour coincide with sunset (that is with Ave Maria) and Oltramontana (beyond the mountain, ie. north of the Alps) hours, in which the 24th hour coincides with midnight. The major complication of the change was the problem of reconciling *Tempo Vero* (true time) and *Tempo Medio* (mean time): the true solar time of the meridian and that indicated by mechanical clocks. Zambeccari's gift to the basilica proved very useful for comparing the two time systems. The clock is composed of two separate but identical trains controlled by means of a single pendulum. Each clock, has a uniform motion, and is provided with a cam suitably formed to give a predetermined variable velocity to the hands over the course of the annual cycle. This motion is said to be the Equation of Time and this advances and retards the hands by almost half an hour in the course of the annual cycle. From one clock dial one can observe the two distinct systems of hours: true or solar time and mean time. The adjacent clock dial indicates Italian hours. This mechanism also requires a special cam which is not like that of the true time cam with which it has nothing in common. In fact to obtain tolerable accuracy it is indispensable that a correction be given almost daily. In this particular case the hand of the "Italian hours" indicates 12 at midday indicated by the meridian line (in other words the clock is adjusted to follow the noon to noon indication of the sun).

Up to the year 1930 the regulation of the clocks constituted a ritual which was repeated at certain intervals of days. At the approach of noon (local time) the keeper of the Cathedral, attired in suitable livery and furnished with a long stick, placed himself at the side of the meridian. At the instant when the sun's image was central on the meridian, he struck a blow with his stick. The timekeeper standing on a ladder at the side of the clock, then corrected the dials of the clock, whilst below the faithful looked on attentively and those who happened to be passing by at that moment were astonished at the sight and sound.

* * * * * *

PHOTO 7: The equation clock of Fornasini near the Meridian Line. On the marble tablet below the dials is the Latin inscription:

D.O.M. QUOD SOLO AQUABILI MOTU OBTINERI NON POTUIT UT HOROLOGIA UNA CUM SOLE TEMPUS COMMUNE SIGNARINI DUPLICI MINUTORUM INDICI AQUABILITER ALTERO PROCEDENTI ALTERO CONRRECTIONE ACCEPTA AD SOLARIUM MOTUM ACCOMMODATO CURATUM EST ANNO DOMINI MDCCLVIII

GENERAL DETAILS OF THE SAN PETRONIO MERIDIAN

Latitude	44° 29′ 37·6″ N
Longitude	11° 20′ 39·0″ E
Height of Gnomon	27·069949 metres
One Module	270·69949 mm
Diameter of Gnomon aperture ...	27·069949 mm
Subdivision of module (Part)	0·27069949 mm

PRESENT SOLSTICE PROJECTIONS

SUMMER SOLSTICE

Midday (true) ... 12h 16m 12s		Declination = +23° 26′ 34″
Dawn 4h 35m 20s		Zenith angle = 21° 03′ 04″
Sunset 19h 57m 04s		Italian angle = 15h 49m 08s
Centre of ellipse	10·419 metres	38·489 module
Limb (inferior)	10.575 metres	39·065 module
Limb (superior)	10·263 metres	37·914 module
Minor axis	0·292 metres	1·081 module
Velocity on line	0·125 m/min	0·467 mod/min

WINTER SOLSTICE (See photo 6)

Midday (true) ... 12h 12m 29s		Declination = -23° 26′ 34″
Dawn 7h 53m 20s		Zenith angle = 67° 56′ 03″
Sunset 16h 31m 38s		Italian angle = 19h 10m 51s
Centre of ellipse	66·780 metres	246·694 module
Limb (inferior)	67.711 metres	250·135 module
Limb (superior)	65·869 metres	243·332 module
Minor axis	0·708 metres	2·617 module
Velocity on line	0·314 m/min	1·161 mod/min

MASS DIAL GROUP MEETING

FRANK EVANS

The photograph accompanying this account, see page 13, was taken during the programme of visits when the Mass Dial Group met at Malton, North Yorkshire in June 1994. It shows the attendees outside St. Gregory's Minister, and was taken by Robert Sylvester, our assiduous Membership Secretary. The camera was mounted on a tripod placed on a high stepladder. Robert's agility is attested since he slipped down the ladder to get himself into the picture.

The portrait contains numerous noteworthy characters, including the lady member who, on the Sunday of the weekend meeting, played the opening hymn in Malton Parish Church before leaving the congregation stranded in order to join the dialling group for the rest of the day. The two muscled campanologists who rang the Malton bells for the same service, to the astonishment of the resident bell-ringers, will be instantly recognisable. The Reverend chauffeur and organiser, who went to early service to keep tabs on the Yorkshire clerical opposition, is there. So too is his good wife, who did not, sensibly believing herself to be on retirement leave from the parish. And the person who accidentally set off the fire alarm in the hotel is also there...

We observe Mr. Mass Dial himself, poised to receive all those dial records and force them into the procrustean beds of his computer program. ("I have a few fields left", he says, referring to his database but sounding like an auctioneer at a farm sale). There too is the renowned authority on the mass dials of Leicestershire, still residing comfortably in the Middle Ages with his copy of Bede, logarithm tables, tables of sines and other quaint anachronisms.

Who would have thought that among the numerous wall dials stretching from Anglo-Saxon to scratch dial times, that we saw on our expedition we would have stumbled at last on the solution to Shakespeare's reference in Henry VI part 3, to shepherds' dials, those dials which are cut in the short turf of the sheepwalk. Run your eye along the faces in the picture, for one of us had the vital clue in his knowledge of an old book by Barclay Wills - *The Downland Shepherd:*

O God! Methinks it were a happy life
  To be no better than a homely swain;
To sit upon a hill, as I do now,
  To carve out dials quaintly, point by point . . .

Next, notice the slightly concerned look upon the face of our good Secretary. He had recently learnt that as well as her famous sundial book, the remarkable Mrs. Alfred Gatty also wrote a book about seaweeds. Has his local library possibly got a copy? Should he apply to join the British Seaweed Society?

We were all sorts in the group, dial makers, dealers, photographers, recorders, academics and Sun readers, and a vexillologist. We had one thing in common, and that was our interest in dials, and our determination to have an instructive and pleasurable weekend. Which, of course, we did.

There are so many Anglo-Saxon dials in the region - did we hear that of the thirty-eight in the whole country, fifteen are local? Over the two days we went from ancient church to ancient church, our cameras making a fortune in the process for the financial barons of the sensitive halides. David Watts drove the minibus; he and his wife Betty were the unsung heroes, having done so much preparation for a pretty faultless itinerary. But we were just in time, for some of the dials, the soft golden limestone of North Yorkshire was visibly crumbling in the lithotoxic modern air. Recording is so urgent. It is not only at St. Gregory's Minster that all is *tobroken and tofallen*, and time is so short.

We were all glad that we went. Under Edward Martin's guidance we formed a gallant company. The Mass Dial Group is flourishing. Hopefully we shall meet again in the not-too distant future. Happy dialling and may good fortune attend you all.

* * * * * * * *

Key to photograph on page 13

FRONT ROW:
Mr. W.D. Wells (Leicester) / Dr. M.W. Stanier (Cambridge) / Mrs. M. Whitaker (York) / Mrs. D.H. Watts (Wetherby) / Mrs. A. Featherstone (Derby) / Mrs. M. Ta'Bois (Buckhurst Hill)

MIDDLE ROW:
Mrs. F. Evans (Tynemouth) / Mrs. A.R. Astbury (Woodbridge) / Mr. R.B. Sylvester (S. Cumbria) / Dr. F. Evans (Tynemouth) / Mr. A. Featherstone (Derby) / Harriet Wynter (London) / Mrs. W.D. Wells (Leicester) / Mrs. D.A. Young (London)

BACK ROW:
Rev. D.H. Watts - Event Organiser (Wetherby) / Mr. A. R. Astbury (Woodbridge) / Mr. R.C. Mallett (Dunstable) / Mr. E.R. Martin - Mass Dial Group Co-ordinator (Stourbridge) / Mr. D.A. Young - Group Chairman (London) / Mr. W.J. Hazell (Hayes)

CONTEMPORARY MOTTOS FOR SUNDIALS

FREDERICK W. SAWYER III

Much of the personality of old sundials derives from the thought-provoking mottos they often carry. In centuries past the sundial motto was often considered an essential part of its design, without which the dial only communicated part of its message. Various collections of old mottos appear in the literature; the most common examples generally allude in some way to the mortal condition of humanity or rely on almost manichaean religious correlations between light and creation.

My purpose here is to offer a few additions to the general supply of mottos. Each of the following offerings has suggested itself to me as an appropriate dial motto; some of them are far more obvious candidates than others, but I believe they will all serve. I would appreciate any additional suggestions readers may offer.

The most elegant invention in the world was the sundial, which has only one moving part - the sun.
- Athelstan Sphilhaus, 1975

To him whose elastic and vigorous thought keeps pace with the sun, the day is a perpetual morning.
- Henry David Thoreau

Civilisation loses its treasures by an unconscious process. It has lost them before it has appreciated that they were in the way of being lost. - Hilaire Belloc, 1940

The sun and his shadow complete the work.
- Michael Maier, 1687, Scrutinum Chymicum

If the form of Heaven is contemplated,
the changes of time can be discovered.
If the forms of man are contemplated,
one can shape the world. - I. Ching, KO Revolution

Man is but a dream of a shadow. Yet when there comes a gift of heaven a gleam of sunshine, there rests upon man a radiant light and, aye, a gentle life. - Pindar

. . . there is nothing that draws more Admiration from all Men, than to see Strait-lines drawn on a Plane at Unequal Distances, to measure exactly the equal Divisions of the time of the Continuance of a Day.
- Philippe de la Hire, 1685, Gnomoniques

The gnomon serves as one who knows, one who interprets.
- J.T. Fraser, 1982, The Genesis and Evolution of Time

The sundial is part of the universe of man: it is a human artifact whose mission is to regulate the life of its maker. It is also a part of the astronomical universe: the motion of the shadow is independent of human volition.
- J.T. Fraser, 1982, The Genesis and Evolution of Time

The sly shadow steals away upon the dial and the quickest eye can discover no more, but that it is gone.
- Glanville

Till now you dreamed not what could be done
With a bit of rock, and a ray of sun.
- James Russell Lowell

Let it be literature to the bookless; a monitor to the heedless; an encouragement to the virtuous; a reproof to the wicked; let it be a delight to the eye, and above all let it be significant of something.
- Alice Morse Earle, Sundials & Roses of Yesterday

Whoever carries over into the afternoon the law of the morning . . . must pay for it with damage to the soul.
- Carl Jung, The Stages of Life

Read not the Times; read the Eternities.
- Henry David Thoreau

In a dark time, the eye begins to see,
I meet my shadow in the deepening shade.
- Theodore Roethke, 1985, Sequence, Sometime Metaphysical

'Tis nothing but a Magic Shadow-show
Play'd in a box whose Candle is the Sun.
- Omar Khayyam The Rubaiyat

Le temps n'est rien si aucun evenement ne le marque.
- Pierre Kohler

The sun when it appeareth, making proclamation at its rising, is a wonderful instrument. - Ecclesiasticus 43

I am the knowledge of the knower. There is no limit to my divine manifestations. - (Brahman) Bhagavad Gita

I am time without end: I am the sustainer: my face is everywhere. - (Brahman) Bhagavad Gita

The pattern of time in the heavens is the pattern of time on the earth. - Kenneth L. Patton

Why should not we enjoy an original relation to the universe? . . . The sun shines also today.
- Ralph Waldo Emerson

Earth warmed by sun, lit by sunlight: this is our home.
- Robert T. Weston

I knew not but the next
Would be my final inch -
This gave me that precarious gait
Some call experience. - Emily Dickinson

On the earth the broken arcs, in the heavens the Perfect Round. - Elizabeth Barrett Browning

Time we may comprehend; 'tis but five days older than ourselves. - Sir Thomas Browne, 1643, Religio Medici

The sun will not overstep his measures; if he does, the Erinyes, the handmaids of Justice, will find him out.
- Heraclitus

You would not find out the boundaries of the soul, even by travelling along every path: so deep a measure does it have. - Heraclitus

I am apt to fear that men are wont, with greater confidence than evidence, to assign the systematical ends and uses of the celestial bodies, and to conclude them to be made and moved only for the service of the earth and its inhabitants. - Robert Boyle
The Theological Works 1715

The presence of both dark and light are necessary to seeing.
- Carol K. Anthony, The Philosophy of the I Ching

. . . he determined to make a moving image of eternity . .
- Plato Timaeus

THE ALBERT PARK, MIDDLESBROUGH, SUNDIAL

BY DR. JOHN WALL

The vertical direct south sundial in the Albert Park, Middlesbrough in Cleveland is unusual if not unique in Britain, not least on account of the number and extent of the literary quotations inscribed on its surface. It was the collaborative achievement of two men who were very dissimilar in their station in life and background - John Smith (1807 - ?) who designed it and Henry William Ferdinand Bolckow (1806-1878) who commissioned it in July 1876. H.W.F. Bolckow was a prominent and wealthy ironmaster, partner in the firm of Bolckow and Vaughan. He was also Member of Parliament for Middlesbrough, and a generous benefactor to the constituency. In 1867 he presented 72 acres of his estates in Middlesbrough for the creation of a public park, named in honour of Queen Victoria's consort, which was opened by her son, Prince Arthur (later Duke of Connaught) on 11th August, 1868. The park was furnished with many attractions from the beginning but the sundial was evidently an afterthought, as appears from the date of the commission - 1876 - carved on the front and the back of the stone pediment. In the event it was erected some three years later, on 11th October, 1878, eleven years after the park was opened to the public and, sadly, a year after Bolckow's death. Until recently his statue stood alongside the sundial (Plates 1 and 2). In the light of its present dilapidated state, such that many of its features are indistinct or eroded, we are fortunate to possess an almost exact copy of the sundial from which much of this account will be derived (Plate 3).

The panel on which the sundial proper is inscribed, composed of a cement-like material, is three feet wide and five feet high. It is inscribed with no less than eight quotations in four different languages. Reading from top to bottom they are:

1. TIME BY MOMENTS STEALS AWAY FIRST THE HOUR THEN THE DAY.
2. In the spandrels of the square a text from the New Testament, Ephesians ch. 5 v. 16, in the original Greek (slightly adapted), which translates: 'Redeem the time because the days are evil'.
3. A quotation from Ovid in Gothic Latin script: TEMPUS EDAX RERUM, which translates 'Time is a consumer of all things.
4. A composite text from the Old Testament. The first phrase is the beginning of Proverbs ch. 27 v. 1, the second phrase is the end of Job ch. 16 v. 16: Therefore "Boast not thyself of tomorrow", "For on thine eyelids is the shadow of death". (The original has "on *mine* eyelids . . .").
5. An Old Testament text from Isaiah ch. 21 v 12: (The watchman said) "The morning cometh and also the night". The text is split by the gnomon so that each half appears in its proper place on the dial, ante- and post-meridian.
6. An Old Testament text from Proverbs ch. 3 v. 19: "The Lord by wisdom hath founded the earth, By understanding hath he established the heavens".

PLATE 1:

PLATE 2:

The Earth and Planets,
Motion round the Sun.
Neptune
Saturn
Jupiter
Uranus
TIME BY MOMENTS
Εξαγοραζ τον καιρον,
Tempus Edax Rerum.
Therefore
"Boast not thyself of to-morrow;" "For on thine eyelids is the shadow of death."
1877.
NEW YORK TIME.
A.M.
Mid day
P.M.
MELBOURNE
Mid-night
AUSTRALIA
The morning cometh
and also the night.
Park
TIME
FIRST THE HOUR
STEALS AWAY,
ὅτι αἱ ἡμέραι πονηραι εἰσι.
THEN THE DAY.
"The Lord by wisdom hath founded the earth, By understanding hath he established the heavens"
How grand the orbs of light on high,
With all the blue ethereal sky,
And spangled heavens a shining frame,
Their great Original proclaim;
In reason's ear they all rejoice,
And utter forth a glorious voice;
For ever singing as they shine,
"The hand that made us is Divine."
Jno. Smith, Sculp.
לאלהים לבדו - כל־הכבוד.
Stockton-on-Tees.

PLATE 3:

7. The first and last verses of a hymn by Joseph Addison (1672-1719). This fine poem is outstanding in the number of its astronomical and sidereal references, and expresses an early 18th century understanding of the nature of the universe with a corresponding theology of creation. It is more familiar to us from its altered first line "The spacious firmament on high . . .", and is featured in all the principal denominational hymn books. It is worth reproducing in full:

How grand the orbs of light on high,
With all the blue ethereal sky,
And spangled heavens, a shining frame,
Their great original proclaim;

The unwearied sun, from day to day,
Does his Creator's power display;
And publishes to every land.
The work of an almighty hand.

Soon as the evening shades prevail,
The moon takes up the wondrous tale,
And nightly to the listening earth
Repeats the story of her birth:

While all the stars that round her burn,
And all the planets in their turn,
Confirm the tidings as they roll,
And spread the truth from pole to pole.

What though in solemn silence all
Move round this dark terrestrial ball;
What though no real voice nor sound
Amid their radiant orbs be found:

In reason's ear they all rejoice,
And utter forth a glorious voice;
For ever singing as they shine,
"The hand that made us is Divine".

8. Finally, in a cartouche at the foot, a Hebrew text which translates (reading from right to left) 'To God alone (belongs) all the glory'. It is curious that this text does not appear in the Old Testament.

Occupying the whole of the central square is a circle containing three concentric dials which give the time, respectively, in New York, Melbourne Australia, and Albert Park. (The time in New York is 4 hours 52 minutes behind the time in Middlesbrough, being 75° west longitude from the Greenwich meridian. The time in Melbourne is 9 hours 45 minutes in advance of the time in Middlesbrough, being 144° east longitude). "The one shadow of the gnomon or rod passing across the three dials shows the time at each place at the same moment".

The choice of Melbourne time may be in honour of Captain James Cook (1728-1779), who charted the coast of Australia. He was born in the village of Marton only two and a half miles south-east of Albert Park. The cottage in which Cook was born had stood in the grounds of Marton Hall (now Stewart Park), which was built by H.W.F. Bolckow as his principal residence in 1853. Although the cottage had been demolished in 1768, Bolckow erected a granite fountain a century later in 1867 to mark the spot. It may have been his interest, therefore, which resulted in 'Melbourne Time' being included in the commission.

The dials proper are complemented by two diagrams, below and above. Each has features which are puzzling. The first diagram is a representation of a terrestrial globe with lines of latitude and longitude (Figure 1*). It exhibits

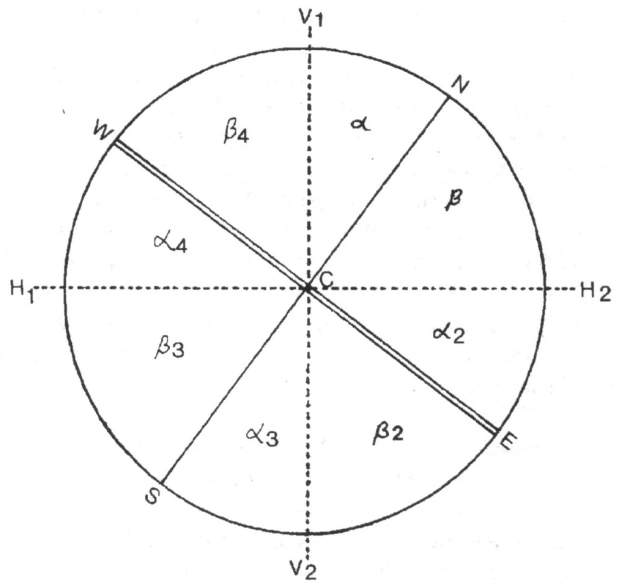


FIGURE 1

some unusual aspects which are illustrated in Figure 2. The axis of the globe N - S is inclined from the vertical V1 - V2 clockwise by an angle (V1 - C - N) which corresponds to the co-latitude of Middlesbrough - i.e. 35° 26′. It follows that the equator (represented on the globe by the median of of the double line W - E) is also displaced from the horizontal by the same angle. In effect, a 'terrestrial' cross consisting of the earth's axis and equator has been ingeniously superimposed on an (imaginary) cross consisting of a vertical and a horizontal. From this combination it is possible to measure off four equal angles which correspond to the latitude of Middlesbrough - for example β (N - C - H2). Yet the line of latitude of Middlesbrough does not appear on the globe itself. We have been obliged to add it to figure 1 (VI - L). However, six lines of latitude are drawn on the globe, three in the northern hemisphere and three in the southern. What do they represent? Neither of the two lines centred on the north pole coincide with the Arctic Circle, at 66½°N. (The same is true of the two lines of latitude centred on the south pole in respect of the Antarctic Circle). These can therefore represent the polar regions only in a rough and stylised manner. The two remaining lines of latitude, however, do coincide with the Tropic of Cancer drawn at 23½°N (C1 - C2) and the Tropic of Capricorn drawn at 23½°S (C3 - C4). If these two lines had corresponded to the latitude of New York (at 40° 45′N) and Melbourne (at 37° 45′S) - place names which appear on the dial above - then the mysterious line which joins them (C1 - C4) would have some significance. The globe as drawn gives the appearance of an armillary sphere reduced to two dimensions.

Although the second diagram is titled 'The Earth and Planets, Motion Round the Sun' and four planets are pictured and named, it only depicts four elliptical orbits, of which the earth's is one. The other three ellipses have a small disc randomly placed on each one to signify the planet in orbit. One assumes that these must be the named planets - except that one is missing.

The earth, represented as a miniature version of the globe at the foot of the sundial occurs four times, at the cardinal points of the diagram, as it were north, west, south and east, respectively, adjacent to the seasonal names

Spring, Summer, Autumn and Winter, reading anti-clockwise. (These names appear in an elliptical border which is missing in the copy). In each case the orbit of the moon (also signified by a disc) around the earth is indicated by a circle, although in fact it is elliptical. Four phases of the moon are depicted, in the same order, that is beginning with the orbit adjacent to Spring, although of course the phases of the moon are independent of the seasons: (a) The moon is its first quarter - a half-moon. (b) The new moon - a blank disc. (c) The moon in its third quarter - a half moon. (d) The full moon. To be consistent one would have expected this last to be placed on the orbit at a point furthest away from the sun, that is at 90°, but in fact it is placed at right angles to the sun (sun - earth - moon), that is at 0°/360°. This therefore appears to have been a mistake.

The elliptical shape of the diagram as a whole imposes constraints on the positioning of these four circular 'lunar' orbits such that the two to the left and right appear to touch the second and fourth 'planetary' ellipses, whilst the two at the top and the bottom overlap these ellipses. Curiously, a second disc appears on the left hand lunar orbit where it meets the elliptical orbit of the earth. This could be a trial mistaken 'new moon' symbol not in its proper place (cf. the misplaced full moon symbol dealt with earlier), or it could represent the missing planet, as if it and the earth shared the same orbit.

In fact, of course, nine planets orbit round the sun. They are, successively: Mercury, nearest to the sun, Venus, *Earth,* Mars, *Jupiter, Saturn, Uranus, Neptune,* and *Pluto* furthest from the sun. The elliptical orbits of all four of John Smith's named planets are therefore *outside* the earth's orbit, whereas two of his planetary orbits are depicted *within* earth's orbit. The discrepancy can only be partly accounted for by the constraints on draughtsmanship mentioned above. The limited space may also have precluded John Smith from incorporating the ellipses of the remaining four planets in his diagram. It is unlikely that in 1876 he would have been unaware of their existence.

The symbols for the four planets, the four representations of the earth, and the sun were all gilded on the original sundial (only traces remain). All four of the globes representing earth are depicted with the polar axis

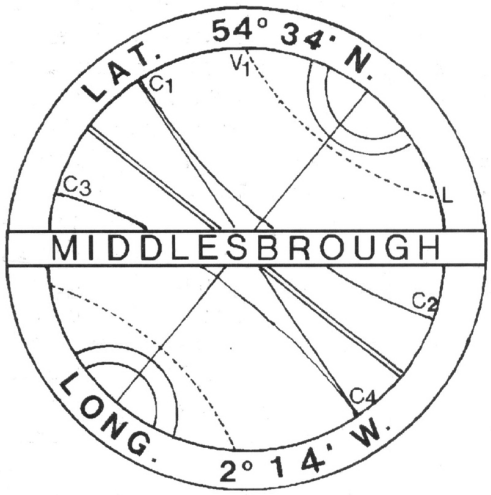


FIGURE 2

* (The ten lines of longitude have been omitted for the sake of clarity.)

inclined from the vertical by *c* 25° 26′ (the co-latitude - see above). That being so they cannot relate to the seasonal names which appear on the inner border. (Such a relation could only have been achieved if the 'summer' and 'winter' globes had their polar axes inclined at 23½° to the vertical, and the 'spring' and 'autumn' globes with their equators in line with the sun in the centre). On the other hand the designer may have intended the seasonal names to relate to the signs of the zodiac which he has placed in an outer border, since these appear *opposite* their corresponding seasonal positions on the other side of the elliptical diagram.

A contemporary account of the sundial betrays a Victorian preoccupation with arcane statistics: "We will now endeavour to give a few interesting particulars respecting the number of letters, words, circles semi-circles, lines &c., contained in the work. Number of English letters throughout, 664; words, 134. Greek letters, 40; words 8. Latin letters, 15, words 3. Hebrew letters, 20, words 3. Number of lines throughout, 84. Numbers of characters and drawings, representing the Planets, &c., in the solar system, 32. Total number of letters, characters, drawings, &c., 853; words, 148. Number of divisional lines for indicating the time on the three dials, 288; and these, besides a variety of other circular, semi-circular, elliptical, and straight lines, we find a measurement, if placed in one straight line, would reach the distance of 45 yards. Thus the reader may be able to form an idea of the designing, labour, patience and perseverance required to complete such a work".

The sundial is completed with a slate panel inset in the stone base inscribed 'Equation of Time (in Gothic letters) For each 5th day of the month'. There follows the appropriate table, concluding with yet another, tenth and final slogan: 'Learn to Value Time and Prepare for Eternity'. Regrettably, at the time of writing, this panel had been torn off by vandals and was in the custody of the Parks Department.

The name of the designer of the sundial (but not that of H.W.F. Bolckow who commissioned it) appears at the foot of the panel thus: Jno. Smith, Sculpt.(tor) (the Hebrew text) Stockton-on-Tees. In his own way, John Smith was as remarkable and eccentric a character as H.W.F. Bolckow. He was born in the village of Bielby, near Pocklington in the East Riding of Yorkshire, in 1807 (he was therefore an exact contemporary of Bolckow), son of a farmer, William Smith. From his childhood he showed a natural gift and a strong inclination for the study of astronomy, 'astro-meteorology', and dialling, which pursuits were strongly opposed by his father. Nevertheless at the age of eighteen he made a wooden sundial which indicated the time in Bielby and New York. Shortly after he made another sundial, which stood on a pillar in his father's garden, and showed the time by either sun, moon or stars - termed 'the astronomical clock'. This was followed by an astronomical almanac for his own private use, and when he was only twenty-two, by a spherical or terrestrial globe dial. This curious construction had drawn and painted on it a map of the world, and incorporated a device 'which being adjusted to the true latitude of the place, gave the correct solar time without the need of a gnomon'. I appears to have been a species of armillary sphere. Since he was obliged to work for his father during the day, this sundial was made during the night by candlelight, whilst the rest of the family were asleep in bed!

The following year this inventive young man perfected (but alas, did not patent) a clockwork mechanism then called a hodometer. This was fixed to the rear wheel of his father's wagon to measure the distance travelled, which was indicated on a dial resembling a clock face with two hands. One hand completed a revolution in one mile (when a hammer struck a gong), the other in thirty-six miles. The dial was ornamented with a diagram of the heavens representing the earth and moon revolving round the sun (of which the Middlesbrough dial was perhaps reminiscent?). In 1837 he made a vertical south declining dial inscribed on stone for a Wesleyan chapel newly erected in the village. (The sundial is still *in situ* although the building no longer serves as a Methodist chapel). In 1842 aged thirty-five he removed to Spaldington village, near Howden, also in the East Riding, to farm on his own account. He immediately began devising a vertical south sundial for a National School which was being erected there by the landlord, Sir Henry Vavasour. Since the estate shortly after passed into other hands the sundial was not erected. Some years later it was bought by an Alderman of Halifax, in the West Riding, where it was erected in the People's Park. The dial shows the time in Halifax and - again - in New York, for which city John Smith seems to have had a strong attachment'. His creative talents seem to have lain fallow for the next fifteen years during which he farmed at Crayke near Easingwold in the North Riding. In 1875, however, aged sixty-eight, he retired to South Stockton-on-Tees, the neighbouring borough to Middlesbrough. Now, for the first time, he enjoyed sufficient leisure to perfect the design of, and to construct, a masterpiece of a sundial which he had been contemplating for some years, and which seems to have incorporated many features from his earlier creations. It is not clear if the design of the Albert Park sundial as we have it today and completed before he was approached by H.W.F. Bolckow, or whether that commission prompted the completion of a scheme which was only present in his mind's eye. One account which supports the second alternative maintains that the sundial was commenced at the beginning of 1876, 'and (he) completed the engraving of it in the month of July, and, *shortly after, had a photograph taken of it*'. (Italics mine.)

In the craft of sundial making John Smith was no doubt an amateur, but the fact that he was a self-taught farmer's son only serves to make his achievements the more remarkable. The Albert Park sundial, which represents the peak of this career, bears comparison with the best work of contemporary professionals in the field. If some minor astronomical errors are apparent, they may be attributed to his lack of formal training, and forgiven. Among his many other accomplishments, John Smith was a very popular Wesleyan lay preacher, which may go some way to account for the very religious sentiments expressed in the quotations inscribed on the Middlesbrough sundial. They would not have been acceptable, however, had not the climate of the Victorian era itself been amenable to such overt moral and spiritual exhortation. One doubts if such a sundial could be created and displayed in today's intellectual climate.

The copy of the sundial from which most of this description has been derived is painted on a wooden board, and is in excellent condition. Until recently it was hanging on the inner (south facing) wall of the north wing of the stable block at Castle Howard in North Yorkshire. Sadly the costume gallery housed in this wing has been obliged to close permanently at the end of the 1993 season. The sundial has been placed in store and its future is uncertain.

An element of mystery attaches to this full-size copy. It was donated to the Costume Gallery some years ago by a descendant of John Smith. The date of the copy, however, is 1877, whereas, as we have seen, the date inscribed in the same place on the original (and carved on the front and the back of the stone surround) is 1876.

Two theories have been advanced to account for this discrepancy. Either this was a copy made by the designer a year after the original was completed, or it was a prototype on which he painted in advance the year when he believed it would be installed. Two small features on the copy tend to bear out the second theory. The names of the seasons on the diagram at the top, and the lines of latitude and longitude on the globe at the foot, are omitted from the 'copy', as if they were afterthoughts later incorporated in the finished product.

As a postscript, it would be fitting if a means could be devised to return this handsome copy to Middlesbrough, to be placed in display in the Dorman Museum by the entrance to Albert Park, and only a few yards from the original sundial. That would be appropriate tribute to, and a reminder of, the man whose genius created what is now, alas, a neglected treasure from Middlesbrough's Victorian heritage. Hopefully, the copy might even serve as a model for the sundial's eventual restoration.

ADDENDUM

In the September, 1989 issue of *Sky and Telescope,* on page 299, is the following:

CASTLE HOWARD SUNDIAL

Pictured in this department last January, page 81, was an elaborate wall-mounted sundial at Castle Howard near Malton, England. The photographer, Pattou Gaston, speculated from the inscriptions that the dial was a replica of one made by Albert Park for use at a different site, Stockton on Tees.

"Gaston's assumption is incorrect on two counts", writes Neil M. Haggath. "The latitude and longitude shown on the dial are not those of Stockton on Tees but of neighbouring Middlesbrough, which happens to be my hometown. 'Albert Park' is not the sundial's designer but the name of our public park!

"The Castle Howard sundial is a wooden replica of one that is mounted, along with a plaque giving the equation of time, in a stone wall of this park. The designs are identical except for the date. The Castle Howard dial is marked 1877 and the Middlesbrough one 1876.

"Ron Shaw, a fellow member of our local astronomical society, has researched the history of these two instruments. It was Henry Bolckow (1806-78), a prominent town figure and founder of the region's iron and steel industry, who had financed the park's construction. At Bolckow's request, Jonathan Smith began work on the stone sundial in 1876, but it was not completed and installed in the park until 1879. He probably made the wooden one first, as a working model. It remained in storage until the 1960's when Smith's descendants had it restored and donated it to Castle Howard.

"Sadly, though the Albert Park dial must have been a magnificent example in its time, it is now badly eroded and in a sorry state of disrepair."

THE GREGORIAN REFORMATION OF THE CALENDAR

GIROLAMO FANTONI (ITALY)

A Calendar is a means by which mankind accounts for the passing of days in a uniform and constant manner. Since time immemorial the design of a calendar in various areas of the world has been adjusted to the cultures, religion, habits and customs prevailing in each social organization. All calendars up to the present have been consistently tied to the most striking astronomical events which are observable from the Earth; actually all calendars invented by humanity during its history have been based on the most apparent cycles of the Sun and of the Moon, events that produce the impressive of the season's changes, the night and day alternations, or the evolution of the lunar phases.

In European regions the first technically designed calendar was the Roman one, set up by Romulus and subsequently corrected by King Numa Pompilius around the year 700 BC. It was a lunar calendar, based upon the cycles of the Moon; but was so inaccurate that a considerable discrepancy between calendar and seasons became apparent after a few centuries. In the year 46 BC the Roman leader Julius Caesar decided to correct these errors and with the assistance of the Greek astronomer Sosigene, he ordered drastic modifications of the current calendar. Firstly, in order to put the Sun positions and the seasons in consonance, he inserted an additional ninety days to the year 46 BC (for which reason this year was called the "Year of Confusion"); in addition he transformed the inaccurate Moon calendar into a more rational solar calendar; and lastly he invented the so-called "bissextile day", to be inserted every four years after the 24th February (1).

The need for an additional day to be inserted every four years derived from the fact that, according to Sosigene's belief, the length of the solar year was 365.25 days, the excess of one quarter of a day (0.25) in comparison with the 365 days of the normal year being taken into account in the new calendar by the insertion of the bissextile day after each period of four years.

The Roman calendar, which was justly called "Julian", remained in use for many centuries in all the regions which were part of the vast Roman Empire. In comparison with the reality of the astronomical cycles, there was a small discrepancy because the precise duration of a solar year is 365.2422 days and not the 365.25 days reckoned by Sosigene. [A difference of about 11 minutes 14 seconds in 525,960 minutes!, and seemingly of little consequence - Editor].

In the year 1582, sixteen centuries after the inauguration of the Julian Calendar, the consequences of that small discrepancy induced Pope Gregory XIII (the octogenarian Ugo Boncampagni, from Bologna) to intervene again in the structure of the calendar. To understand the reason for Gregory's intervention we must go back almost 1,300 years and take a look at a famous event which occurred in the year AD 325: the Christian Ecumenical Council of Nicea.

The beginning of the fourth century was a period of great refulgence for Christian religion; this new religion was in a phase of great expansion and of theological rethinking in the fields of faith and liturgy. In the year AD 325 the Christian Emperor Constantine I the Great, faced by the spreading of the Ario's schism, decided that the time had arrived for a drastic intervention. He convened a huge Christian Council in the town of Nicea in the region of Bitinia (near the south-west coast of the Black Sea).

Among other theological decisions (like the solemn rejection of Arianism) the Council also promulgated the general rule to establish the date on which Christians should celebrate the Festivity of Easter. The rule stated "that all Christians will celebrate Easter on the first Sunday after the first full moon that falls on or immediately after the vernal equinox".

This appeared to be a simple rule, but it was not so in practice because the astronomical cycles of the Sun and Moon involved in the Easter Rule, are irregular and not very compatible. The famous Alexandrian astronomers consulted about the date of the vernal equinox, replied that the date was March 21; therefore the Nicean Council, in order to make the implementation of Easter Rule easier, established that the vernal equinox meant March 21; thus the date of Easter could be readily determined and uniformity thus imposed on the Christian world.

THE PROBLEM OF THE CALENDAR

Let us now turn again to the problem of the calendar as seen by Gregory XIII.

Whilst the centuries were passing, the consequences of the slight difference in the duration of the year between the 365.25 days of Sosigene and the 365.2422 of the actual solar year became apparent. In particular this difference produced a slow shifting of March 21 away from the vernal equinox where it was located in the year AD 325 (Fig 1). At the time of Pope Gregory XIII (1582) the Sun, running slightly faster than the Julian calendar, passed through the vernal equinox almost ten days before the date inserted into the Easter Rule by the Nicean Council.

March 21 in the year 325

March 20 in the year 450

March 19 in the year 575

March 18 in the year 700

March 17 in the year 825

March 16 in the year 950

March 15 in the year 1075

March 14 in the year 1200

March 13 in the year 1325

March 12 in the year 1450

March 11 in the year 1575

(March 11 in the year 1582)

Figure 1: Days on which the Sun passed the Vernal Equinox throughout the centuries (Shift of one day in about 125 years)

Obviously, from a practical point of view, this shift of ten days had no influence at all on secular life, nor in the relationship between calendar and seasons. As far as the effects on social life were concerned, the Julian calendar could have continued to run smoothly with very little nuisance to anyone. Today the discrepancy between the Sun and the seasons would have reached 13 days, an amount easily tolerated by most people.

But Gregory's worry was that the new and still moving date of the vernal equinox changed the determination of the Easter date in an unacceptable way, in fact, in accordance with the Nicean Council orders, the Easter date should have been established with March 21 as the date of the vernal equinox.

To confirm the Pope's perplexities, the great Vatican astronomer Egnatio Danti, using a meridian line constructed and still existing in the "Tower of the Winds" in the Vatican Palace gardens, demonstrated to Gregory that the Sun touched the vernal equinox on the 11th March by the Julian calendar and not the correct March 21, and this was an unacceptable deviation from the Nicean Council directions.

Therefore Gregory XIII, with the exclusive aim of applying the Nicean Easter Rule correctly, decided to modify the Julian calendar to achieve agreement between the Sun and calendar.

After some investigations by an appropriate work force, he adopted the brilliant study of the astronomer Luigi Lilio (from Calabria, Italy) and ordered a calendar reformation based on the following two actions:

a Complete phasing of the date with the Sun's position, obtained by dropping ten days from the current Julian calendar: therefore in Rome in the year 1582, Thursday October 4th was followed by Friday October 15th (2).

b A new rule for the leap years, to avoid a future repetition of the undesired shifting of March 21st; in short the years multiple of 4 would be leap years, except those which were multiples of 100 (such as 1700, 1800, 1900) which would be treated as normal years: as an exception the years multiple of 400 (such as 1600, 2000) would be leap years.

With these simple changes the new Gregorian calendar achieved the result of having and maintaining March 21 almost perfectly on the vernal equinox, to the great satisfaction of the priests charged with the calculation of the date of Easter. A discrepancy of one day in the March 21 position of the vernal equinox will have to be reckoned with around the year 4900, but we may leave to posterity the task of deleting one of the prescribed bissextile days.

The fact that the calendar reformation was promulgated by a Pope of the Holy Roman Church produced a very different reception among the various peoples of the world. Naturally the new calendar was put to use immediately in Italy and the Iberian Peninsula, elsewhere other countries accepted the Gregorian reformation at various dates conditioned by religious and other differences. The Protestant and Greek Orthodox Churches were the most reluctant to adopt the Papal decrees. France adopted the reformation of the calendar by the end of 1582, Poland and Hungary in 1586, Prussia in 1610, and the Scandinavian countries in 1700. Not until 1752 did England implement the Gregorian calendar reform with an Act of Parliament, Russia did not change its calendar until 1918 (the so-called October Revolution actually took place in November according to the Gregorian calendar. The last of the modern nations to change to the Gregorian calendar were Turkey (1927) and Orthodox Greece (1929).

Of course the number of days to be dropped to correct for the change into the Gregorian calendar depended upon the delay, an increase of 1 day for every 128 years after 1582. For example, in England the lost days were eleven when the 2nd October 1752 was followed by the 14th of September.

We must note that at the beginning, even inside the Vatican there were some doubts about the validity of the Gregorian action. A good proof of these doubts was the construction of the huge meridian line inside the Basilica of Santa Maria degli Angeli in Rome (Fig 2). When the year 1700 neared (it was the first centennial non-leap year in the new calendar), the current Pope Clement XI ordered the construction of this magnificent meridian line for the exclusive purpose of checking the exactitude of the new calendar. The work was completed in 1702 when all the checks performed by its constructor (the astronomer and architect Francesco Bianchini) provided satisfactory results; the meridian line showed that the Sun very obediently passed over the vernal equinox on the 21st of March Gregorian style.

FIGURE 2: The great meridian line in the Basilica of Santa Maria degli Angeli in Rome.

Another anecdote, related to the meridian line of Santa Maria degli Angeli, may be of interest to British readers. Near the commencement of the line there is a small oval plate inserted in the marble floor on which two Latin dedications may be read (Fig 3):

a. In the annulus: "IACOBVS III D.G. MAGNAE BRITANNIAE ETC REX" (James III by the will of God King of Great Britain etc.);

b. In the centre: "FELIX TEMPORUM REPARATIO" (Happy adjustment of the times).

The first dedication disguises a riddle (a common trick in in many old inscriptions, called a chronogram because it hides a date). The underlined letters are engraved taller than the other letters, and are also numerals in the Latin language; their summing reveals the date of the plate (or the date of the celebrated event); in this case the date is 1721. The dedication evidently refers to James Stuart, the

FIGURE 3: The inscribed marble plaque dedicated to James Stuart (The Old Pretender) inserted in the floor of the Basilica of Santa Maria degli Angeli in Rome.

Old Pretender, who in that year was in exile in Rome, recognized as the King of England, James III by the Pope.

In my opinion, the second dedication refers to the Gregorian calendar reformation (it was checked in 1702 by the use of the meridian that commences near the site of the plate); therefore the entire meaning of the plate celebrates the acceptance in 1721 of the Gregorian reformation by James III as King (in exile) of England. In actual fact it was not until 1752, some thirty-one years later, that the new calendar was legally accepted in England.

At the end of this short journey through the Gregorian calendar, I would like to reply to a question born of curiosity - "After 411 years of work, how much has the new calendar shifted from the Sun's cycle?", or in other words, "How great is today's discrepancy between the 21st March and the vernal equinox of the Sun". The computation is easy and shows that in 1993 the Sun, which continues to run slightly faster than the calendar, is almost 3 hours (precisely 2h 57m) ahead of the calendar. I believe that our generation and the priests involved with the setting of the date for Easter may bear with this discrepancy with no worry at all.

Another curiosity which arises when dealing with calendars; how long is the Gregorian calendar expected to remain in operation with no further changes? Actually the present calendar has been under discussion for many years, the main defects of it cited as the variable length of the months and the variations of the weekdays in different years.

In 1927, the former League of Nations, having nothing better to do, carried out an investigation of the possible improvements of the calendar, and accepted two proposals. The first offered a "constant calendar" with 13 months of 28 days each, giving a total of 364 days; each month would start with a Sunday and would comprise 4 weeks: New Year's Day and the bissextile day (when required) would remain out of the month's cycle.

The second proposal was a "universal calendar" structured with four equal quarters, each with 91 days; the total days per year would be 364. In each quarter the first month would always commence with a Sunday and would have 31 days; the other two months with 30 days in each, would start with a Wednesday and Friday respectively. In this proposal also, New Year's Day and the bissextile day would remain out of the month's cycle.

To date nothing has happened in the practical field, and in the last few years the tendency to prepare more rational calendars to replace the Gregorian has decreased. No strong current desire to improve the present situation has surfaced, apparently the world has more important problems to deal with than trifle with matters which most people take for granted.

Continued from page 40

UNDER DIAL WORK

The blued steel shutters rise to their maximum height in mid-winter, and just sink out of sight in mid-summer. The gilt sun wheel turns behind these two sectors and makes one turn in twenty-four hours, the sun being at the 12 o-clock position at noon, mimicking the passage of the real sun.

Referring to Figure 2, the hour wheel (lowest wheel on centre line of watch) has 32 teeth which engage with an idler wheel of 64 teeth, hence it turns once in 24 hours. The idler wheel is pivoted and separate from the year wheel seen beneath. A pin on the idler wheel engages with the day of the month wheel once each 24 hours and moves it forward 1/31 of a turn. On the arbor of this 31 tooth star wheel is a pinion of 6 leaves, and this engages with the year wheel below of 72 teeth. On this year wheel are 12 pins which move the month star wheel one complete turn in twelve monthly moves. The star wheels are prevented from moving, except when impulsed by the pins, by the light pressure of two spring detents.

Mounted on this same year wheel is a cam, on which a detent fixed to the right hand sector bears. The corresponding left hand sector is spring loaded and linked to the right hand sector by a slot and pin action. The spring loading is sufficient to keep both sectors securely in the position dictated by the cam.

Figure 3 shows the rear of the movement, rather plain and bearing no marker's mark. It has the usual Continental bridge for the balance, with a steel coqueret. Under the silver regulator disc are the initials "TPDC 277", and I have been unsuccessful in identifying the Swiss watchmaker from these. Perhaps some member may be able to enlighten me. Stamped on the pillar plate is CH 62048, which I imagine to be that of the ebauche maker. The bar on the lower left is to reinforce the fusee pivot bearing. The barrel is rather larger than usual and will keep the watch running for thirty-five hours. The escapement is the usual Continental verge with adjustable potence and counter potence. The watch is quite large in diameter but is thin for its size, it would appear to have been made circa 1800.

Editors Note: Mr. Foster passed away 26th March, 1994 at Christchurch in New Zealand.

WINDOWS AND BALCONIES AS SIMPLE SUNDIALS

GIROLAMO FANTONI (ITALY)

Everyone has noticed that on sunny days in his room, the shadows of the window sill and jambs move on the floor and on the walls, following the course of the Sun; the same phenomenon takes place on balconies and terraces for the shadows of their parapets.

Perhaps not everyone has thought that, as a result, window sills, jambs and parapets can be used as styles for simple sundials, that can be drawn on the floor and on the walls of the room, or of the terrace, or of the balcony.

The general criterion to take advantage of these shadows stems from the fact that each point of an indefinite rectilinear line (horizontal or vertical) can be considered a gnomonic point producing shadows.

Each one of these points projects on the floor or on the walls a "shadow point"; the whole of these points forms on the horizontal or vertical plane a "shadow straight line"; the position of this line on the plane is variable with the time and can therefore be used as an indicator of the hour.

For the sake of simplicity, we will limit this presentation to the instance of the shadow of a window sill which appears on the floor and on the back wall of a room. This technique however can be applied to all analogous situations.

SYMBOLS

- a - difference between angles Z and d
- d - declination of the window sill (from South to East or to West)
- G - date
- h - altitude of the Sun
- H - height of the window sill from the floor
- L - distance of the shadow from the base of the window sill
- L′ - distance of the shadow, on the vertical wall, from the horizontal line whose height from the floor is H
- F - distance of the rear wall from the window sill
- t - hour
- Z - azimuth of the Sun (from South to East or to West)
- δ - declination of the Sun
- γ - latitude

The main element of this unusual sundial is the moving distance L between the base of the window sill and its shadow. The elements that intervene on this distance are, first of all, the constant elements, geometric and geographic, of the window sill. They are:

- the latitude γ of the place;
- the height H of the window sill from the floor;
- the orientation of the window sill in respect to the cardinal points of the horizon.

In this regard, we call "declination d" of the window sill the angle between the local meridian plane and the perpendicular plane to the window sill, measured from South to East (positive) or to West (negative).

In addition to these fixed elements, we must also consider the variable ones, which are the two local coordinates of the Sun altitude h and azimuth Z; these coordinates are dependent on the two parameters hour t and astronomic declination δ, which cause the shadow of the window sill to move, in this case we prefer to measure the azimuth Z from South to East (positive) or to West (negative). We also remind that to say "declination δ" is equivalent of saying "date G".

The calculation of the distance L between the two parallel lines "style shadow" and "style base" is elementary (Figure 1); first of all, the oblique distance OB between the shadow B of any of each point A of the style and the projection O of A on the floor must be determined (OB = H/tg h). Then the distance L of the shadow MN is found using the angle *a*, which is the difference between the declination *δ* of the window and the azimuth Z of the sun (a = d-Z or a = Z-d depending on the situation). The distance L, at the variation of hour t and date G, is finally obtained by the formula:

$$L = H \frac{\cos (Z-d)}{\operatorname{tg} h}$$

In this formula the sign of the angle (Z-d) is indifferent; furthermore cos (Z-d) is always positive since (Z-d) cannot be more than 90°.

The values of h and z, necessary to obtain L, can be found in the Nautical Tables or can be obtained with the usual trigonometric formulas, easily programmable with every pocket calculator.

Once the distances L are obtained, the dial can be drawn on the floor (Figure 2). First of all a graduation of dates (or declinations of the Sun) is drawn on the base of the window sill; from the points of some selected dates (or declinations) lines perpendicular to the base are marked out; on these lines a point is marked at the distance L corresponding to each date and each hour. On that date and on that hour the shadow of the window sill will pass over this point.

Finally a set of *hour lines*, which represent the dial of our instrument, will be obtained by joining all the points relative to the same hour.

The rectilinear shadow of the window sill, which move with the passing of time, now works as the hand of a clock and marks the hour on the point where it crosses the line of the date.

The Figure 3 indicates, with solid lines, the dial on the floor of a room, calculated for latitude 42° North and sill declination 45° East.

The graduation of the year on such a type of dial is totally arbitrary. If can be drawn either using the Sun declination (as in illustration 3) or using the date, in a uniform fashion or in any other non-uniform one; it can be narrowed or widened to adapt the drawing to the available geometric situation; it can also be moved in any part of the floor, and so forth.

As an example, the illustration 4 shows another dial of this kind, drawn for sill declination 30° West, with a uniform annual graduation January/December.

Since the same declination of the Sun appears twice a year, the annual graduation can comprehend all the 365 days of the year (as in Figures 3 and 4) or can be halved, doubling it between the two solstices, with the advantage of its major scale. Of course, as in all sundials, the halving of the annual graduation can be easily done when the Sun declination or the zodiacal calendar (symmetric to the declinations) are used; it will present some difficulties with

the civil calendar, since it is asymmetric in respect to the ecliptic of the Sun.

It can be noticed that a dial of this type can be used for the same sill declination East or West, as long as the AM and PM hours are exchanged.

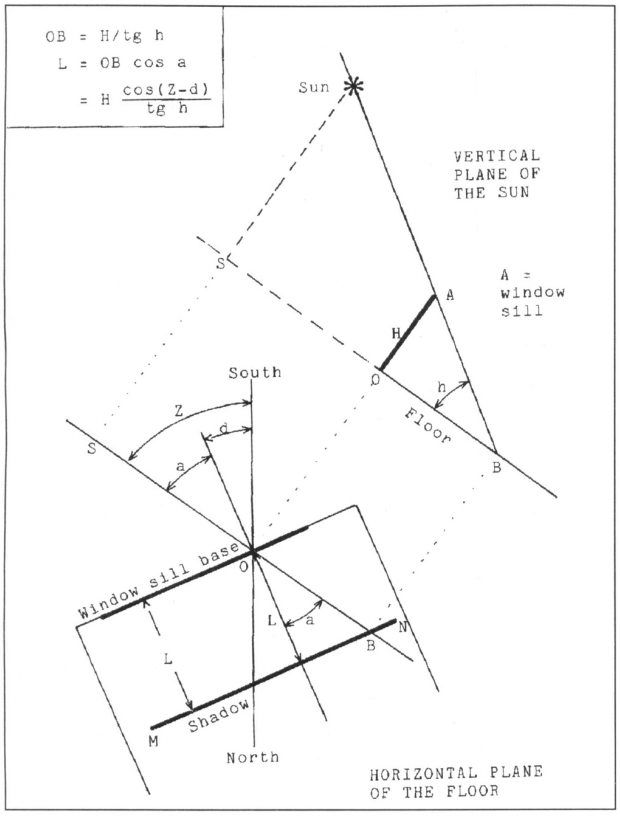


FIGURE 1

In some instances the scheme of this kind of dial may present some practical difficulties. There are situations in which the hour lines narrow down or overcross; this makes it difficult or impossible to pin point the hour line which corresponds to the date. A typical case of such occurrence (Figure 5) takes place when the sill declination is Ø (room or terrace oriented exactly South). In this situation during the two days of the equinox all the hour lines pass on the same point and the shadow line does not move during the whole day; on these dials during these days it is impossible to read the time: the clock does not work because it has stopped! (This result can be proved by trigonometry, but for this time I will save the reader from calculations).

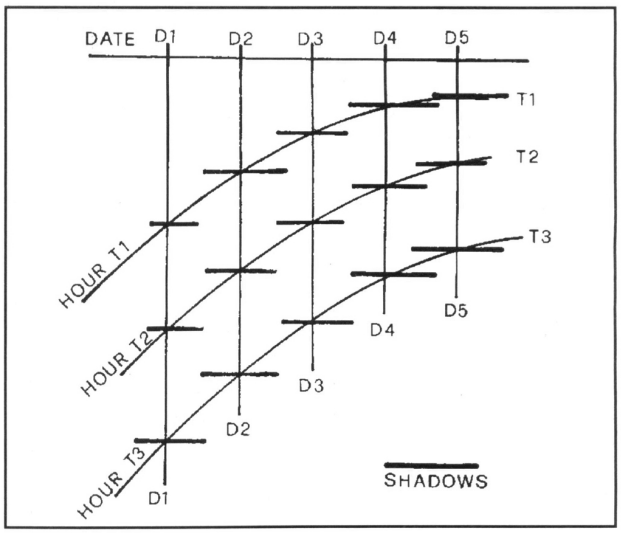


FIGURE 2

When the shadow of the style, having reached the end of the available plane of the floor, starts climbing on the back wall the sundial can be continued just as easily.

In this case the shadow of the horizontal style, still parallel to the window sill, is an horizontal line which climbs the wall as the altitude of the Sun decreases, or goes down as the altitude increases.

To obtain the elements of the dial on a vertical wall parallel to the style (Figure 6) we will call L′ the vertical distance of the shadow from the horizontal line on the wall which is at the same height H of the window sill. The formula which gives L′, as shown in the Figure, is:

$$L' = F \frac{\text{tg } h}{\cos (Z\text{-}d)}$$

in which F is the horizontal distance of the back wall from the window sill.

Nothing has changed in this dial about what has previously been said for the graduation of the dates.

If the same date graduation is used for dials on the floor and on the black wall, the horizontal hour lines start climbing on the wall where they reach the edge of the wall.

In illustration 3 and 5 the hour lines on the back wall are the dashed lines.

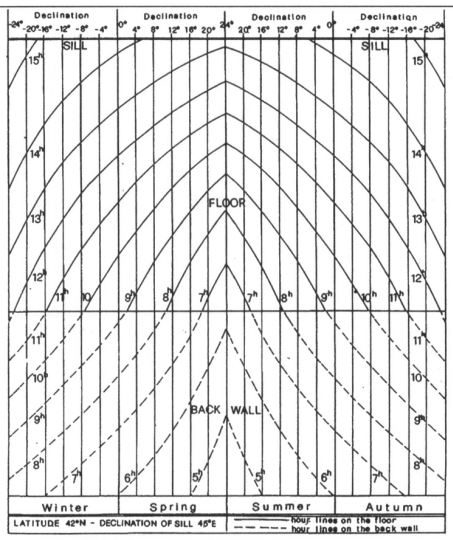


FIGURE 3

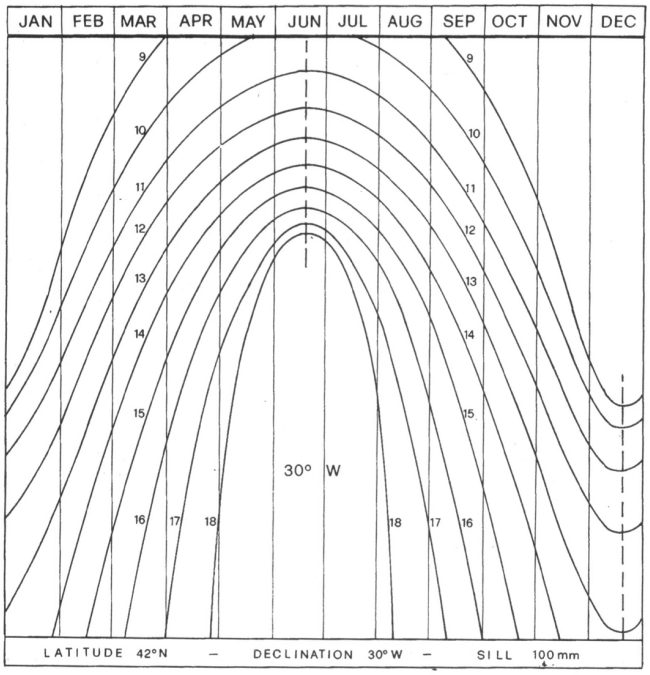


FIGURE 4

From a practical point of view, the construction of a large sundial inside a furnished room can present some difficulties; the window sill in many instances cannot be used. This technique is certainly of easier application on terraces, balconies, outside surfaces.

A simple alternative to a complete sundial inside a room could be the drawing of a single hour line (on which the graduation of the dates can be transferred); it could allow the reading of a daily time-signal, always at the same hour. I also want to point out that this type of sundial may easily receive the corrections for the longitude (time-zone) and for the equation of time, so that the mean time-zone hour of our wrist watch can be read by the sundial shadows.

I leave to the readers, who feel like it, the prosecution of this little gnomonic play in the instances of shadows that are produced on the lateral walls of the room, or that are generated by vertical elements, such as the jambs of a window. The development of these cases is as easy as those that we have illustrated. I wish "good luck" to anybody that tries these techniques!

As an example and for encouragement, I show in Figure 7 the drawing of a sundial of this type, produced by the jamb of a window and set on the three back and lateral walls of a room with 30° West declination.

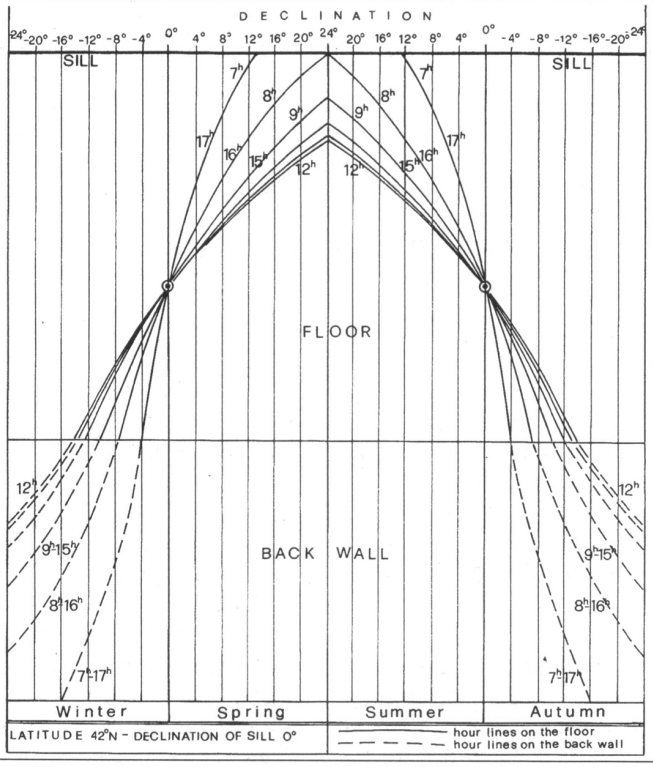


FIGURE 5

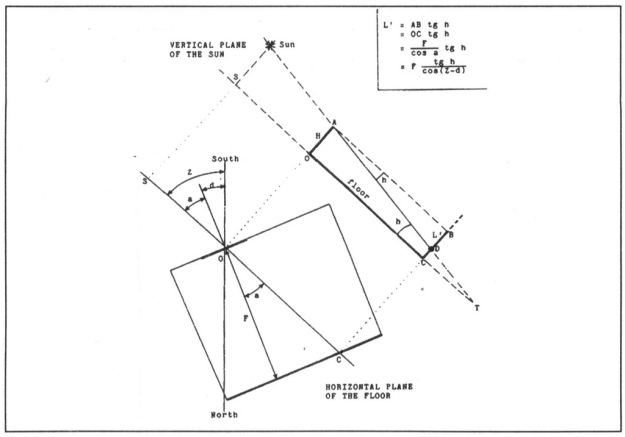


FIGURE 6

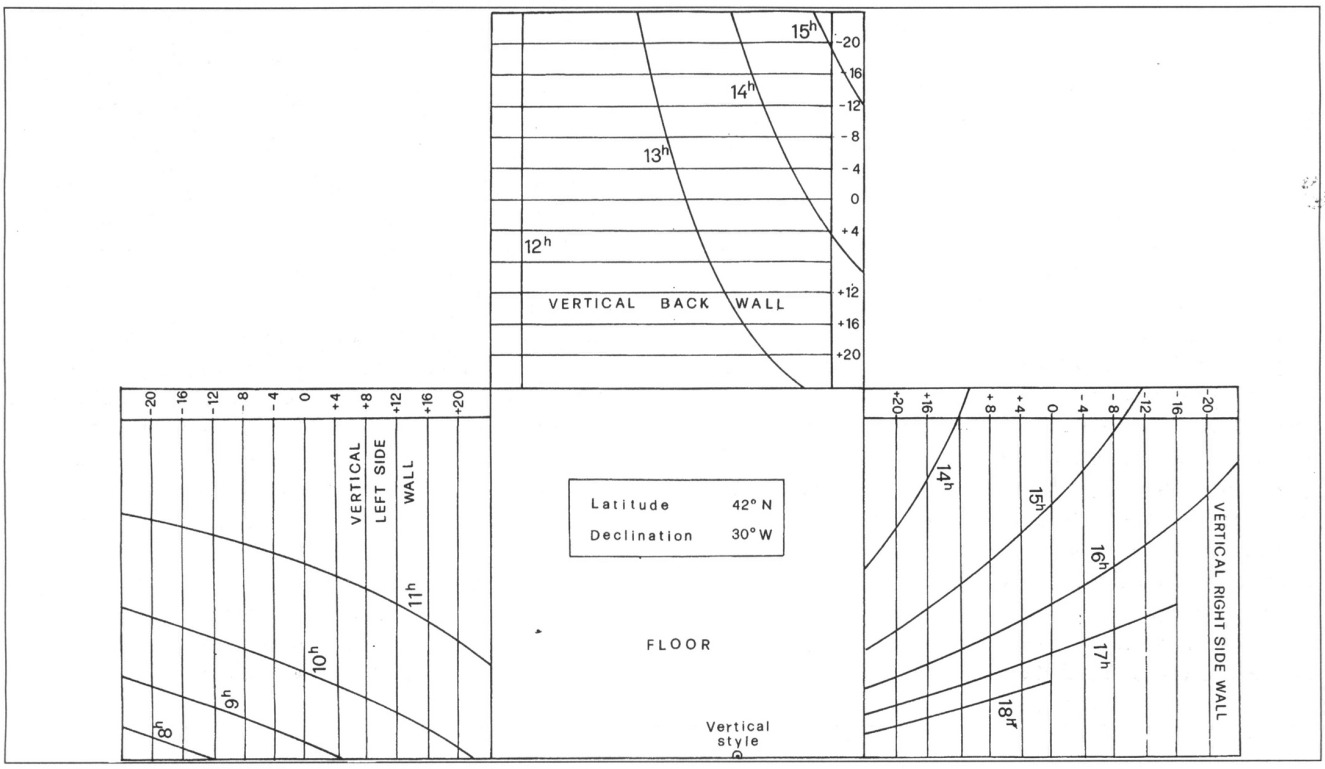


FIGURE 7

* * * * * * * *

COMPUTER PROGRAM

Please note that as the Editor has disposed of his PC with 5¼″ disc drives, it is no longer possible to supply the British Sundial Society Sundial Program in this form to members. The 3½″ discs are still available from the Editor, 54 Swan Road, West Drayton, Middlesex UB7 7JZ. The price, including postage, is £8.50, not free as one member thought recently. The profits from these sales goes towards the BSS funds, and once again Mr. Fer de Vries must be thanked for supplying this program to the BSS without charge.

The program runs IBM compatible systems but the drawing function requires a graphic adapter (CGA, or EVA/VGA with screen dump. Four pages of explanatory text prepared by Mr. Piers Nicholson will be sent with the disc, although all the explanatory files necessary are included in the program itself.

Overseas members must include the cost of air mail postage and pay in sterling since the bank charges exceed the amount for the disc.

The editor will be pleased to hear the experiences of members who have used this program. Mr David Young has written a simpler program, for details write to the Secretary, address on inside back cover. There is also a much simpler program devised by Mr. H. C. Parr which is listed on page 36 of BSS *Bulletin* 91.3. The program is no longer available from him in disc form.

At some time in the future, it will be necessary to form a group to deal with this specialised aspect of dialling. Hopefully it will be possible to pool ideas so that all members with computers can keep up with the developments devised by BSS members and also exchange information on discs.

LUNAR DISTANCES

THE TWENTIETH CENTURY RELIEF CHRONOMETER AT SEA

RENÉ R.-J. ROHR (FRANCE)

A generally held belief, that star observation alone is sufficient to afford the approximate latitude of places on the earth, is as old as the hills. But as to longitude, its solution entails knowledge and resources not available to the ordinary observer. In theory it merely requires the difference of local solar time at two places to be known and converted into degrees from the difference in time. The Earth is divided for this purpose into 360° at the Equator (for convenience [-180°.0°.+180°]) and this angular distance is turned through in 24 Hours. If one meridian is used as a reference eg Greenwich, the difference in time between that and another meridian can be converted into degrees and the longitude (or angular displacement) of the unknown meridian may be made known. The method demands that the time at both places be known simultaneously. It could easily be known if an accurate timekeeper set to the reference meridian time was available at the unknown meridian when an observation was made. This was not possible until the middle of the eighteenth century when John Harrison devised his sea clocks. This method demands that some event in time is noted simultaneously by the observer at each meridian.

In 150 BC Hipparchus, using sundials, put observers at two meridians and had observations made of the commencement and the end of eclipses of the sun. He possibly ignored that the results obtained could not be perfect, for these events are not seen at precisely the same time at different longitudes.

In later centuries it was realised that other astronomical events which were visible from earth could provide the simultaneous event for observers to check against their local time. These included the transits of Venus across the Sun, occultations and eclipses with stars or the Moon, or between Jupiter and its moons. These observations needed to be reduced to the centre of the earth for accuracy, and would have been of enormous importance if only such observations could have been made at sea, but this was not possible.

As long as dependable timekeepers at sea did not exist, the only remaining solution was to utilise the motion of the moon, which had to be seen from an altogether different point of view.

Given its disproportionate size and close proximity to the earth, the forms of the two bodies, and the comparative nearness of the sun's planets; the moon's orbit is subject to numerous influences which make it the most complicated of all the celestial orbits known. Even the great Sir Isaac Newton said that calculating the moon's orbit made his head ache. In the renowned astronomical clock built some 150 years ago in Strasbourg Cathedral, only five of the necessary corrections have been included, the rest, being less important, or perhaps insufficiently or not even known at the time.

It was the proximity of the moon and the ensuing very obvious speed of its eastward course amid the stars that indicated the solution. Not very long ago the inhabitants of our towns and villages used to pay the this nocturnal aspect of the firmament an attention of which almost nothing remains today. In the Middle Ages, the nocturlabium (Fig 1), an unsophisticated device, made its appearance. It was a sort of star clock marking the hours of night all through the seasons by simple observation of the rotating alignment of two stars around the polar star. In spite of its very modest accuracy, it was appreciated at sea as well as on shore, and it remains a highly esteemed device in museums and collections even to this day.

FIGURE 1: Nocturlabium. From Rohr, Die Sonnenuhr, 1982.

In the same way, artistically decorated astrolabe monumental clocks were set up in cathedrals and town halls, of which examples remain in a number of cities like *Prague*, *Ulm*, and even in market places like *Haguenau* in Alsace (Fig 2). The view given on their dials is an imitation of the heavens in a stereographic projection of the clockwise daily movement, complete with the different motions of the sun, moon, and even the nodes on the orbit of this latter body on account of its roles in dating eclipses. This is usually shown as a pointer in the form of a dragon and turns clockwise with regard to the sky, whereas the hands depicting the sun and moon travel backwards. The sun turns once in 24 hours, the sky in 23 hours 56 minutes, and the moon needs some 48 minutes more than the sun, so the angle between the two indicators steadily increases throughout the month. It is this angle of difference to which sailors gave the name of *lunar distances*, later extending its meaning to the distance between the moon and planets and stars.

To navigate a ship from Europe to China or some far distant coast, the captain has frequently to determine the precise position of his ship. In the first place observation of the sun tells him the local solar time, which has to be corrected to clock mean time. His ship carries a carefully rated chronometer, and as a precaution, one or two more. Any error in the chronometer can be a dangerous thing as

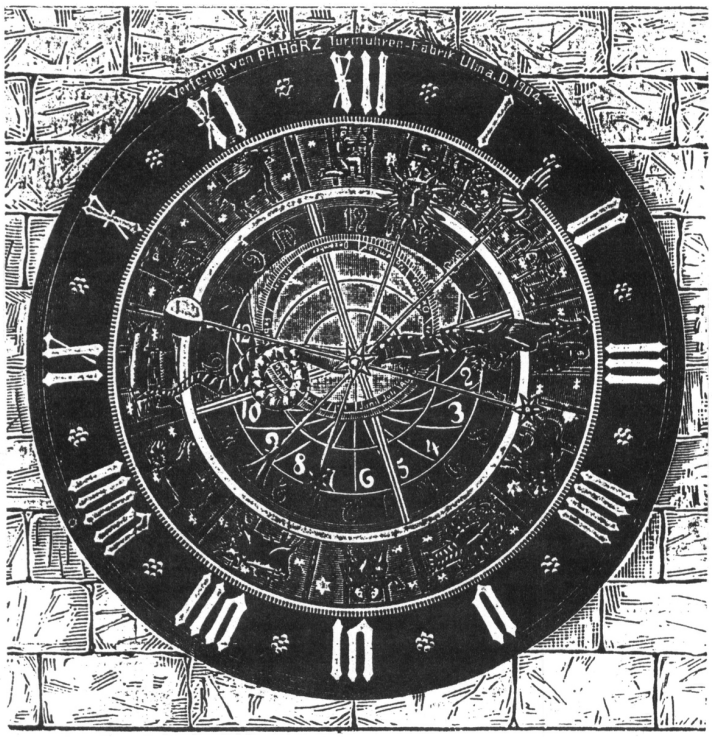


FIGURE 2: Astronomic clock on the facade of the Library in Haguenau, Alsace.

one minute of error (time) can mean fifteen miles out of reckon-ing. Many years ago there was no such thing as wireless existing to check up the true time!

The proposal to make use of the moon's fast orbital motion for navigation was first proposed by Johann Werner in 1514. He was a Nuremburg mathematician and astronomer, soon to be succeeded by Peter Apian, and later by Gemma Frisius, Pedro Nunez and Kepler, who all included, in addition to the sun, the stars neighbouring the ecliptic. But these new ideas were to remain purely platonic as long as there were no moon emphemerides to forecast lunar events. Kepler and Newton had uncovered the required laws of celestial mechanics, but even so important components of the gravitational forces acting on the moon were then still unknown and could not therefore be allowed for in calculations.

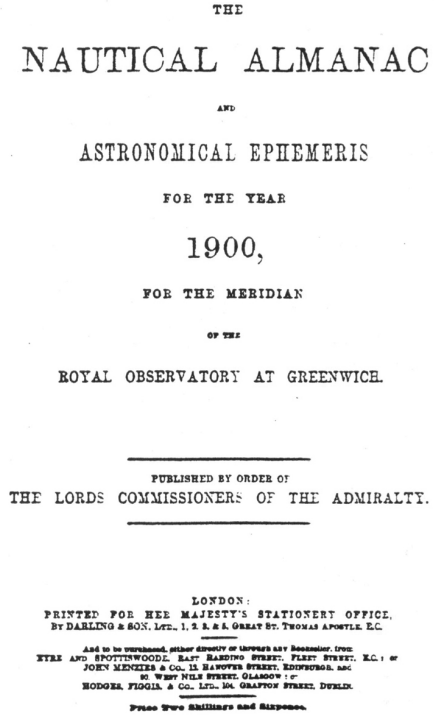
Meanwhile the progression of deep sea navigation urgently demanded the provision of lunar tables to avoid the great loss of vessels and men. Important premiums were offered by a number of governments, for even approximate solutions which might be in error up to 30 miles. In England, where the problem was of the utmost urgency, the then fabulous amount of £20,000 was offered (probably more than £2,000,000 in present-day money). Important astronomical observatories were built, Greenwich being one of these at the command of King Charles II, with the object of providing adequate lunar emphemerides. At last, in 1752, Tobias Mayer, a Professor of Astronomy and Mathematics in Göttingen University succeeded in preparing tables fit for such use. In England these began to be published in 1765 in the form of the *Nautical Almanac*, possibly established at least partly on the tables of Mayer (by now deceased). The British crown had paid his widow the sum of £3,000 for these table. Mayer had provided a copy of his tables in 1755, and these were proved to be capable of giving the position of the moon within one minute of arc.

Little by little, with the help of a number of collaborating mathematicians and astronomers, continually improved tables were issued until at last, towards the end of the 19th century, these could be considered as perfect or almost so. The German *Nautisches Jahrbuch* had its first edition in 1852 which included the new tables, whilst the widespread *Nautical Almanac* had them in more perfect form some 13 years later. The French *Connaissance des Temps* and the Spanish *Almanaque Nautico* followed. All these ephemerides were published in an identical form, (Figs 3 and 4), each one referring to the prime meridian of the respective country until at last, by International agreement in 1884, the meridian of Greenwich was adopted as the prime meridian of the world. Only two countries did not agree to accept Greenwich, Ireland which kept to Dublin until 1916, and France which adopted a meridian 9m 21 seconds in advance of the Paris Observatory, which is the same as Greenwich.

The angles being henceforth often being beyond the limits of the octant scale, the sextant was adopted and has remained up to the present day one of the most important instruments in navigation. Well-to-do shipowners gave their ships captains the instrument with a somewhat cumbersome title of *Repeating and Reflecting Circle* (Fig 5), a device first proposed by Tobias Mayer and later produced by Bordas, a French Navy captain. The extant examples are now looked upon as jewels in museums and collections.

A correct measure of a lunar distance required the collaboration of three observers, and possibly another to note the times of observations. Two of them took the altitudes of the moon and another suitable celestial body, the third the proper moon distance. At the time the majority of the ships were sailing vessels and the method remained so throughout most of the nineteenth century. Officers, even captains, who mastered the not-too-easy task of the necessary calculations must have been in great demand. Old navigation manuals show detailed examples of the complicated calculations required (Fig 6).

In addition to the necessary corrections innate in the sextant itself, it was important to take into account the



THE

NAUTICAL ALMANAC

AND

ASTRONOMICAL EPHEMERIS

FOR THE YEAR

1900,

FOR THE MERIDIAN

OF THE

ROYAL OBSERVATORY AT GREENWICH.

PUBLISHED BY ORDER OF

THE LORDS COMMISSIONERS OF THE ADMIRALTY.

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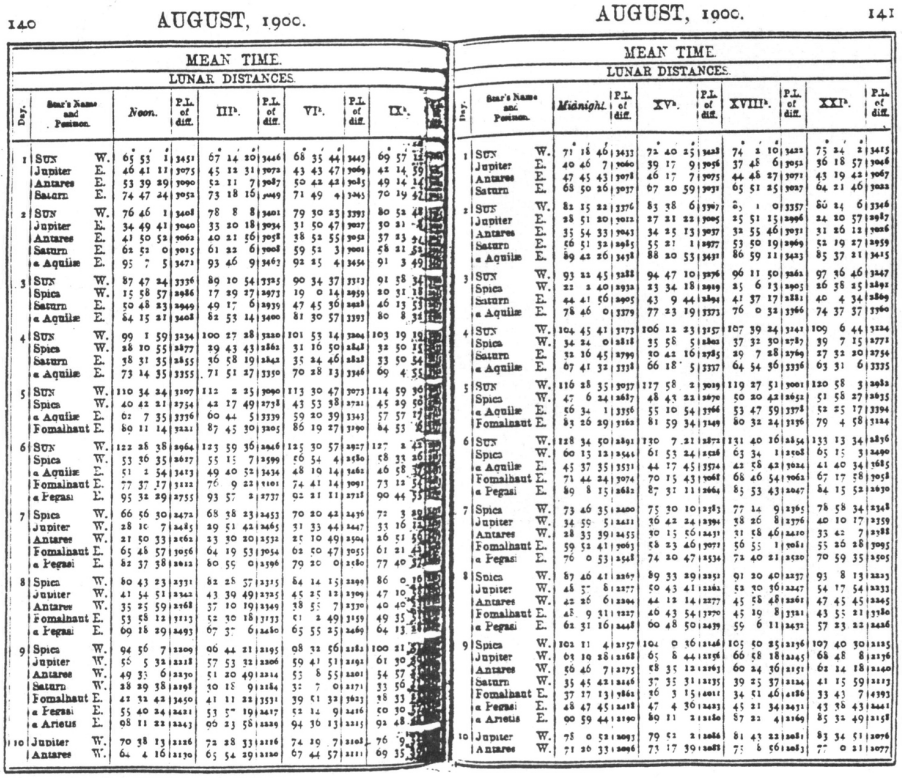
FIGURE 3: The title-page of the Nautical Almanac, 1900.



140 AUGUST, 1900.

MEAN TIME.

LUNAR DISTANCES.

Day.	Star's Name and Position.		Noon.	P.L. of diff.	III^h.	P.L. of diff.	VI^h.	P.L. of diff.	IX^h.
1	SUN	W.	65 53 1	3451	67 14 20	3446	68 35 44	3443	69 57 12
	Jupiter	E.	46 41 11	3075	45 12 31	3072	43 43 47	3069	42 14 59
	Antares	E.	53 39 29	3090	52 11 7	3087	50 42 42	3085	49 14 14
	Saturn	E.	74 47 24	3052	73 18 16	3049	71 49 4	3045	70 19 52
2	SUN	W.	76 46 1	3408	78 8 8	3401	79 30 23	3393	80 52 48
	Jupiter	E.	34 49 41	3040	33 20 18	3034	31 50 47	3027	30 21 [illegible]
	Antares	E.	41 50 52	3062	40 21 56	3058	38 52 55	3052	37 23 [illegible]
	Saturn	E.	62 52 0	3015	61 22 6	3008	59 52 3	3001	58 21 55
	α Aquilæ	E.	95 7 5	3471	93 46 9	3463	92 25 4	3454	91 3 49
3	SUN	W.	87 47 24	3336	89 10 54	3325	90 34 37	3313	91 58 34
	Spica	W.	15 58 57	2986	17 29 27	2973	19 0 14	2959	20 31 18
	Saturn	E.	50 48 23	2949	49 17 6	2939	47 45 36	2928	46 13 53
	α Aquilæ	E.	84 15 21	3408	82 53 14	3400	81 30 57	3393	80 8 32
4	SUN	W.	99 1 59	3234	100 27 28	3220	101 53 14	3204	103 19 19
	Spica	W.	28 10 55	2877	29 43 43	2861	31 16 50	2844	32 50 15
	Saturn	E.	38 31 35	2855	36 58 19	2842	35 24 46	2828	33 50 54
	α Aquilæ	E.	73 14 35	3355	71 51 27	3350	70 28 13	3346	69 4 53
5	SUN	W.	110 34 24	3107	112 2 25	3090	113 30 47	3073	114 59 36
	Spica	W.	40 42 21	2754	42 17 49	2738	43 53 38	2721	45 29 56
	α Aquilæ	E.	62 7 35	3336	60 44 5	3339	59 20 39	3343	57 57 17
	Fomalhaut	E.	80 11 14	3221	87 45 30	3205	86 19 27	3190	84 53 [illegible]
6	SUN	W.	122 28 38	2964	123 59 36	2946	125 30 57	2927	127 2 43
	Spica	W.	53 26 35	2617	55 15 7	2599	56 54 4	2580	58 33 26
	α Aquilæ	E.	51 2 54	3413	49 40 52	3434	48 19 14	3462	46 58 [illegible]
	Fomalhaut	E.	77 37 37	3112	76 9 22	3101	74 41 14	3091	73 12 [illegible]
	α Pegasi	E.	95 32 29	2755	93 57 2	2737	92 21 11	2718	90 44 [illegible]
7	Spica	W.	66 56 30	2472	68 38 23	2453	70 20 42	2436	72 3 [illegible]
	Jupiter	W.	28 10 7	2485	29 51 42	2465	31 33 44	2447	33 16 [illegible]
	Antares	W.	21 50 33	2262	23 30 20	2232	25 10 49	2204	26 51 [illegible]
	Fomalhaut	E.	65 48 57	3056	64 19 53	3054	62 50 47	3051	61 21 [illegible]
	α Pegasi	E.	82 37 58	2812	80 55 0	2796	79 20 0	2780	77 40 [illegible]
8	Spica	W.	80 43 23	2331	82 28 37	2315	84 14 15	2299	86 0 18
	Jupiter	W.	41 54 51	2242	43 39 49	2225	45 25 12	2209	47 10 [illegible]
	Antares	W.	35 55 59	2068	37 10 19	2049	38 55 7	2030	40 40 [illegible]
	Fomalhaut	E.	53 58 12	3113	52 30 18	3133	51 2 49	3159	49 35 [illegible]
	α Pegasi	E.	69 18 29	2493	67 37 6	2480	65 55 25	2469	64 13 [illegible]
9	Spica	W.	94 56 7	2209	96 44 21	2195	98 32 56	2182	100 21 [illegible]
	Jupiter	W.	56 5 32	2228	57 53 32	2206	59 41 51	2191	61 30 [illegible]
	Antares	W.	49 33 6	2230	51 20 49	2214	53 8 55	2201	54 57 [illegible]
	Saturn	W.	28 29 38	2298	30 18 9	2284	32 7 0	2271	33 56 [illegible]
	Fomalhaut	E.	42 32 42	3450	41 11 22	3531	39 51 32	3623	38 33 [illegible]
	α Pegasi	E.	55 40 24	2421	53 57 19	2417	52 14 9	2416	50 30 [illegible]
	α Arietis	E.	98 11 22	2243	96 23 58	2229	94 36 13	2215	92 48 [illegible]
10	Jupiter	W.	70 38 13	2126	72 28 33	2116	74 19 7	2101	76 9 [illegible]
	Antares	W.	64 4 16	2130	65 54 29	2120	67 44 57	2111	69 35 [illegible]

AUGUST, 1900. 141

MEAN TIME.

LUNAR DISTANCES.

Day.	Star's Name and Position.		Midnight.	P.L. of diff.	XV^h.	P.L. of diff.	XVIII^h.	P.L. of diff.	XXI^h.	P.L. of diff.
1	SUN	W.	71 18 46	3433	72 40 25	3428	74 2 10	3422	75 24 2	3415
	Jupiter	E.	40 46 7	3060	39 17 9	3056	37 48 6	3052	36 18 57	3046
	Antares	E.	47 45 43	3078	46 17 7	3075	44 48 27	3071	43 19 42	3067
	Saturn	E.	68 50 26	3037	67 20 59	3031	65 51 25	3027	64 21 46	3022
2	SUN	W.	82 15 22	3376	83 38 6	3367	85 1 0	3357	86 24 6	3346
	Jupiter	E.	28 51 20	3012	27 21 22	3005	25 51 15	2996	24 20 57	2987
	Antares	E.	35 54 33	3043	34 25 53	3037	32 55 46	3031	31 26 12	3026
	Saturn	E.	56 51 32	2985	55 21 1	2977	53 50 19	2969	52 19 27	2959
	α Aquilæ	E.	89 42 26	3438	88 20 53	3431	86 59 11	3423	85 37 21	3415
3	SUN	W.	93 22 45	3288	94 47 10	3276	96 11 50	3262	97 36 46	3247
	Spica	W.	22 2 40	2932	23 34 18	2919	25 6 13	2905	26 38 25	2891
	Saturn	E.	44 41 56	2905	43 9 44	2892	41 37 17	2881	40 4 34	2869
	α Aquilæ	E.	78 46 0	3379	77 23 19	3373	76 0 32	3366	74 37 37	3360
4	SUN	W.	104 45 41	3173	106 12 23	3157	107 39 24	3141	109 6 44	3124
	Spica	W.	34 24 0	2818	35 58 5	2801	37 32 30	2783	39 7 15	2771
	Saturn	E.	32 16 45	2799	30 42 16	2785	29 7 28	2769	27 32 20	2756
	α Aquilæ	E.	67 41 32	3358	66 18 5	3357	64 54 36	3356	63 31 6	3355
5	SUN	W.	116 28 35	3073	117 58 2	3059	119 27 51	3041	120 58 3	2982
	Spica	W.	47 6 24	2687	48 43 22	2670	50 20 42	2652	51 58 27	2635
	α Aquilæ	E.	56 34 1	3356	55 10 54	3366	53 47 59	3378	52 25 17	3394
	Fomalhaut	E.	83 26 29	3162	81 59 34	3149	80 32 24	3136	79 4 58	3124
6	SUN	W.	128 34 50	2891	130 7 21	2872	131 40 16	2854	133 13 34	2836
	Spica	W.	60 13 12	2561	61 53 24	2536	63 34 1	2508	65 15 31	2490
	α Aquilæ	E.	45 37 35	3531	44 17 45	3574	42 58 42	3624	41 40 34	3685
	Fomalhaut	E.	71 44 24	3074	70 15 43	3068	68 46 54	3062	67 17 58	3058
	α Pegasi	E.	89 8 15	2682	87 31 11	2664	85 53 43	2647	84 15 52	2630
7	Spica	W.	73 46 35	2400	75 30 10	2383	77 14 9	2365	78 58 34	2348
	Jupiter	W.	34 59 51	2421	36 42 24	2394	38 26 8	2376	40 10 17	2359
	Antares	W.	28 33 39	2455	30 15 56	2431	31 58 46	2410	33 42 7	2388
	Fomalhaut	E.	59 52 41	3063	58 23 46	3077	56 55 1	3081	55 26 28	3095
	α Pegasi	E.	76 0 53	2548	74 20 47	2534	72 40 21	2520	70 59 35	2505
8	Spica	W.	87 46 41	2267	89 33 29	2251	91 20 40	2237	93 8 13	2223
	Jupiter	W.	48 57 8	2277	50 43 41	2262	52 30 36	2247	54 17 54	2233
	Antares	W.	42 26 6	2204	44 12 14	2277	45 58 48	2261	47 45 45	2245
	Fomalhaut	E.	48 9 31	3227	46 43 54	3270	45 19 8	3321	43 55 21	3380
	α Pegasi	E.	62 31 16	2468	60 48 50	2479	59 6 11	2491	57 23 22	2506
9	Spica	W.	102 11 4	2157	104 0 36	2146	105 50 25	2136	107 40 30	2125
	Jupiter	W.	63 19 28	2168	65 8 44	2156	66 58 18	2145	68 48 8	2136
	Antares	W.	56 46 7	2175	58 35 12	2163	60 24 36	2151	62 14 18	2140
	Saturn	W.	35 45 42	2246	37 35 31	2235	39 25 37	2224	41 15 59	2213
	Fomalhaut	E.	37 17 13	3862	36 3 15	4011	34 51 46	4186	33 43 7	4393
	α Pegasi	E.	48 47 45	2418	47 4 30	2423	45 21 34	2431	43 38 43	2441
	α Arietis	E.	90 59 44	2190	89 11 2	2180	87 22 41	2169	85 32 49	2158
10	Jupiter	W.	78 0 52	2093	79 52 2	2084	81 43 22	2081	83 34 51	2076
	Antares	W.	71 20 33	2096	73 17 39	2083	75 8 56	2083	77 0 21	2077

FIGURE 4: Page 140 and 141 of the Nautical Almanac, 1900.

altitude of the observer's eye above sea level, atmospheric refraction, the radius of the sun or planets, and certainly the moon and its parallax correction. It is not possible to produce empherides for all places of the world, so they are given for an observer supposed to be located at the centre of the earth, to which the obtained observations are reduced by addition of the parallax. This parallax is the angle at which an imaginary inhabitant of the celestial body being observed would see the radius of the earth at the end of which the observer is placed. Its value is a function of the altitude of that body and is the reason why the two altitudes are taken.

The whole calculation therefore, easy in itself, turns into such a delicate affair that no captain could assume the risk of navigating in dangerous waters without repeating it once or even twice before taking the difference of Greenwich time and local time transformed into degrees and minutes of longitude!

But little by little, in the meantime, the accuracy of marine chronometers was nearing perfection. The general interest in lunar observations began to wane and disappeared completely when at last radio communication became universal. Lunar tables ceased to be published in France in 1905, followed shortly after in England, Germany in 1914 and the USA in 1925.

Apart from the unification of the different prime meridians towards the end of the nineteenth century, the size and style of the almanacs remained standardised. Figure 4 shows the disposition of the eight columns of lunar distances given at three hourly intervals from 0 to

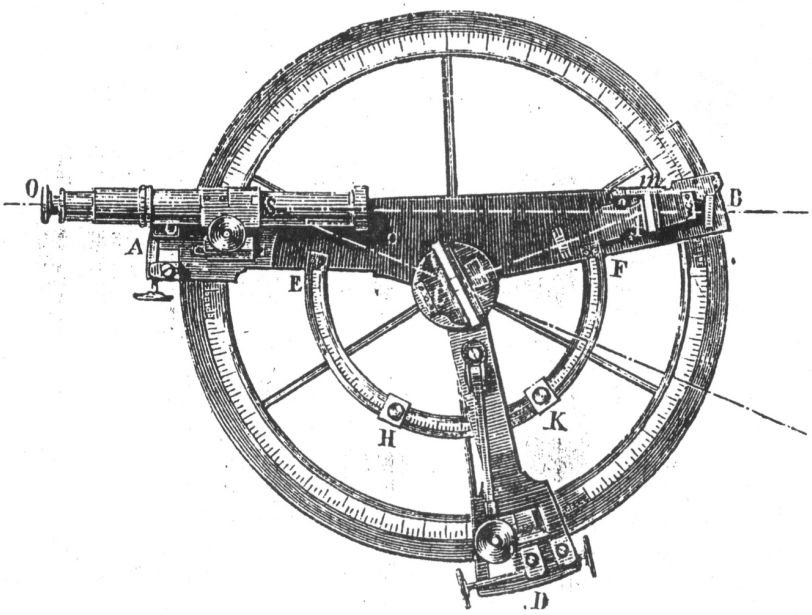


FIGURE 5: Repeating and Reflecting Circle.

LE GUIDE DU NAVIGATEUR. 318 N°. II.

MODÈLE D'UN CALCUL DE LONGITUDE.

Le 20 Octobre 1776, étant par 20° 29' 29" de Latitude Nord, & par 67° 30' de Longitude estimée Occidentale; (ce qui en temps donne 4 h. 30) à 2 h. 41' 20" sur la Montre, on a observé la Hauteur du bord inférieur du Soleil, de 39° 30' 18", ayant l'œil élevé de 18 pieds: après quoi, on a fait les Observations suivantes.

OBSERVATIONS.	Temps à la Montre.	Dist. obs. des plus proches bords du Soleil & de la L.	Hauteurs obser. du bord inférieur du Soleil.	Hauteurs obser. du bord infér. de la Lune.
	4h 2' 10"	94° 51' 25"	20° 26' 36"	32° 15' 30"
	4 17 16	95 3 18	17 19 6	34 33 30
	4 25 15	95 7 24	15 45 21	36 15 30
	4 30 15	95 3 51	14 41 53	37 10 32
Somme	17 14 56	380 15 48	68 12 56	140 37 0
Dont le quart	4h 18' 44"	95° 3' 57"	17° 3' 14"	35° 9' 15"
	Heure moyenne.	Dist. moyenne.	Haut. moyenne.	Haut. moyenne.

CALCUL DE L'HEURE VRAIE, Comptée sur le Vaisseau.

Correction de la Hauteur.

Hauteur observée du bord inférieur du Soleil	39° 30' 18"
Inclinaison de l'Horison, pour 18 pieds, Soustractive	4 21
Hauteur apparente du bord inférieur	39 25 57
Réfraction Soustractive	1 20
...	39 24 37
Parallaxe Additive	7
Hauteur vraie du bord inférieur	39 24 44
Demi-Diamètre Additif	15 8
Hauteur vraie du centre du Soleil	39 40 52
Distance vraie du Soleil au Zénith	50° 19' 8"

Calcul de la Déclinaison.

Différence Occidentale des Méridiens	4h 30' 0"
Temps Astronomique compté à bord	2 42 20
Temps Astronomique compté au même instant à Paris	7 12 20
Déclinaison du Soleil le 20 à Midi	10° 39 16
Déclinaison du Soleil le 21 à Midi	11 0 37
Variation en 24 heures	21 21
Variation en 7 heures 12 minutes 20 secondes	6 24
Déclinaison du Soleil le 20 à 7 h. 12 min. 20 sec.	10 45 40
Distance du Soleil au Pôle élevé	100° 45' 40"

Calcul de l'Angle Horaire.

Distance du Soleil au Zénith	50° 19' 8"	
Dist. du Soleil au Pôle élevé	100 45 40	Comp. ar. Sin. 0.007705
Distance du Pôle au Zénith	69 30 31	Comp. ar. Sin. 0.028388
Somme	220 35 19	
Demi-somme	110 17 39	
Dif. de la ½ som. à la dif. de l'A. au Pôle	9 31 59	Logarit. Sin. 9.219104
Dif. de la ½ som. à la dif. du Pôle au Zén.	40 47 8	Logarit. Sin. 9.81[illegible]
Somme des 2 Logar. Sin. & des 2 Complem. Arithmétiques		19.070203
½ Som. ou Log. Sin. de la moitié de l'Ang. Hor. 20 d. 3' 7"		9.535101
Angle Horaire en degrés	40 d. 6' 14"	
Angle Horaire en temps, ou heure de l'observation		2h 40' 25"
Heure marquée par la Montre		2 42 20
Erreur de la Montre A.		1 55
Heure de l'Observation de la distance		4 18 44
Heure vraie de cette Observation		4 16 49
Différence Occidentale des Méridiens		4 30 0
Heure comptée à Paris au même instant		8h 46' 49"

Calcul du demi-Diamètre de la Lune.

Diam. hor. le 20 à midi	31' 42
Diam. hor. le 21 à midi	32 8
Changement en 24 heur.	26
Chang. en 9 h. 47 min.	11
Diam. hor. le 20 à 8 h. 47'	31 53
Demi-Diamètre	15 5
Aug. du ½-Diam. p. 35°	5
Vrai demi-Diamètre	16' 1

Calcul de la Parallaxe Horisontale.

Paral. hor. le 20 à midi	58' 2
Par. hor. le 20 à minuit	58 25
Changement en 12 heur.	23
Changement en 8 h. 47 m.	17
Par. hor. le 20 à 8 h. 47 m.	58 20

Correction de la Hauteur observée du Soleil.

H. ob. du b. inf. du S.	17° 3' 14
Inclinaison Soustract.	4 21
Haut. ap. du b. inf.	16° 58 53
Demi-Diam. addit.	16 8
Haut. ap. du centre.	17 15 1
Parallaxe additive.	8
...	17 15 9
Réfraction soustract.	3 20
Haut. vraie.	17° 11 49

Correction de la Hauteur observée de la Lune.

Haut. ob. du bord inf.	35° 9' 15
Inclinaison Soustract.	4 21
Haut. ap. du bord inf.	35 4 54
Demi-Diamètre add.	16 5
Haut. ap. du centre.	35 20 59
Correct. additive.	46 14
Hauteur vraie.	36° 7' 13

Correction de la distance observée des plus proches bords du Soleil & de la Lune.

Dist. observ. des plus proches bords du Sol. & de la Lune	95° 3' 57
½-Diamètre du Sol.	16 8
½-Diam. de la Lune.	16 5
Dist. ap. des centres.	95° 36' 10

RÉDUCTION DE LA DISTANCE APPARENTE A LA DISTANCE VRAIE.
Méthode de M. le Chevalier de Borda.

Distance apparente de la Lune au Soleil	95° 36' 10				
Hauteur apparente de la Lune	35 20 59	Comp. arith. du Cosinus.	0.088504		
Hauteur apparente du Soleil	17 15 1	Comp. arith. du Cosinus.	0.019988		
Somme	148 12 10				
Demi-Somme	74 6 5	Logarithme du Cosinus.	9.437649		
Différence de la demi-Somme à la Distance apparente	21 30 5	Logarithme du Cosinus.	9.968674		
Hauteur vraie de la Lune	36 7 13	Logarithme du Cosinus.	9.907294		
Hauteur vraie du Soleil	17 11 49	Logarithme du Cosinus.	9.980137		
Somme des Hauteurs vraies	53 19 2	Somme des six Logarith.	39.402246		
Demi-Somme des Hauteurs vraies	26 39 31	Demi-Somme	19.701123		
Soustrayez de cette demi-somme le Logarithme du Cosinus de la demi-Somme des Hauteurs vraies.			9.951189	Idem	9.951189
Reste le Logarithme du Sinus de	34° 22' 43		9.749934	dont le Logarith. du Cosinus est	9.917487
La Somme de ces deux derniers Logarithmes est le Sinus de	47° 39' 3"				9.868576
dont le double est la Distance vraie ou corrigée.	95° 18' 6"				

CONCLUSION DE LA LONGITUDE.

Distance vraie ou corrigée	95° 18' 6	Différence de Distance 1° 20' 30". Son Logarithme proportionnel 3495
Distance de la Lune au Soleil, à 6 h. 9' 16"	93 57 36	
Distance de la Lune au Soleil, à 9 h. 9' 16"	95 32 11	Variat. de Dist. en 3 h. 1° 34' 35" Son Logarithme proportionnel ..... 2795 / 700
Différence des Logarithmes proportionnels qui répond à	2h 33' 12"	qui ajouté à 6 h. 9' 16", donnent 8 h. 42' 28".
Temps vrai compté à Paris	8 42 28	
Temps vrai compté sur le Vaisseau	4 16 49	
Différence Occidentale des Méridiens en temps	4h 25' 39"	qui en dégrés donnent 66° 24' 45" pour la Longitude Occidentale cherchée.

FIGURE 6: Calculation of Longitude from an observation of the Moon, Lévèque, Guide de Navigation, 1779.

XXI hours for a fortnight. The adjoining smaller columns did not exist in the first almanacs but were later judged useful in comparing with Greenwich time. In fact the observed lunar distance was looked up between two main columns and its difference with the distance on the left compared to that between the main columns. The whole calculation were to be made in seconds of time and arc, so 3 hours was written 10800 (3 x 3600 seconds). The portion of time to be added to the hour marked on the top of the next column to the left was obtained as the logarithm of the fraction:

$$\frac{\text{Difference between observed lunar distance and left column x 10800}}{\text{Difference between distances in the two main columns}}$$

The logarithm of the division of 10800 by the denominator is given ready computed in the small column, to which the captain added the number obtained from the sum of the logarithm to the hour on top of the left column - it being Greenwich time at the moment of the observation. Its difference with local time was the longitude of the ship.

Almost a century ago the system of lunar distances went out of fashion, and long ago the captains who employed them for navigational purposes died. All of them, to be sure, when recalling their old sailing days, must have experienced a feeling of melancholic nostalgia.

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THE LATE GEORGE ROBERT HIGGS

He had a puckish sense of humour. Only in February this year he completely took me in when he telephoned me in respect of the National Trust for Scotland sundial plate (see BSS *Bulletin* 94.1, page 44). He outlined the various short-comings in the design by Deborah Phillip and I could not understand just how he could determine such details from the poor reproduction of the plate (the transparency supplied was poor). He chatted away as though he was in possession of the original design. It was only some time later that when I mentioned that the plate I had obtained was serial number 5 that he let it slip that he had serial number 1, and of course he was quoting his remarks straight from the plate, not the fuzzy reproduction! It quite took me aback when he was mentioning things about the dial plate which I thought were known only to me. But that was only George having his bit of fun.

I shall miss his piquant letters, his stimulating telephone calls, and above all his pleasant personality. He was one of those rare persons who revived one's faith in the innate goodness of mankind. He was an example to us all, if anyone deserves a place in Heaven, then George Robert Higgs is there.

CHARLES K. AKED

A SUNRISE-SUNSET WATCH

BY GEORGE FOSTER, NEW ZEALAND

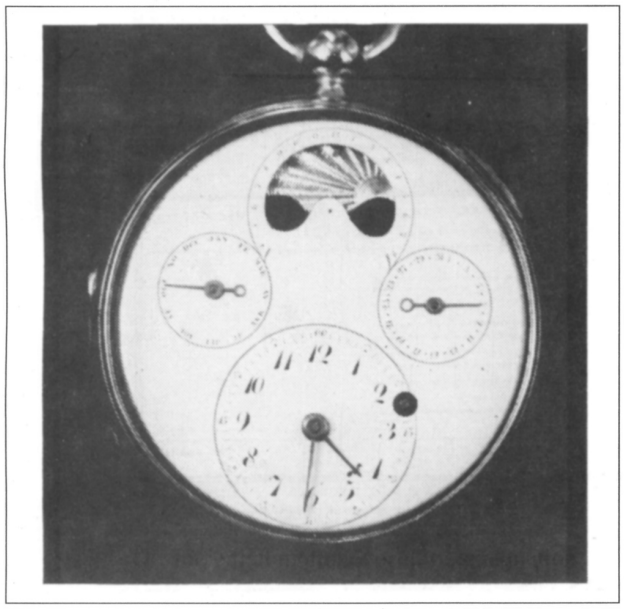


FIGURE 1: The impressive dial of the sunrise/sunset watch

Astronomical watches have, from the earliest times, often incorporated the feature of sunrise-sunset indications, perhaps following the fashion of the complex public sundial of the period. This indication is quite useful for anyone intending to set out on a long journey, allowing the owner to plan his day so that he arrives at the required destination whilst still in daylight.

One of the earliest examples I have found is a beautiful watch by Hans Schneeberger, Augsburg, made in the early part of the seventeenth century. An illustration of this marvellous watch may be found as figure 85 in Hans von Bertele's Book of Old Clocks and Watches. It is a superb example of the watchmaker's art.

Towards the end of the 18th century and the beginning of the 19th century, the fashion was resumed in Switzerland, and there are many similar watches which suggests that they were based on the movements from one ebauche maker. It was my good fortune to acquire one of these in 1946, and encouraged by Professor Willis Milham, then the Editor of the NAWCC Bulletin in America, I described my watch, the article being published in the December, 1948 issue.

In the same year the late Oscar T. Lang of the USA had been on a purchasing trip to Europe and wrote to me of the successful deals he had struck. Lang was a protege of Major Paul Chamberlain (author of It's About Time), and when Chamberlain died, Lang bought most of the technical pieces and escapement variations collected by Chamberlain, from his widow Margaret. In this letter he described a watch which seemed exactly similar to mine.

Lang was an architect by profession, often adding delightful little sketches to illustrate his descriptive text. He was exceedingly proud of his watch and never lost faith in its rarity, in fact when he had his portrait painted by the American portrait painter Edward V. Brewer, he chose to have a tabernacle clock in the background, whilst he held his "famous" sunrise-sunset watch in his left hand.

THE SUNRISE-SUNSET WATCH

My example is housed in a base metal case, which is probably not the original, see Figure 1. The dial shows the sunrise-sunset indications at the top, where a gilt sun is engraved on a wheel, with blued steel shutters at each lower side. The dial on the left indicates the month, that on the right indicates the day of the month, whilst the lower main dial gives hours and minutes, the numerals being Arabic. The 15, 30, 45 and 60 minutes are marked as such, but the other five minute intervals merely have an open arrow head against them. The time dial is rather spoilt by the winding hole cutting into the dial markings. The calendar indications (1-13) and (January-December) are quite usual and are not perpetual, the day of the month pointer has to be reset for all months of less than 31 days (by inserting a pointed object into the tail of the pointer). The central upper dial reads from 4am on the left, and down to 9pm on the right.

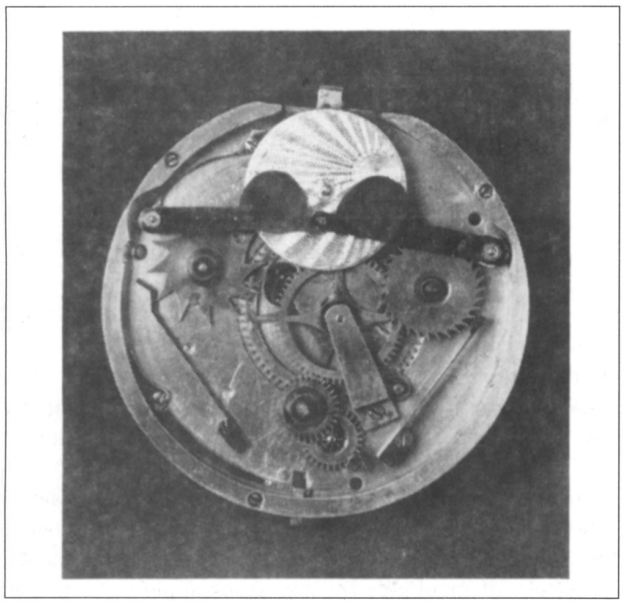


FIGURE 2: The underdial motion work, for explanation see text.

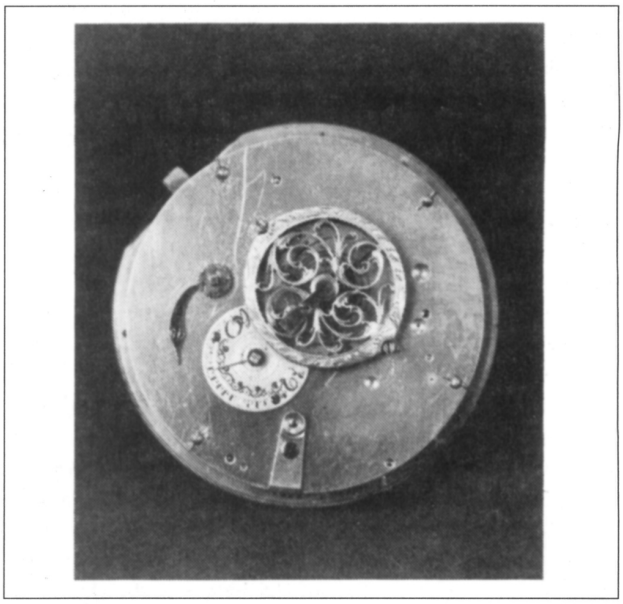


FIGURE 3: A view of the back plate, typical of a Swiss watch circa 1790-1810

Continued on page 31

VERTICAL DIAL FURNITURE

PETER J. MEADOWS

INTRODUCTION

Many vertical sundials contain additional information, or furniture, other than the hour lines. Take, for example, the vertical dial at Queens College, Cambridge which gives solar altitude and azimuth lines of the zodiac, the sunrise time and the length of daylight hours together with the hour lines.[1] Incidently this dial also contains data to enable the dial to be used for the moon instead of the sun. With so much information on a single dial it can become very difficult to identify each furniture type. This is especially true when examining black and white photographs that populate most sundial literature. The aim here is to illustrate, separately, a selection of dial furniture and to explain, briefly, how each can be calculated. The purpose behind this work has been to enable the author to include a selection of furniture on his own garden vertical dial.

All the furniture shown here is based on the shadow cast onto the dial by a nodus. The nodus is situated along the style and can be thought of as the end of a thin rod which is placed perpendicular to the dial face. Calculation of where the nodus shadow will fall is simplified by transforming the vertical dial to an equivalent horizontal dial. This is achieved by noting that a vertical south facing dial at a latitude of 50°N, for example, is equivalent to a horizontal dial at a latitude of 40°S. With the equivalent horizontal dial, the nodus can now be thought of as being at the tip of a rod which points to the zenith. Given any solar altitude and azimuth angle, the location of the nodus shadow on the horizontal plane can be easily calculated. This position can then be drawn onto the vertical dial. In the case of a declining vertical dial this can be included in the transformation to the equivalent horizontal dial.

For all the following diagrams, the furniture has been calculated for a declining vertical dial at at latitude of 50°43' and a declining angle towards the west of 15°42' - these values are for the dial constructed by the author. It has been assumed that the nodus is a point. The location of the nodus has been arbitrarily chosen to be 30% of the sub-style length shown in the accompanying diagrams. This value has been selected so that the furniture fits sensibly onto the dial face. Where appropriate the mean sun has been used. All the results presented here have been produced using a computer program written by the author.

EQUINOX AND SOLSTICE DECLINATION LINES

During the year, the sun appears to traverse along the ecliptic plane. This plane intersects the plane of the celestial equator by an angle known as the obliquity of the ecliptic (ε). Thus, the angle of the sun above or below the celestial equator (the solar declination) is greatest when it equals ε (the current value of which 23° 26·4').[2] The solstices occur when the sun is at its highest or lowest declination while the equinoxes occur when the sun is on the celestial equator (i.e. at a declination of 0°). The equinoxes usually occur around 21st March and 23rd September, with the solstices around 21st June and 22nd December each year.

The equinox and solstice declination lines are those which show the passage of the nodus shadow on the dial face for the appropriate day. These lines are calculated, for a particular declination, be selecting a set of solar hour angles (angles from the southern meridian to the sun) and then calculating the appropriate solar altitude and azimuth angles. Transforming these to our equivalent horizontal dial, the position of the nodus shadow can then be calculated. By selecting enough hour angles for the day in question, the path of the nodus can be drawn on the vertical dial.

The two curved lines and the straight line in Figure 1 show the equinox and solstice declination lines. The dashed line indicates the sub-style line while the cross is for sub-nodus location (i.e. the point directly behind the nodus). The lower curved line indicates the position of the nodus shadow throughout the day of the summer solstice. As the sun is highest in the sky at this solstice, the nodus shadow appears furthest from the sub-nodus point. The middle straight line is for the equinoxes (both spring and autumn). Finally the upper curve is for the winter solstice. As can be seen this curve only appears when level with or below the sub-nodus point as this is when the sun is above the horizon.

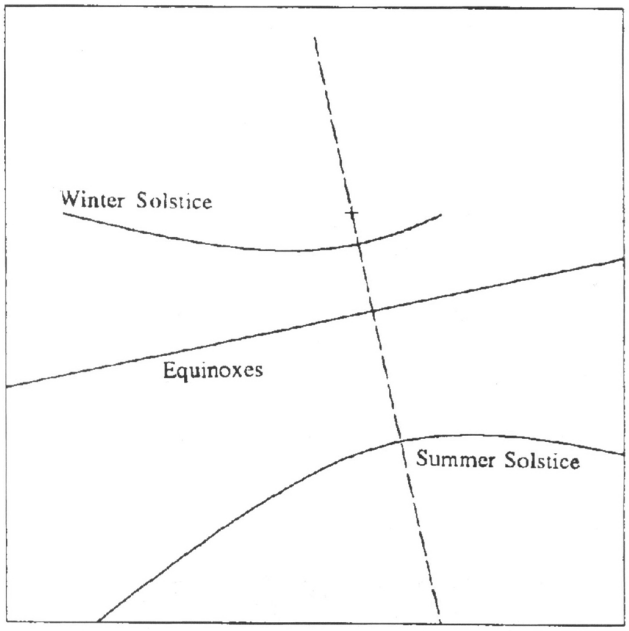


FIGURE 1: Equinox and Solstice Declination Lines. The dashed line is the sub-style and the cross the sub-nodus point.

The winter solstice line together with the sub-nodus horizontal and summer solstice line indicate the upper and lower bounds for any dial furniture produced by the nodus.

ALTITUDE AND AZIMUTH LINES

As each day progresses the angular height of the sun above the horizon (altitude) will vary. The maximum altitude reached on any day will depend on the time of year. At the northern hemisphere summer solstice this will be $90 - \phi + \varepsilon$ where ϕ is latitude and ε is the obliquity angle. At the equinoxes, the maximum altitude is $90 - \phi$ while for the corresponding winter solstice this will be $90 - \phi - \varepsilon$. The azimuth angle is the angular direction of the sun as measured on the horizon. The azimuth angle increases from north (0°) through east (90°), south (180°) and west (270°)

and back to north.

An altitude line is calculated by selecting a set of azimuth angles stretching around the horizon. For each altitude and azimuth angle, the position of the nodus is calculated via the corresponding horizontal dial. With sufficient points, the profile of the nodus shadow can be drawn for a given altitude angle. Azimuth lines are calculated in a similar fashion: a selection of altitude angles for a given azimuth angle determine the position of the nodus shadow which can then be drawn on the vertical dial.

Altitude and azimuth lines are shown in Figure 2. The altitude lines are shown in steps of 10° from 0° (i.e. sunrise and sunset) to 60° (the maximum altitude for the author's vertical dial is 61° 43'). As the higher solar altitude angles occur only during mid-summer, the 50° and 60° altitude lines are located near to the summer solstice declination line. The lower altitude lines are applicable at some time during each day. These lie close to the declination line for the winter solstice (at which the maximum altitude is only 14° 51'). The azimuth lines are shown in steps of 20° and all appear as vertical lines. As the dial declines towards the west, more lines from the western hemisphere of the sky are shown compared to the east. The 180° azimuth line corresponds to the local noon hour line.

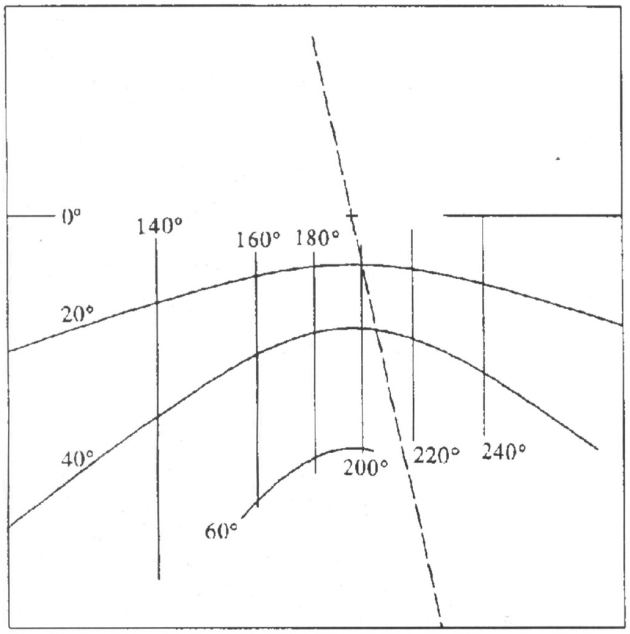


FIGURE 2: Altitude Lines (0° to 60°) and Azimuth Lines (140° to 240°)

MONTHLY DECLINATION LINES

As already mentioned, the declination of the sun changes throughout the year with the highest and lowest declinations occuring at the solstices. Thus for a given year the sun will have a specific declination on the first day of each calendar month. From year to year the solar declination, on the first day of each month, will vary slightly due to the fact that a year is not a complete number of days. A tropical year (equinox to equinox) is in fact 365.24219 days.[2] Over the period of 4 years, it can be seen that an almost complete number of days would have elapsed and so the cycle of solar declination values will almost repeat. The maximum variation in declination from year to year will occur at the equinoxes. For the 1st April for the years 1994 to 1997 inclusive, the maximum variation in solar declincation is only 0.29°.

The declination at noon on the first day of each month is calculated by taking the average declination for the years 1994 to 1997. With the declination, the dial furniture can be calculated in the same way as for the equinox and solstice declination lines described above. Figure 3 shows the monthly declination lines for the author's vertical dial. For clarity, the first day of the months January to June are shown to the left of the sub-style lines while the other six months are to the right. The spacing between the declination lines illustrates the fact that the change of solar declination is fastest around the equinoxes (wide spacing) and slowest at the solstices (narrow spacing).

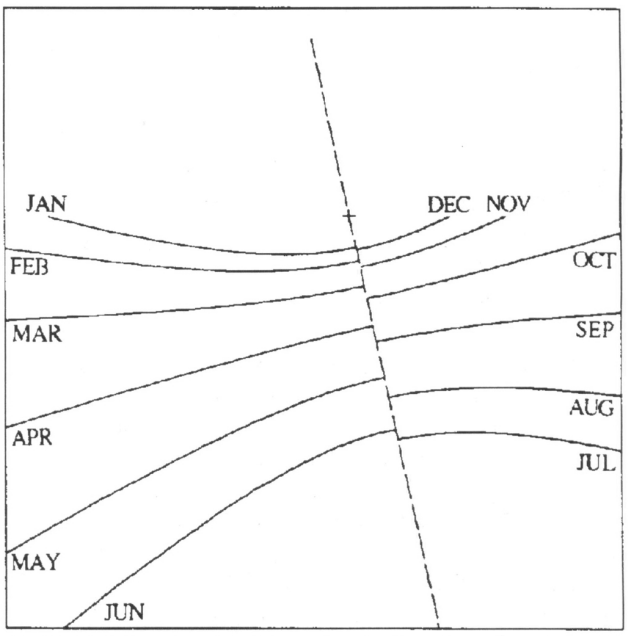


FIGURE 3: Declination Lines for the first day of each month

Instead of using the first day of each month, any particular day or set of days could be used. For example the day when the sun enters each sign of the zodiac is quite common, while your own birthday or other anniversary could be used.

TIME FROM SUNRISE AND TIME TO SUNSET LINES

The final vertical dial furniture to be considered here is firstly the time from sunrise and secondly the time to sunset. These indicate the length of time, in hourly intervals, that have elapsed from sunrise and the time, again in hourly intervals, to elapse before sunset.

The calculation of the nodus shadow for this type of dial furniture is the most complex of those described here. The sunrise and sunset times are required to be calculated for a selection of days throughout the year. For regions outside the arctic and antarctic circles, the sun will rise and set on each day of the year. These sunrise and sunset times will, if you are not on the equator, also vary throughout the year. Given a sunset or sunrise time, the hour angle for each hourly interval is calculated together with the corresponding altitude and azimuth angles. The nodus shadow position is then calculated using the equivalent horizontal dial as described earlier. With a sufficient selection of days the path of the nodus shadow for each time interval from sunrise or to sunset can be drawn.

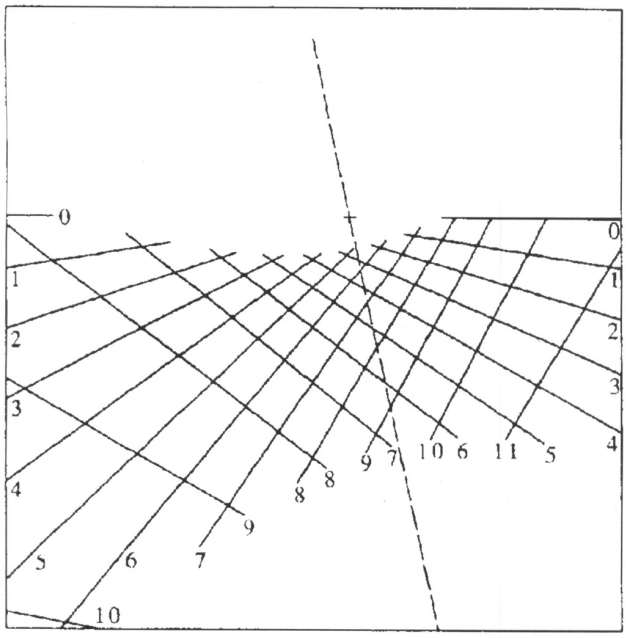


FIGURE 4: Time from Sunrise Lines (sloping bottom left to top right) and Time to Sunset Lines (sloping bottom right to top left)

The time of sunrise involves calculating the solar right ascension and declination (i.e. the position of the sun on the celestial sphere) for a time of 6 am. The hour angle at sunrise is then calculated followed by the sidereal time and then the time of sunrise. Sunrise is taken here to be when the solar altitude is 0°. As the solar position is calculated at 6 am rather than the actual sunrise time, the solar position is re-calculated using our calculated time of sunrise (the position of the sun on the celestial sphere will have moved between 6 am and the sunrise time). The above steps are then repeated to give a more accurate sunrise time. Further re-calculations may be required to give an accurate sunrise time. A similar procedure is carried out for the time of sunset except that 6 pm is used for our initial calculation of the solar position.

Figure 4 shows both the time from sunset and the time to sunset lines. The time from sunrise lines are those which slope from bottom left to top right and which have the hourly intervals increasing from left to right. The time to sunset lines slope in the opposite direction and have the intervals increasing right to left. All these lines are in fact straight. With the dial declining to the west, there are more time from sunrise lines than there are time to sunset lines appearing on the dial face.

Interestingly, the cross-over points of the two sets of lines give the length of daylight. For example, the cross over of the two 8 hourly interval lines give 16 hours for the length of daylight. For the latitude of the author's dial, this occurs near mid-summer as indicated by the fact that this appears on the dial near the summer solstice declination lines (see Figure 1). Other cross-over points can also indicate a total of 16 hours daylight. Another example is where the 6 and 2 hour interval lines intersect giving a length of daylight of only 8 hours. This occurs near the winter solstice declination lines.

In summary, several different types of dial furniture have been presented which I hope will aid in their identification and explain how they can be calculated.

REFERENCES

1. Mayall, R.N. & Mayall, M.W., *'Sundials: How to know, use and make them'*, Second Edition, Sky Publishing Corporation, 1973.
2. 1994 Handbook of the British Astronomical Association, London, August 1993.

COMPENDIUM 3

Issue No 3 of the Journal of the North American Sundial Society for August 1994 contains twenty pages. The first article is "A Choice of Sundial Books" by the Chairman Ross McCluney. The sundial books listed and discussed will be familiar to the majority of BSS members, even though five of the nine listed are American publications. Ross McCluney mentions that the BSS has grown significantly as a result of the introduction of sundials to the National Curriculum for schools, this is incorrect. Indeed it is the BSS which caused the reintroduction of dialling to the school system after it was taken out following the BSS efforts to produce a suitable publication for teachers. There has been no funding from Government sources for this work. The resurgence of interest in dialling owes nothing to the introduction of dialling to schools although it might well do in years to come.

Next is a little extract from *Through the Looking Glass* where Humpty Dumpty is answering Alice's question about the meaning of "Jabberwocky", which leads on to the subject of "toves". As every BSS member knows, these make their nests under sundials

An article which has appeared in the BSS *Bulletin* on transparent window dials is repeated in condensed form in *Compendium*, followed immediately by a stained glass diptych dial designed by Fred Sawyer using the same principles. The same author deals in the next article with the solution of the spherical triangle. It is so clearly set out and informative that the Editor is going to seek permission to reproduce it in the BSS *Bulletin*.

This is followed by a very useful outline "The Fuzziness of Solar Shadows" by Ross McCluney. The knowledge of the fuzzy shadow cast when very large sundials are made is of great importance in determining whether the proposed sundial design is feasible or not. This article condenses the rationalisation of the subject into a compact reference source.

An article on the William and Mary sundial in William, Virginia, is authored by Professor George Crawford. A short piece follows about the BSS Annual General Meeting in April 1994 by our US member - Dr. James Holland who brought the fraternal greetings of the NASS to the BSS.

Lastly is a gallimaufry of news items, the most important of which is the news of the reprint of Margaret Gatty's 1900 edition of *The Book of Sun-Dials* by Adams Brown Co., priced at 29.95 dollars. Every diallist should have a copy of this indispensable work. Also mentioned is the BSS *Bulletin*, referred to as an "impressive publication". These words warmed the heart of the *Bulletin* Editor.

Membership of the NASS costs 25 dollars for either a hard copy version of a 3½" disc version, or 35 dollars for both. Enquiries about membership to Robert Terwilliger, 2398 SW 22nd Avenue, Miami, FL 33145, USA. Air mail costs 10 dollars extra, bank charges must be added if US currency is not sent. **(See also page 49)**

READERS LETTERS

THE FOOLISH SERVANT

May I be permitted to put my tongue in my check and, with all respect, add a few observations on the "foolish servant" illustration (Bulletin No. 94.1, page 9).

Accepting for the moment that the VI mark is for noon, the conclusion is not that we are in the southern hemisphere, but that we are using temporal hours. Both of these are in fact true but by reasoning from other parts of the evidence.

The dial belongs to the southern hemisphere because the figures run anticlockwise. We can go further, and deduce what point in the southern hemisphere it belongs to, namely the South Pole. This is because the figures are equally spaced and centred on a spike - the gnomon - which will be vertical when the dial is set up. The sloping bar is only a prop.

The dial is marked with 12 hours, not 24, for a revolution of the earth. This shows we are in temporal hours, which divide the period when the sun is up, in each revolution, into 12. At the poles, if the sun is up at all it is up all the time; so the 12 temporal hours are spread over a complete revolution.

Milord has not only his right foot, but both feet and at least one hand, well wrapped up. We need not condemn the poor fellow to gout - he is feeling the cold! and his evident fury does not result from a painful disease, but from frustration over the impossibility of reconciling a watch with the temporal hours.

Dialling is confusing at the poles. The concepts of "day", "noon", and "direction" lose their meaning, and there is no specific rotational position (cannot say "orientation"!) at which a dial should be set. So when the servant comes to replant the dial and finds that his compass does not work, it will not matter. Any position that is upright will be correct.

JAMES RICHARD,
Bristol.

* * * *

KIRCHER'S SUNFLOWER CLOCK

Correspondents are having difficulty with the Greek and Latin inscriptions in the illustration to John Briggs' paper (*Bulletin* 93.2, pp. 42-43), not only in establishing the correct wording in the original language but in interpreting the English meaning.

The correct transliteration of the Greek is HŌROSKOPION HĒLIOTROPIKON, the first word a noun meaning an instrument for telling the time, the second the adjective of the word for a heliotrope, a plant which follows the Sun with its flower and leaves. (The sunflower is not the only such plant.) The literal translation of the Greek is therefore "A Heliotropic Timepiece" (Peter I. Drinkwater does not get it quite right in *Bulletin* 93.3, p. 42), and I do not think the literal translation can be bettered in the context.

W.A. Dukes (*Bulletin* 94.1, p. 16) gives the correct reading of the Latin words on the scroll - "Artis et Naturae Coniugium" - and their correct literal translation - "A Union of Art and Nature". Perhaps a less prosaic expression of their full meaning would be better - (say) "A Mixture of Nature and Human Skill".

W.A. Dukes (*ibidem*) and George Wyllie (*Bulletin* 94.2, p. 49) between them give the correct reading of the Latin words on the base of the dial in the illustration:-

"Annos circuitu Sol tempora Signat et horas.
Omnia Solisequa haec Simia Solis agit."

This is an elegiac couplet (a hexameter followed by a pentameter), and its purpose is obviously to describe what is shown in the illustration. (It is of some interest that, apart from the first word in each line, the only words with capital letters are all those beginning with S: this I ascribe to a whim on the part of the author to emphasise to the *reader* the couplet's sibilant alliteration, which is obvious to the *listener*.)

The correct translation of the couplet is open to conjecture, principally (but not entirely) because of the use of the word "Solisequa". This word does not appear in Lewis and Short *A Latin Dictionary* and would therefore seem to be the invention of the couplet's author (though it would be interesting to know where George Wyllie has come across it in reference to the planet Venus). In our couplet I have no doubt that it is intended to mean "Sun-follower", i.e. the sunflower in the illustration. The literal translation of the couplet as it stands is "In its course the Sun points to years and seasons and hours. This sunflower does everything as an ape of the Sun". For a more elegant expression of its meaning, in rhythmic wording, I suggest:-

"Years, Seasons, hours the Sun in its course denotes.
In what this Sunflower does it apes the Sun."

J.R. BRADSHAW,
Dorchester.

* * * *

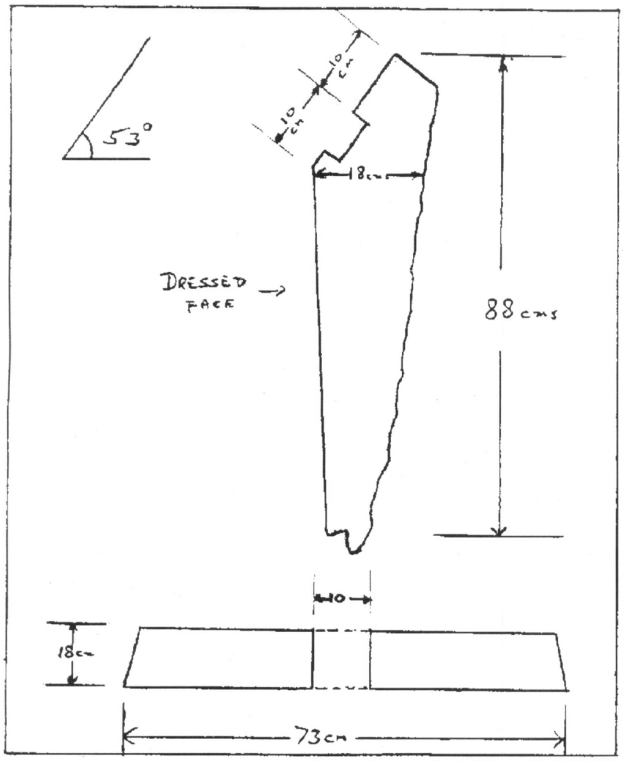
IRISH POLAR DIAL

There is a small medieval ruined church and graveyard near to where I live, and recently there was an effort made to clear away the weeds and general growth from the graves. During this process it was discovered that two of the grave markers had been used for something else previously. One was a square base with a socket cut into the middle of it and the other was a short stone post which could fit into the socket.

It is 88 cms. high and at the widest point, 18 cms. square. Only one face is dressed, the other three being left in rough granite.

I enclose a drawing of the post and its base from which it can be seen to resemble the base and pillar of a Polar Sundial, but with the dial plate and gnomon missing from its socket.

The angle between the upper face and the horizontal is 53°, which is approximately the latitude of this area. I wonder if any member has seen such a dial complete, and if



so whether they can send me a photograph of the dial plate and gnomon with approximate dimensions. Would it have been also made of stone, or would it be more likely to have been made of, or faced with, bronze?

I have never come across a polar dial in Ireland and it is so unusual that I would like to complete it and put it back to its original use!

ANDREW OGDEN,
Ireland.

* * * *

HAN DIAL

Until there are sound archaeological grounds for accepting a Western Han origin of the soft limestone slab illustrated in Dr Allan Mills's article [*BBSS* 94.2, 30-31] I believe more weight should be given to the evidence published in 1909 on the jade slab which appears to pre-date it. There are in U.K. at least two copies of Duan Fang's 1909 catalogue of his collection of stone artefacts, including the photo-lithographic reproduction of an original ink-squeeze of the jade slab, which was later reproduced in White and Millman's Figure 1 [see Dr Mills's reference].

The 1909 print itself shows clearly that in its original state the slab was engraved with maybe no more than a central meridian setting-out line, central gnomon socket-hole, and two boundary circles (inner and outer) joined by sixty-nine radial lines of which one is on the northern half of the meridian line and the others are spaced centesimally on either side of it. Sixty-nine circumferential holes, at the junctions of the radial lines with the outer circle, may also be original but the originality of their clockwise numbering from 1 to 69 in standard 'seal script' characters remains doubtful as it makes neither astronomical nor horological sense.

Cruder markings, meant for a square outside the inner circle, four T-shapes springing outwards from the centres of its sides, four half-squares in the corners of the slab, four diagonal lines joining their corners to those of the central square, four arrow-heads meant to be on the diagonals, and four L- shapes meant to spring clockwise inwards from the four 'cardinal points' of the outer circle, are all later additions roughly scratched on top of the numbers, some of which they deface.

Norton's Star Atlas, 1964 edition, shows [pages xiii, xv], that the radial lines, other than that on the meridian, would not have been useful for equatorial time-keeping in the Han capital in latitude 34° 40' N, or even at the Han northern border about 43°N. Midsummer sunrise and sunset at 35°N are at no more than 7h. 16m., or about 30 centesimal parts of the day-and-night, before and after noon. Thus if the dial had been set equatorially its gnomon shadow would never have fallen outside the limits of the radii now numbered 5 and 65. At other dates even fewer of the radii would have been relevant to the day's timekeeping.

The great French scholar Henri Maspero [Needham 1959, 305, 776(4)], who died in 1945 in the concentration camp of Buchenwald, showed in 1938-39 that the radial lines on the jade dial were meant for use with the dial resting horizontally. They were for observing sun-shadow azimuths at sunset and sunrise, to guide the choice of seasonally-appropriate time-scale float-rods for use in the 'day' and 'night' clepsydra-water receivers which were used for palace and urban time-keeping in the Han period and many following centuries.

Unvarying duodecimal, biduodecimal, and centesimal divisions of the day-and-night, equator, and horizon were Chinese imperial standards for millennia. It is regrettable that sundial amateurs should have been encouraged to think that they may have been 'confined to a special group within one part of the Empire, and found favour for a comparatively limited period'.

Five equal but seasonal night-watches, each with five equal but seasonal divisions, were however sounded by palace and urban night watchmen until the last or present century. It was for this purpose that seasonal time-scale rods were needed. At least two mechanical clocks sounding seasonal night-watches survive, one in Beijing Old Palace Museum and one in an American private collection. Rural populations may not have felt a need for any systematic time-keeping.

Dr Mills will be interested to learn that the equatorial sundial illustrated by him, after W.P. Yetts' Plate XXXIV, is one of the many present-day survivors which appear in recent guide-books. It also appears on one of three colour-slides taken by Dr. Margaret Somerville, daughter of our co-founder Dr. Andrew R. Somerville, and kindly copied by him to me in 1986.

The other two of those photographs show equatorial sun-and-moon dials divided (as the first is believed to be) in 96 Western quarter-hours and inscribed duodecimally and biduodecimally in both Chinese and Manchu characters, probably under the direction of Ferdinand Verbiest, the Flemish Jesuit who from 1669 was tutor to the young second Munchu emperor and Chief Astronomer. One of them was reproduced in Andrew Somerville's article on 'The sundials of John Bonar, Schoolmaster of Ayr' *Antiquarian Horology*, September 1986, *16*, 233-242.

JOHN H. COMBRIDGE

BOOK REVIEWS

***GEOMETRY IN MOTION A Mathematical Demonstration: Volume I,* H. Stephen Stewart.** (A series of Monographs describing the Astronomical, Numerological, Geometrical, Pictographical and Horological Disciplines of Christ Church, Weems, Virginia).

12 pages preliminaries; 194 pages text and diagrams, including 13 pages of B/W photographs; hardback 11″ x 8½″. Published by Stewart Horological Surveys, Weems & Williamsburg, Virginia, U.S.A. 1993.

In the small community of Weems, Lancaster County, Virginia, is a brick-built, colonial, early 18th century (1732) church/mausoleum, known as Christ Church. The extraordinary nature of this church is that it was built to specifications which would incorporate, through its alignment and other details, the most complex indications of the solar calendar and other astronomical information. The whole building is, in fact, a solar dial or compendium as well as being a Christian church and the resting place of an immigrant colonist and planter, John Carter, and seven other people.

All this is revealed in a series of five fascinating monographs which comprise Volume I of a book entitled GEOMETRY IN MOTION. Georgian architects were faithful to the ancient architectural 'orders' and rules of proportion, but in the case of the church at Weems many subtle and scientifically significant dimensions were built into the structure. Sunlight and shadow are used to indicate the time and the changing dates of the year, the progression of the seasons, the dates of the equinoxes and solstices, the 'cross-quarter' days (half way between the equinoxes and solstices), while the beam of the sun, shining through carefully aligned oval windows, enables a pool of sunlight to fall exactly on the tomb of one David Miles four times a year, and twice each year the sunbeam advances and retreats across the altar table and Cross. The eaves of one wing are carefully aligned to act as a summer sundial, casting its shadow on the ground within the confines of the perimeter wall, while the shadow from the peak of the west wing on the morning of the summer solstice just touches the ground where the gates to the enclosure close. This is the kind of information, including *very much more,* with which this volume is concerned.

For those who are interested in the wider aspects of horology (philosophical rather than purely practical) this is a marvellous piece of analysis of a building which may not be unique. Apparently the astronomical significance of the church came to light through American newspaper articles in 1988, since which time the author has been conducting his exhaustive studies. It is well known that many ancient civilisations were vitally conscious of astronomical events and designed their structures with celestial parameters in mind (e.g. Stonehenge, the Pyramids of Egypt, the Aztec temples of Mexico) in which the variations of the solar year were measured and foretold. In the case of the church at Weems Stephen Stewart has shown, through meticulous research and measurement, that its designer was anxious to include as much solar information as was possible, indeed that the progression of the solar calendar would determine *all* the details of its construction. From the shape of the roof, the alignment of the walls of its four wings, the placing of doors and windows and even the number of courses of brickwork from the cornices to the watertable, to such fine details as the proportions of the tombstones, the placing of the interior mouldings and even the numbers of letters on the gravestone inscriptions - all these precise components would conform to a design which would be in perfect harmony with nature. That it was also in harmony with mathematical principles of proportion and geometry, that it carried secret and inscrutable information in such parts as the decoration of the pulpit canopy, the escutcheon plate on the west door and an accessory stone associated with the Miles tomb, is also investigated with minute precision. An example of the kind of detail which much impressed this reviewer was that Stewart had discovered that the whole of the cruciform plan of the building (which lies at longitude 76° 25′ 25″ W) had been aligned 3·5° west of geographical north in order to render *the equation of time* similar to that of the 75th Eastern Standard Time meridian, which is about 78 miles east of the church. If the building had been aligned *true* north/south the equation of time analemma showing the annual variations of solar time (when the sun is at its 'southing') compared with mean time, would coincide (or *zero*) with mean time only *twice* a year instead of *four* times a year as it does on the standard meridian. The standard meridian for Eastern Standard Time is, of course, 5 hours behind Greenwich (UT) mean time.

To know more about the design of the building, its architectural history and something of its designer we must wait for Volume II, which is in preparation. For the present detailed analysis and a very large number of explanatory drawings Mr Stewart must be congratulated.

ALAN SMITH

OXFORD SUNDIALS, Margaret Stanier, pp.32, 19 coloured plates. A5 format with Astrolux cover bearing the sundial of Somerville College, 1994. Price £5.50, post free. Obtainable from Dr. Margaret Stanier, 70 High Street, Swaffham Prior, Cambridge, CV5 0LD.

This little booklet opens with a brief outline of the main types of sundial, the difference between Oxford solar time and clock time, plus a little history on Oxford sundials. The introduction also outlines the plan of the book, the dials being arranged in geographical groups. Each sundial is listed as P, O, or R for Private, Open or Restricted access. The open access dials will be of interest to the ordinary person, some of the private ones can be inspected by application at the appropriate College Lodge during visitors' hours.

The group of dials in the city centre include most of the Colleges, and although this is a compact area, it requires at least two hours to go round them all comfortably, and it is quite tiring. The sundials in North Oxford are less well known and are completely insignificant. There are only two sundials on churches listed, both badly in need or renovation.

The final section deals with the stained glass sundials in Oxford, which form the major grouping of such dials in England. Three of these can be seen in the Museum of the History of Science in Oxford, although two are hidden away in the Curator's Office and require prior permission to be viewed.

It is commendable that the sundial illustrations are all reproduced in colour. Alas the photographs, in most cases, are out of focus. The photographs supplied by those listed in the Acknowledgements are much better. In some cases, e.g. the sundial on the Killcanon building in Christ Church college, the accompanying text can only be described as meagre. There is no map included to show where the colleges are located, so a street map is essential before embarking on a tour of the Oxford dials.

CHARLES AKED

THE GEOMETRY OF SUNLIGHT

JOHN LYNES*

The position of the Sun in the sky depends on:

1. Geographical latitude. Equator = 0°
North Pole = 90°N
Hull = 53½°N

2. The time of year. This can be expressed as the *declination,* i.e. the latitude at which the sun is overhead: this varies from season to season, being 0° at the equinoxes, 23½° North at midsummer and 23½° South at midwinter.

3. The time of day. The Earth rotates once every twenty-four hours, hence 15 degrees per hour or one degree every four minutes.

SOME DECLINATIONS

Date:	Declination:
June 22 (summer solstice)	23½°N
May 21 and July 24	20°N
April 16 and August 28	10°N
March 21 and September 23 (equinoxes)	0°N
February 23 and October 20	10°S
January 21 and November 22	20°S
December 22 (winter solstice)	23½°S

THE HELIODON

The model is placed on a tiltable turntable whose geometrical relation to an artificial sun reproduces the relation between the real sun and a point on the earth's surface at different seasons (i.e. different solar declinations).

The rotation of the earth is simulated by spinning the tilted turntable, so the movement of shadows throughout a chosen day can be readily followed.

NOON AND MIDNIGHT

The sun reaches its highest altitude at noon.
At noon and at midnight, the sun is always due South or due North.

HEMISPHERE

The sun travels *clockwise* (in plan) in the northern hemisphere; anti-clockwise in the southern hemisphere.

EQUINOX ANALYSIS

At the equinoxes (March 21 and September 23) the sun travels in a *straight line* from East to West, rising at 06.00 hr solar time (07.00 hr BST) and setting at 18.00 hr (19.00 BST). At the equinoxes, the altitude of the sun at noon is equal to (90° minus the latitude).

The latitude of Hull is 53½°N. Therefore, the altitude of the sun at noon at the equinox is (90°-53½°, or 36½°). At that moment, all shadows fall due North [illegible]

The transparent overlay shows solar orbits at the following declinations:
23½°S, 20°S, 10°N, 0°N, 10°S, 23½°S.

To find the position of the sun, set the latitude pointer and read off the solar altitude and azimuth for the time, date and place in question.

EQUATIONS OF SOLAR ORBITS

$$\sin \alpha = \sin \lambda \sin \delta + \cos \lambda \cos \delta \cos 15t$$
$$\sin \phi = \sin 15t \cos \delta \sec \alpha$$

Where α = solar altitude
λ = latitude (negative in southern hemisphere)
δ = declination (negative when South)
t = hours before or after noon
ϕ = azimuth, from due South.

THE MATCH BOX SUNDIAL

To assemble a match box sundial, paste the five scales on the base and four walls of the tray of a match box. A thin stick 14mm long should be stuck upright at the centre-point indicated. This serves as a gnomon. The lid of the match box protects the gnomon, so you can carry this sundial safely in your pocket.

USING A SUNDIAL

You can use a sundial in two ways for studying the sunlighting of an architectural model:

1. Place the sundial close to the model and orientate it correctly. Use a 'Pearl' lamp to represent the sun. Position it so that the gnomon's shadow picks out, on the sundial scale, the time and date at which you want to study the pattern of sunlight. The appropriate shadows will be cast on the model.

2. "Aviator Method". Let your eye represent the sun. Place your eye so as to align the tip of the gnomon with the required time and date on the sundial scale. Whatever you cannot see the sun does not see; so it is in shadow.

VISUALISING THE SUN'S POSITION

Step 1: visualise equinox sunpath, as a straight line from east to west. Height above horizon at noon = (90° -λ).
Step 2: visualise 'hour lines', as straight lines crossing to the equinox sunpath at 15-degree intervals. 06.00 hr. is due east; 18.00 hr. is due west; noon and midnight are on the north/south meridian. Sun travels clockwise in northern hemisphere, anticlockwise in southern hemisphere.
Step 3: visualise the remaining hula-hoops for other declinations.

THE SOLAR BRACELET

In the hula hoop demonstration the solar orbits are shown

equal to the geographical latitude in the northern hemisphere. A circular bracelet sitting on this sloping roof with completely shield a circular window in its base. However this arrangement is restricted to circular windows in north-facing roofs.

PROTECTING A RECTANGULAR SKYLIGHT

The key to the solar bracelet is the recognition that the view from the centre of the cylinder must be unchanged when the cylinder itself is redrawn as a box. The technique for producing a rectangular bracelet is to project the limiting rays of the hula hoops outwards onto the box. The rectangular bracelet has the same shielding properties as the circular bracelet.

SOME ARCHITECTURAL APPLICATIONS

Check penetration of sunlight around buildings.

Note: planted areas
outdoor seating
playgrounds
car parks

Check penetration of sunlight through windows at critical times and seasons.

Note: hotels
schools
living rooms
bedrooms
offices
art galleries and museums

Design fins and canopies to provide solar protection where necessary.

Note: Little sunlight reaches north-facing windows; fins give good protection.
Sunlight reaches south-facing windows throughout the year; canopy gives good protection.
Protection is difficult on east and west facades.

FOR FURTHER READING:

'Predicting the sun's track', *Architects' Journal*, 30 October, 1968.
'Windows and Environment', edited by D. Turner.

* Mr. Lynes is at the University of Humberside and these notes were prepared for his First Year Architecture Students.

APPENDIX

The Chairman's article on Blagrave's Mathematical Jewel (BSS Bulletin 93.2, pages 30-32, June 1993; prompted Mr. Lynes to communicate with the Editor in respect of the two variants of the Mathematical Jewel in the 1960's produced by Pilkington Glass Ltd., St. Helens. He also sent a copy of his own version of the Mathematical Jewel, this is made by his students as a practical exercise. This is shown in figure 1, the lower part of which is to be traced on a thin piece of transparent plastic sheet. This plastic is then pivoted at the intersection of the centre vertical line and the equinoctial line marked Mar/Sep. The other centre is the intersection of the 90° altitude and the 90N and 90S line. A small press-stud is used to provide the means to hold the two parts together and allow the transparent plastic to turn as required. By placing the latitude arrow on to the local latitude, the possible hours of sunlight at the various times of the year are easily read off. Thus at the latitude of London the day has about 16 hours of daylight in June, and just over 8 hours in December. The great advantage of this arrangement is that the whole year's sunlight and the diurnal path of the sun on any day can be seen at a glance.

COMPENDIUM

Issue No 2 for May 1994 commences with a two-page address by the Chairman, Ross McCluney and is mainly concerned with the creation of the organization necessary to the running of a successful sundial society. "Books on Demand" listed by Fred Sawyer is a revised version of the list published in BSS Bulletin 92.2, June 1992. Next a six page article by the same author which deals with moondials and includes a computer program which will eliminate the usual error in the estimation of time by the shadow cast by moonlight on a sundial. He gives an example which estimates the time with an error of less than 1·5 minutes. The Editor will be requesting permission to reprint this in the BSS Bulletin for the benefit of those who cannot sleep and must contemplate the moon in its flight, in the still of the night, whilst the earth is in slumber.

Robert Terwilliger, in a 2½ page article deals with the construction of an Equatorial Dial, together with a computer program for its calculation. In the next issue he will be dealing with polar dials. An amusing aside is the practical lesson from Benjamin Franklin for an acoustic sundial which uses guns to sound the hours, one for one o'clock, two for two o'clock and so on. He recommends the use of thirty-two pounder guns with charges of about 16 pounds. Twelve o'clock would thus require the expenditure of 192 pounds of gunpowder, but as Franklin points out, there would be a great saving of powder on cloudy days. He does not mention how the sun's rays are to be directed to set the guns off in a suitable sequence, but concludes with the observation that many a private and public project are like this proposed striking dial - Great Cost for Little Profit.

The dialling sculpture projects of Kate Pond are covered in the next article covering three pages, followed by an article on J.G. Thews Patented Sundial of April 1960. This utilises perforations in an equatorial band which allow sunlight to fall on a target gnomon. Lastly there is a short feature on the new form of sundial proposed by J.J. De Lalande in June 1758 in a letter to the *Journal des Sçavans*.

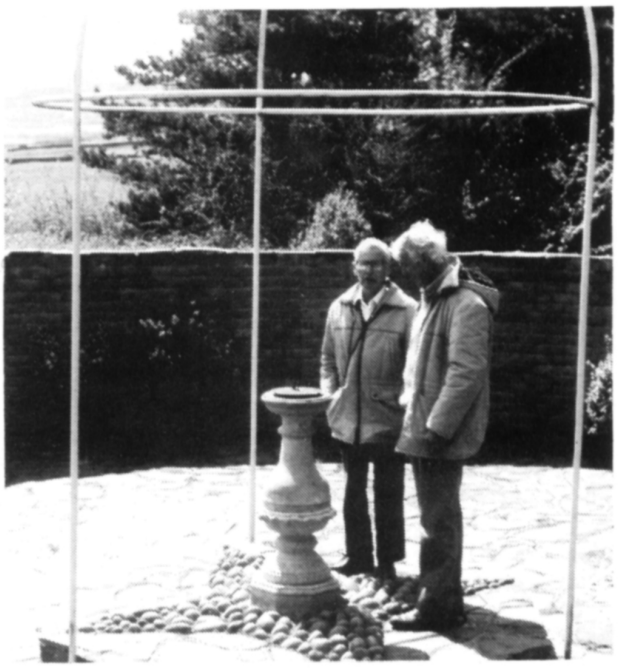
The Editor of *Compendium* is Fred Sawyer, 8 Sachem Drive, Glastonbury, CT 06033-2736 U.S.A. Membership subscription 25 dollars either for print edition or disc form, or 35 dollars for both. Air mail costs ten dollars extra. Send to Robert Terwilliger, Treasurer NASS, 23908 SW 22nd Avenue Miami FL 33145. The new society welcomes information, articles and donations.

This new publication is going to develop into a treasury of dialling information and computer techniques as the years go by, so it must be considered as essential to the library of any philognomonic.

(See also page 43)

THE LATE GEORGE ROBERT HIGGS

George Higgs - the enthusiastic dialler



George with Andrew Somerville at Threave

In the last issue of the British Sundial Society *Bulletin,* the short "In Memoriam" notifying members of the death of our oldest member, mentioned that there would be more details published later. The two following eulogies, one from his son John Higgs, the other from his great friend David Gulland, are ample testimony to a very worthy man. They were read at George's funeral service and are given here in full.

ADDRESS BY JOHN HIGGS

Friends and family, thank you for coming today to what I hope will be a farewell to my father and also a celebration of his extraordinary life. At the age of 93, it still comes as a shock and a grief to us all when somebody fit and active and so full of life and enthusiasm has a stroke. But we were given a week during which Dad recovered considerably, and it was a great consolation and privilege that he was able to speak to us, to say in such definite terms how he had enjoyed his life, how content he was with his life and to indicate also that he was completely relaxed and happy at the idea that he should die at this point. He did not wish to live on with what he felt was perhaps a half life, and he was content to let what happened, happen. During the week which followed, he very peacefully and in a dignified manner faded away. We had the privilege as family and friends to visit him, to hold his hand; and he knew who was there, he knew he was within the loving embrace of his family and even at the instant of his death we were holding him and I believe that he knew we were there.

For me, the fact that we were able to talk to him, that he reassured us, reassured me, of his wish to go and his contentment to go, and his great contentment at a life which he felt had been well spent, is a great consolation to me. I hope that for you also, the knowledge that he was content and happy and died in peace will be a consolation. It allows me to look at that life and to rejoice in it. In phoning around to so many friends and relatives it has been a great pleasure to hear people talking in such loving terms about him and, in that respect, it makes it a happy thing to think of that life.

In looking at that life there are perhaps two themes which come out in particular and I make no apology if perhaps they are technical themes. The quest for knowledge and search for understanding was one theme, and the other one was the delight in designing and inventing and mending things, and in making things work. Throughout his life he was like that, and in many ways, throughout his life, it was the experiences of his life that made him that way. It is perhaps interesting, and a celebration, to think of that life, and I would like to take you through his ninety three years as a little sketch.

He was born in 1900, son of the Minister of the Free Church of Kirkbean, George Higgs, and his mother, Bessie Tainsh, herself a daughter of John Tainsh of Hamilton, who was an engineer, entrepreneur, industrialist and a character of that city, and perhaps that's where Dad got his engineering drive and enthusiasm from. He was educated for the first seven years of his life by his father and then went to the village school in Kirkbean. It was a village community, he was a village lad, and he first saw a motor car when his Uncle Ted - of fame for driving a Ford Model T to the top of Ben Nevis - came to Kirkbean and took Dad and selected special friends to school one day in his motor car. Later on, the family moved to Fife, and my father struck up a friendship, perhaps not entirely altruistic, with the son of the station master who had access to the shunting yard, and there my father and his friends drove the steam shunting locos in the shunting yard. He resolved to be an engineer and went to St Andrews University, being lucky

and talented enough to win one of only two scholarships available, since ministers' families were not well paid then!

That period at St Andrews University was interrupted by the Great War, and it must have been a fearful thing to have said goodbye to his family and friends, to leave for France in the Royal Engineers, knowing that the average life expectancy was counted in hours, or at most, in days, at that time. He was spared by the declaration of the armistice before he reached active service. He resumed his studies and when he left college he joined Metropolitan Vickers Company in Manchester, for whom he worked for the rest of his career.

It is also interesting to note that it was that particular company, because Metrovick was the only company at that time which was actually prepared to pay a small stipend to their college apprentices to work for them. At any other company he would have had to pay for an apprenticeship and that was not possible with the family funds.

For the next 20 years he worked in railway traction, that is, the electrification of railway systems, much of it abroad - India, South Africa, Brazil, Argentina - learning not only railway theory but of the wide cultures of the world.

It was in 1941 that he met and married my mother, Peggy Colson in Brazil, and they came back in 1942 by sea, and again were spared in the face of war - the convoy which left before them and the one that left after them were both lost without trace - only their's came through the North Atlantic and survived the U boats.

Back in England, he spent three years on the historic development of the jet engine and was one of the engineers who brought that to fruition. After that he was back in railway traction and brought up a family, Elspeth and myself, retiring eventually at the age of 65.

When he retired, it was not to a life of intellectual leisure, the questing spirit and the struggle for knowledge continued, and he took great interest in archaeology, geology, historical matters - the Buchanites and Covenanters - and in particular took great delight in his friendship with Johnny Anderson building pieces of farm machinery of which the farm cow feeder was one memorable invention.

In the last twenty years, sundials have particularly dominated his interests, and that, for him, held a fascination in the combination of mathematics, design, artistry, and craftsmanship, and there is a memorial to him scattered around Scotland in over a hundred sundials designed or restored by his hand.

But in talking about Dad, he was not only an engineer, a scientist and an inventor, he was a very warm person. He was caring, considerate, conscientious. He had a tremendous sense of humour and a personal honesty, not only a material honesty, but an honesty to himself and an honesty towards his friends, and it is that aspect which I think has influenced Elspeth and me, and we have been brought up in a caring and supportive family environment and given the confidence to be launched on our own careers. But whilst to his cousins, his grand-children, his sisters, to Elspeth and me and to our partners he has been a relation, above all he has been a close friend, a confidante, and tremendous fun to be with. It is in that respect and in that way we miss him most, but it is also in that way, as a close friend, that I remember him most, that I feel for him, and that I shall cherish the memory of him for the rest of my life.

ADDRESS BY DAVID GULLAND

John and his family have asked me to say a few words today on behalf of all George's friends in and around Kirkcudbright who are gathered here today to bid farewell to a man who has played a lively part in all our lives.

We remember powerful intellect, of his physical strength and above all his questing spirit which enabled him through his retirement years to achieve so much which he shared with such enthusiasm with us all.

It was Robert Louis Stevenson, the writer and poet, himself the son of an engineer who wrote these words:

"If a man loves the labour of his trade, apart from any question of success or fame in it then the Gods have called him."

George Higgs was surely such a man. For undoubtedly George loved the challenge of life, and his obvious enjoyment of the process of *doing* which was so remarkable about him, even in his last years. George had as much delight in solving simple domestic problems as he had in achieving in his professional successes. George had trained his mind to grasp huge concepts of time and space but he was just as happy to deal with the little things of here and now, and that was the humanity in George, that he brought into his love of family and friends and what we remember most today.

George was always ready for anything. He was a man of action: as his next door neighbour for over ten years my images of George are legion. I think of him on top of a ladder; crawling underneath his car; in his workshop at his lathe; in the kitchen making his wonderful oatcakes; down at Carrick, swimming with George in the sea at 11 o'clock on midsummer night; George in the hills; George on the road. Everywhere George *was* George was *doing* George was *creating*.

Many people will remember George as a member of, perhaps, a local society or group. He was an avid student in extra mural classes, some of you will have gone with him to study archaeology, astronomy, local history, natural history. Many of you here will be members of Probus here in Kirkcudbright. George was a founder member of the Probus Club and he was introduced to trout fishing by some of its members twenty years ago. One of George's greatest pleasures in life was in the company of friends to fish in the lochs and rivers of the Galloway that he loved.

Now, on top of all this, George found in the last decade of his life an overriding and increasingly productive interest in the making and the restoration of sundials. In writing in the journal of the British Sundial Society, he describes having first made a sundial for his garden at the Cleuch where he and Peg had retired, and how he came to make and restore sundials for the National Trust of Scotland, first at Threave and then at Culzean Castle, and finally throughout the land. And only a few weeks ago I am sure most of you will have seen that there was an article in the Heritage magazine entitled "The Sundial Man" with a lovely photograph of George taken at Broughton House here in Kirkcudbright at just about the turn of the year.

But George's work with sundials was known farther afield. He was a founder member of the British Sundial Society, and when I went with George by train to Oxford to attend the first annual general meeting of the Society at Exeter College, he delivered an address to the Society with such vigour and eloquence and wit that no-one could have

believed that he was about to celebrate his ninetieth birthday.

George and I collaborated in the making of engraved window sundials where all the mathematical calculations were his doing, and when I was installing one of the biggest such window sundials that we made for the public library in Leominster in Herefordshire, apparently, due to an error in joinery in making the frame, the relationship of the dial to the gnomon was out by about five millimetres. I had an idea what I should do but without George's go ahead I wouldn't dare to, so I 'phoned him - this was about 11 o'clock on a March morning. Fortunately he was home. George, I said, and explained the fault. He told me what to do - I then said, but George, we do not have to allow for parallax. David, he said emphatically down the 'phone, the sun is 93 million miles away from here, I don't think you need to worry about parallax. What a man! He was 93 years old and as alert and as sure as I had ever known him.

On one of the window dials which George and I designed together I engraved these words chosen by my wife:

"We live in deeds not years, in thoughts not breaths, in feelings not in figures on a dial."

George lived like that. His deeds, his thoughts, his feelings were intense about everything he did and our memories of him will remain with us all our lives. But an abiding image of George, and one I wish to leave with you, must be of him with two companions in his beloved Galloway - three men in a boat, fishing on Loch Knochenoch - and the sum of their ages exceeding 240 years, at peace with the world.

I'll let the last words be not mine but from the prelude of William Wordsworth:

"Whether we be young or old, our destiny, our beings, heart and hope is with infinity, and only there with hope. It is hope that can never die, effort and expectation and desire and something more to be."

* * * * * * * *

AN APPRECIATION BY ANNE SOMERVILLE

The Editor has asked me, as a personal friend, to write about my association with George Higgs. In George's own article in BSS *Bulletin* 90.3 - "Some Sundial Safaris with Andrew Somerville", I feel he said it all about we three met, and the fun we had together, although I was not then much more than the helping hand who cooked the vegetables whilst he and Andrew mulled over their "Gnomonic Gnus".

After Andrew's death he continued a treasured friend, and I looked forward to and enjoyed enormously my visits to Kirkcudbright. He treated me as if I had somehow absorbed all of Andrew's sundial expertise simply by having shared so much with him, and I tried to live up to his expectations. I knew, and so did he, that there was a huge gap between his knowledge of sundials and gnomonics and mine. It was part of his charm that he put you on the same footing as himself. I still find it hard to believe that he will not be telephoning some time to discuss his latest doings.

A couple of years ago George took over for me the task of re-restoring the Loudon Castle lectern sundial which Andrew had rescued from a ruined castle in Ayrshire. It travelled up to and from Scotland in the back of his son-in-law's Landrover. It was a hard job removing the masonry paint which Andrew had used on it (and which absolutely nobody approved of!!!). Even George had to admit that lying flat on the floor scraping the surface was tiring and he needed a rest every fifteen minutes or so. But he insisted that as long as he could use his lathe, which stood just outside his kitchen door, he would carry on making and restoring sundials, as well as fixing the innumerable things people brought him to mend. He said that he had had a good life, he had travelled the world, and had always enjoyed good health and the support of a wonderful family and numerous friends. So when his final illness came just before his 94th birthday, he had no intention of fighting the inevitable.

Everybody has a favourite anecdote about George Higgs, whose own fund of stories was inexhaustible. He would talk non-stop even whilst driving his car (he bought a new one when he was 92), an automatic, and wondered why he had never thought of one before. As we journeyed along, he would break off in mid-flow to give a potted history of the owner of a particular farmhouse, or point out the site of some episode in the saga of the Covenanters, always returning to his own story at the precise point at which he had digresse. But my favourite occurred in the year of Halley's Comet. That year, when we were on our usual visit, there was a telescope in the window of our bedroom. So I said to him, "Have you been looking Halley's Comet, George?". He replied, "Och no, Anne, I'm fixing that thing for a lady down the road. Anyway I'm not bothered; I saw it last time". It was not until he said something like that your realized that he was as old as he claimed to be, for he looked and acted and thought like a man twenty years younger. The last time I stayed with him in Kirkcudbright, he was installing a "loop" system in the hall where his local club was to hold a meeting, because some members were hard of hearing, not so George!

Many of the early members of the BSS will remember that George attended the first two Annual Conferences. At Edinburgh in 1991 he gave a talk on his restoration of Scottish sundials. As he went up to me he uttered to me "I forgot my slides". He spoke for half an hour without slides or notes, and no one guessed that it was not the way he had meant it to be.

And, of course, one would never dare to suggest some water to contaminate a malt whisky. He had a good collection of these, presents from grateful sundial owners, among whom he could count the Earl of Perth, the Earl of Southesk, the Countess of Strathmore, and even the author of this humble appreciation of a very dear friend.

EDITOR'S NOTE:

When I was first told of the marvellous George Higgs by Anne and Andrew Somerville, my reaction was one of mild scepticism. Later I found that there had been no exaggeration on their parts, George was a larger than life character, even judged against some of the outstanding men I have known in the past.

He often telephoned me about different aspects of dialling, wrote erudite letters at intervals, was very helpful when asked for advice, and even took some of the tasks off my hands. He was also kind enough to design, and have made at cost of the materials only, a sundial which I presented to Jodrell Bank. He even organised its delivery to Jodrell Bank and sent me a photograph of the finished dial.

(Continued on page 39)

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