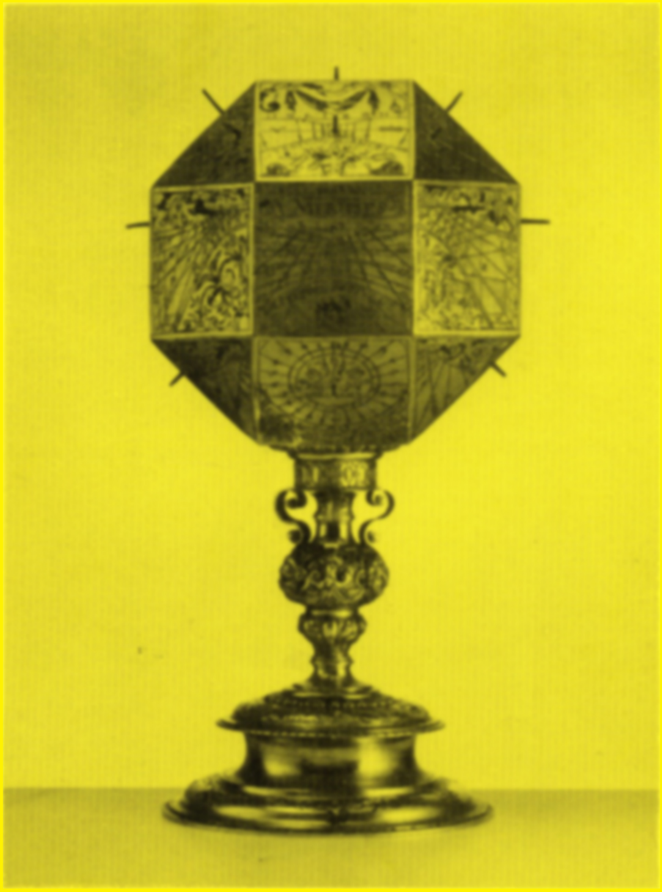
The British Sundial Society



BULLETIN

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HONORARY OFFICIALS OF THE BRITISH SUNDIAL SOCIETY

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Cover Illustration - A fine polyhedral sundial made by Hans Koch, München, 1578.

DIALOGUE

ANALEMMA

This is the first *Bulletin* of the Association of the Friends of Sundials (Boletin de la Associacion de Amigos de le Relojes de Sol) which was founded in April 1988 and based at the Escuela Tecnica Superior de Ingenieros Agronomos, Cuidad Universitaria, 28040 MADRID. Like the BSS *Bulletin*, it is in A4 format and the first issue has 24 pages plus printing on the inside of the thin paper covers bearing the date of February-April 1991. Fortunately for the Editor, the Association has provided an "Abstracts" listing in English on the inside back cover, from which the following may be quoted:

Sundials on the highway from Vitoria to Burgos in the 18th Century by A Merino, features amongst other sundials, the two sundials and a stone orienting-plane placed on the royal road by the architect Manual de Echánove. M Losot describes how to find the tangent of an angle without tables and by a simple formula one is able to design an horizontal dial with the help of a graduated ruler (for DIY addicts). A German article by H Michnik in 1924 is translated into Spanish, it deals with the construction of a sidereal time sundial. M Lombardero explains how to construct horizontal sundials by the use of a protractor and geometry.

An interesting article is on the determination of the declination of a wall, it proposes the time when the solar rays fall perpendicular upon the plane. It is written by J de la Calle. A section by M Mandex sets some gnomonic problems starting with archeological remains, solutions to given in the next issue. Gnomonic Formulae by A de Vincente, with equations to calculate the various hours are given, using vectorial calculus; should interest the mathematical diallists. Alas, as with the BSS, some difficulty has been experienced in the process from text to print, and so a page of *errata* has had to be included. A half page is devoted to literature and gnomonics, actually a poem and a fragment from the Bard of Avon. Finally another half page on the standardisation of dialling terms.

All in all a very worthy entry into the growing field of dialling publications, the printing and presentation are very commendable, the illustrations are all line diagrams except for an engraving on the back cover showing the setting-out of a vertical dial on a house gable. Luis Hidalgo Velayos is the President, he has written the Editorial in which he mentions the British Sundial Society. The BSS Editor, on behalf of the BSS members, wishes all good fortune to the Spanish Sundial Society. Details of subscriptions, etc, are not yet to hand.

DE ZONNEWIJZERKRING

Bulletin 91.3, issue number 43, contains 46 pages plus a table of the sun's declinations for 1992 and a pamphlet from the Gold, Silver and Clock Museum at Schoonhoven. It commences with a four-page description of the 1991 excursion undertaken by the Dutch Society. M. Hugenholtz similarly describes some sundials on an outing on the 12th/13th July 1991. Page 7 shows the sundial for the blind designed by Gerard Sonius, featured in BSS *Bulletin* 91.3, but with a rather fuller description on the following two pages. Fer de Vries gives formulae with examples for delineating sundials. The next article by Van der Wyck deals with a sundial of the 18th century which was shown in the clock museum of Schoonhoven in 1990. The composite and complicated dial is illustrated over the two pages 19 and 20. An engraving showing a horizontal dial is next featured, evidently seen during the June excursion, with outline description of other dials seen by J.T.H.C. Schepman. W.J. de Bode deals with some aspects of astrology. M.J. Hagen continues with his "Sundials in the Netherlands" series, covering fifteen pages with detailed descriptions. It is a great pity that the illustrations are only photocopied. Under "Literature", all the gnomonic magazines of the world are reported, the BSS *Bulletin* heading the list, being listed as an international number because of the number of foreign authors' articles included.

As usual a splendid magazine full of thought provoking articles, with many new insights into the old but ever-new art of gnomonics. De Zonnewijzerkring is fortunate that so much mathematics can be included, a problem for which the BSS Editor has yet to find a satisfactory solution for his readers, and which will attain more and more importance in the future.

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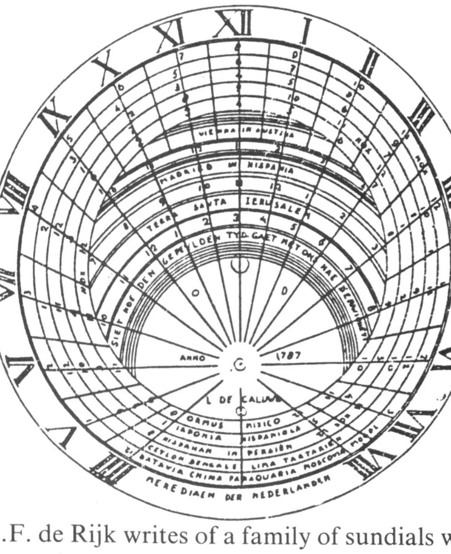
The January 1992 issue includes another rich fare of gnomonics. Members are reminded that their subscriptions of f45 are new due and must be in the form of Eurocheques or Dutch notes (because of the excessive cost of bank conversion charges). Mrs. A. Hanekuijk gives an account of the BSS Conference at Cambridge, as included in the present *Bulletin* 92.1 in English. She also writes of a sundial recently acquired, having the motto "See how the measured Time goes with us to Eternity". (Many place names with their times relative to the meridian of the Low Countries are given, but the outer circle contains places related to trade.) The dial was made in 1787 by L. de Caluwe, see sketch.



J.A.F. de Rijk writes of a family of sundials with split gnomons, he commences with an explanation of the principles involved. One of the remarkable properties of his design is that it can be used in any latitude without altering the time scale.

The series "Sundials in the Netherlands" by Dr. Hagen continues with about thirty examples listed.

The literature reported on includes *Light and Time, Sundials in Landshut* by Knewsch and Holtzhausen; *Cambridge Sundials* by Brookes and Stanier; BSS *Bulletin* 91.3. *Schriften der Freunde Alter Uhren, Clocks,* and many other items. This feature is provided by the indefatigable Dr. Hagens.

There are other articles in the journal but the Editor's limited command of the Dutch language does not allow him to sum them up adequately.

ESSEX CLOCK AND WATCH FAIR

A horological fair is to be held in the Princess Theatre, Town Hall, Clacton-on-Sea, on Monday 4th May at which the British, Sundial Society will be represented with the other leading horological societies. The fair will be open to the public from 10 a.m. to 4 p.m. Enquiries to the organiser A.A. Osborne, Unit 1, R/O Bosworth House, High Street, Thorpe-le-Stoke, Essex, CO16 0EA, telephone 0255 861 913. It is likely that the Chairman, Secretary and Editor will be attending, so this will be an opportunity to buttonhole them and get your views across.

DIALLING LISTING

Those BSS members who own word processors which use the Locoscript system, eg. the 8256, 8512, 9512, and the latest successors, may be interested in the listing of books and other bibliographical material prepared by the Editor and stored on either three 3 in. discs or two 3½ in. discs. There is an initial list of one thousand entries and a chronological index on one disc for £5.00, or three thousand entries on three 3 in. discs for £10.00, both including postage and packing. The first listing has 70 pages, the larger listing has about 250 pages in total, the later entries having more detail than the earlier ones. Most of the titles of the references have been translated into English. The information is supplied on the understanding it is for the personal use of the purchaser only and will not be communicated or copied for any purpose whatsoever to others.

Those members who purchased copies of *Dialling References Antiquarian Horology,* published in 1990, will know the style of the entries. A few copies of this are available, the price has unfortunately increased to £2.00 post free.

All enquiries and orders to Charles K. Aked - address on inside rear cover.

JODRELL BANK

As BSS members already know, the British Sundial Society is collaborating with the Science Centre at Jodrell Bank in Cheshire to provide gnomonic and allied material for its Educational Resources Centre, plus setting up a variety of sundials in the Arboretum. Several demonstration models have already been donated to the Resource Centre, eg. from J.S. Singleton, Dr. A.A. Mills, and Lt. Colonel Colin McVean. An activities workshop is to be given by our member David Brown, of the BSS Education Group, in June.

In the Arboretum, Douglas Hunt's Sunclock is now installed and is proving a great attraction and success. Richard Thorne's Cross Dial is almost ready and will be the next to be erected on site.

Firm promises of donations for the next phase are now required. A series of vertical dials are need to go on the walls of some sort of gazebo or picnic shelter which would be oriented to provided N, S, E, and W faces, as well as some declining surfaces. The BSS Council would be most pleased to receive ideas from members as soon as possible, perhaps even a plan for the building itself from one of our architect members. Provision will also be required for an armillary and also a horizontal sundial eventually.

Plinths will be provided, for which Jodrell will require specifications so that they can be costed, sponsors will be given precise requirements. Money is tight as everywhere, so if those who cannot design a sundial would like to contribute in some way, such as donations of money, or suggestions of possible sponsors, these would be most appreciated. The BSS President, Sir Frances Graham-Smith, is most enthusiastic, after all it was his idea in the first place. Although now retired, he still keeps a keen interest in the Science Centre.

All queries and suggestions to the Editor, David Young or Anne Somerville.

READERS' WANTS AND SURPLUS ITEMS

It has been suggested to the Editor that space should be allocated for the use of members to advertise their wants or any surplus items they may have for sale or exchange. As the BSS *Bulletin* is for the sole benefit of members, the Editor is willing to give this a trial, there will be no cost to the advertisers. Please give details as briefly as possible, address, and/or telephone number. The Editor reserves the right to refuse any such advertisement and the British Sundial Society will not be responsible in any way for any transactions which may result. In cases where security is vital, a reference number will be used in place of the address, etc., and any replies can be made to the Editor, who will forward the replies to the advertiser.

In the case of successful transactions, the Society would be glad for a small contribution to its funds to help expand this activity if it is found useful.

Some members have also indicated that they would like to see commercial advertisements in the BSS *Bulletin,* this has been considered on several occasions by the BSS Council without a decision being arrived at to date. Will possible trade advertisers get in touch with the Editor to see if this matter is worth pursuing further.

XII SCIENTIFIC INSTRUMENT SYMPOSIUM

The International Union of the History and Philosophy of Science, Scientific Instrument Commission, is holding its next meeting from 7-11th September 1992 in Edinburgh. The main theme is the historiography of scientific instruments.

The Conference fee is about £50, which will include the cost of buffet lunches each day, the Conference Dinner, and a visit to Glasgow to see the Natural Philosophy Collections at Glasgow and Strathclyde. Further details from: Miss A.D. Morrison-Low, National Museums of Scotland, Chambers Street, Edinburgh, *EH1 1JF.* Telephone 031 225 7534 Ext. 248.

Applicants must register by 13th April, late comers may be accepted until 7th August by paying a 10 per cent surcharge.

APOLOGY

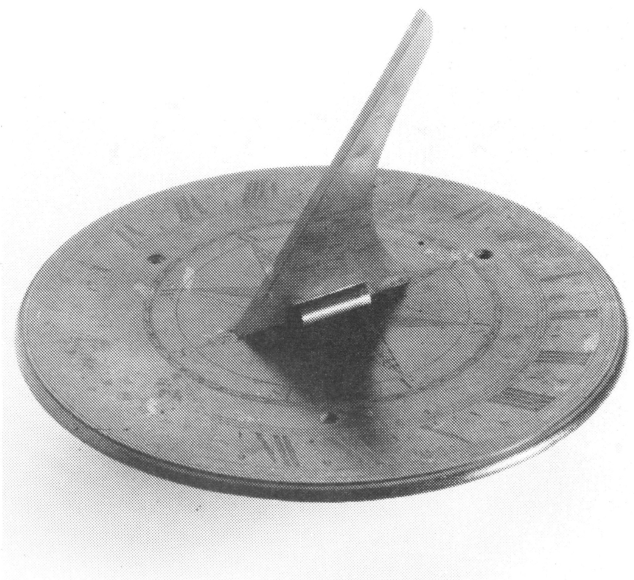
It is regretted that in BSS *Bulletin* 91.3, page 29, October 1991, the first letter under the heading of "Gibbs and Pilkington Type Sundials" somehow lost the signature of the writer during printing. The member who wrote this letter is Mr. J. Cartmell of Cleveleys, Blackpool. The apology is to Mr. Robert Mills who received some unexpected correspondence as a result of the omission.

FROM THE CHAIRMAN'S PEN

One of the principal aims of the British Sundial Society is the preservation of what may be described as the historic sundial heritage of Britain. Of course, the word "heritage" is used so commonly nowadays in the 'marketing' of historic buildings, monuments, museums and other national or local attractions, that it has ceased to have much real meaning. Nevertheless, there can be no doubt that the British Isles has a sundial heritage in the truest sense of the word, albeit one which is rapidly diminishing as the years go by. Neglect, indifference, ignorance and vandalism, especially that which occurs with the so-called 'progress' of development and re-development, all take their toll. As old buildings are modernised or swept away by new buildings, the individual sundial stands little chance of survival, unless it is recognised for its historic value by some sympathetic owner or architect, before it is discarded. Otherwise, it is likely to be considered as an unnecessary ornament and, if not broken up and thrown away, relegated to or sold off into obscurity.

The monumental task of cataloguing, recording and researching the history of the sundials of Britain had long been a cherished personal ambition, which, happily, has now been taken up by the Society. Initially, despite the prospect of such a daunting Herculean labour, I had serious thoughts that I might tackle the matter single-handed, as a 'life-work', with the ultimate aim of producing the 'British Sundial Register'. At the time, over twenty years ago, there seemed to be no-one else similarly concerned with sundials, to the same extent as I was concerned with them, in this country. True, various authorities had written learned technical papers about them, as they had done with other scientific instruments, especially those in museums with collections relating to the history of science. A.P. Herbert had written a light-hearted book on the subject 'Sundials Old and New', (or 'Fun with the Sun') published in 1967. However, at the time, neither he nor the distinguished authors of these various papers appeared to me to have much more than a partial regard for the subject. It was some years before I became aware that Mr. Gordon E. Taylor, our Registrar, had a like interest and before I came into contact with Dr. Andrew Somerville. In 1975 I went so far as to discuss my proposals for a 'British Sundial Register' with Gordon Taylor, then on the staff of H.M. Nautical Almanac Office. However, it was not until the foundation of the British Sundial Society, and the implementation of the programme of sundial recording for a register of the sundials in the British Isles, that I felt the burden of this self-imposed task lifted from my shoulders. To know that there are now many keen and willing kindred spirits working to achieve this aim is singularly rewarding feeling. Nevertheless, the purpose of such a register now comes into question. Why record all the sundials of any note in the United Kingdom? The answer is that, ultimately, this should provide us not only with a greater understanding of the art of dialling in Britain, but that it should enable us to restore sundials that may become broken or 'lost' in the future. In particular, it should be an aim of paramount importance for the Society to record the historic sundials of this country in order to ensure their preservation, as well as their restoration where necessary. Furthermore, as soon as possible, the Society should produce a list of outstanding sundials of historic or gnomonical importance, which list should be published and revised on an annual basis. Such a list should be presented to the proper national authorities responsible for listed buildings and historic monuments, with recommendations for the legal and physical preservation of the individual sundials. Additionally, recommendations for the restoration of such sundials should also be made, where appropriate.

When it comes to the question of restoration, of course, there are innumerable sundials scattered throughout the land that require repair or need to be restored in order to preserve them. Nevertheless, the work of restoration requires not only experience and some considerable knowledge in gnomonical studies; but professional expertise in the materials involved and in the necessary conservation techniques. Much of the expertise exists within the Society; but, of course, membership of the Society does not confer such expertise on individuals. It is one thing to record a sundial; it is entirely another matter to restore a sundial or to give advice on the restoration of a dial. Members should encourage owners of sundials to preserve them; but should be exceptionally careful in offering advice on whether to restore them or on how to restore them. If in doubt, it is preferable to seek a second opinion before suggesting how best the owner may return the sundial to its former glory.



An 18th century brass horizontal sundial by Benjamin Martin (1714-1782). The sundial has lain neglected for years with the gnomon missing. A new gnomon, compatible with the instrument, had to be designed and made to restore the sundial. Plowden & Smith, an expert firm of conservationists, undertook the reconstruction of the gnomon.

CHRISTOPHER DANIEL
CHAIRMAN

THE SECRETARY'S NOTEBOOK

THE COUNCIL

The date has now passed for the receipt of nomination forms and I am pleased to say that all members of the present committee, that were willing to stand together with three new members, have been nominated. This means that there will be no need for an election, which will save us all a lot of work. However the size of the council could well be extended as our activities widen so it does mean that in future we should try harder to persuade members to come forward to offer their services to the society. One of the obvious troubles is that because we are so spread out across the country (indeed we have over seventy members living abroad) it is not easy for many members to get to know each other and therefore the nomination system fails to bring in willing and potentially useful members to the fold. Therefore I would ask any member wishing to serve in the future on the Council or one of its sub-committees, or in any other way, to write to me for further information. There will of course be some travelling involved, Council meets about three times a year, whenever possible at one of our conferences or A.G.M. Up to now reimbursement to officers and council members have not been made for travelling and telephone expenses, but this may change as the Society's financial position improves.

A.G.M. AND CONFERENCE

An innovation this year has been to organise our AGM as a one day event, details of which are enclosed on a separate sheet. By this means we are hoping to attract a good proportion of members to the meeting, which I am sure will prove to be an interesting and memorable day to all participants. Our annual conference will be at the weekend of 11th/12th/13th September at Bath, so please remember to reserve the date now. We hope that this venue will attract a record number of members, being reasonably convenient for all those in the South and the Midlands and being an attractive place to visit for those living further afield. It seems that the likely cost will be in the region of £100 which will include two nights stay, all meals including Conference Dinner, bus tour etc. Full details and application forms will be sent to you with the June 'Bulletin' but advance booking forms can be sent to you shortly if you write to Mr. David Brown, 21 Radstock Road, Midsomer Norton, Bath, Avon, BA3 2AJ.

RESTORATION

In last year's February Bulletin I wrote about the possibility of the restoration of two sundials. I am very pleased to tell you now that Colin McVean has written to me to say that the church dial in Gloucester is now complete. I believe he will be writing an article about it for the Bulletin so I will say nothing more now, but congratulations to Colin for being responsible for the first restoration the society has attempted. The other dial at Collyweston has caused us some frustration. We are having to deal with the local Council, the Burley Estate, and more particularly, English Heritage, as it is a listed monument. It has taken us some six months to get a reply from the latter, to our request for permission to install a new gnomon and we still have to submit the details on their official forms. Several local members are standing by ready to help including, Dick Skinner and Pat Briggs, as soon as the formalities can be settled. Let us hope it will be a working dial by the end of the summer.

Continued from page 38

divisions on its dial. Of course this could be the dial of a mechanical clock, it is difficult to correlate a sundial with a glacier.

Dial, as we all know, can also qualify associated words, eg to describe various types of sundial:

Horizontal, vertical, declining, reflecting, universal dial, and so on.

Moon-dial or lunar dial, sun-dial, ring dial, night or nocturnal dial.

Samuel Johnson, the lexicographer *par excellence,* contents himself thus:

SUNDI'AL [*dial and sun*] A marked plate on which the shadow shows the hour.

Two quotations are annexed: All your graces no more shall you have, Than a sundial in a grave - Donne; and The body, though it really moves, yet not changing perceivable distance, seems to stand still; as is evident in the shadowe of sundials. Locke.

Johnson includes most of the modern dial references. For dial-ling he quotes "The sciaterick science; the knowledge of shadow, the act of constructing dials on which the shadow may shew the hour".

One could go on almost *ad infinitum,* however we can end on a flight of fancy with a reference to the DIAL-BIRD of Upper India, known to the native Hindus as dahyiäl or *dahël,* the *Copsichus Saularis* or Magpie-Robin. It is unlikely that the natives gave the bird this name, it must have been given by the English settlers in India on account of the bird being the first to herald the dawn and hence the term "dial-bird". It should, of course, have been referred to as *Copsichus Solaris.*

The writer is currently thinking of a suitable term prefixed by dial for those birds that specialize in obscuring dials by droppings, suitable that is for inclusion in a directory. No doubt someone else has already thought of it, for there is nothing new under the sun. But who has studied the corrosion effects of such deposits upon copper, brass and bronze? How many noble dials have been corroded into dust by these activities? Probably none at all since sun-dials experience the rinsing effects of rain more often than anything excepting roof tiles. Surely this is an aspect worthy of serious study. Most dial-ists are so busy with new concepts for sun-dials that they have no time to preserve the old dials.

Dial the following number if you have any ideas on the preceding theme - 0895 445332, serious suggestions only please.

ASTRONOMICAL ENDEAVOURS AND HIGHLIGHTS UNDER ALLAH'S SUN

RÉNE R.-J. ROHR, FRANCE

The city of Brussels in 1880 had for some time been the centre of a series of important festivities commemorating the 50th anniversary of the securing of Belgian independence. An important international exhibition took place in a newly created public garden, still in existence today - the so-called *Parc du Cinquantenaire.* One of the striking features of the exhibition was a true representation of a rather spacious mosque in the north-western corner of the park, of which the prominent minaret was visible from all parts.

A century later, in 1980, it had long looked the worse for wear and was in need of a general restoration.

This was then effectively undertaken, with such an abundance of funds that people could not help but wonder at the source of the financial resources, the new inner and outer furnishings reminding the observer of the splendours of the Arabian Nights.

At the time of the restoration I often sojourned in Brussels and dwelt in Avenue Michel-Ange, almost next to the mosque. On seeing that Belgian workmen and decorators freely entered it, I once joined them out of pure curiosity. Inside everyone was busy, after a while I saw the Imam in conversation with someone and found an opportunity to join in their talk. The Imam was an Arab of Tunisian origin, an affable and cultured man, who appeared flattered at my interest in the proceedings and in the ways of Islam. After some more conversation he requested me to determine the orientation of the *mihrab,* and when later I made a proposal to delineate an Arabian sundial with the usual prayer-lines, Instanbul fashion, with the intention of ornamenting the circular and somewhat naked southern facade of the mosque; he told me that he alone could not make the decision but would see what he could do. That day we parted as friends ... but my proposal in respect of the Arabian sundial went awry: not long after our last meeting, together with the Muwaqqit of the mosque, the Imam was murdered by fanatics.

On one occasion, at midsummertime, he expressed to me one of his religious concerns: *"we have no night at all these days",* meaning that the sun, though setting and rising normally every day, never, even at midnight, turned down to a depth of 18° under the northern horizon; is the whole time between sunset and sunrise remained a prolonged twilight with no true night.

Everyone is aware that in Islam, as well as in the Western world, the conception of twilight means the setting or rising sun travels at less than 18° under the horizon line, and that the so-called astronomic night only begins or ends with the sun crossing below or above this depth. In higher latitudes this absence of true night poses problems to Muslims which no theologian appears to have thought of in setting the rules for Islamic prayers. Islamic religion demands that believers say every day an evening prayer *(maghrib)* before the end of the evening twilight, and a night-prayer *(isha)* before the beginning of the following morning twilight - but here in Brussels on the days around the 21st of June, the first of these twilights has no end, and the second has no beginning: the two coalesce together and become indistinguishable!

I made the suggestion that the evening twilight of today ends at midnight, and then begins the twilight of tomorrow, thus the rule would be observed if the two prayers were to be said in sequence at midnight! *"I'll think it over and report",* had been the reply of the Imam.

In Brussels (50° 50′N), at midnight on 21st June, the night still appears rather black; but in Hamburg (53° 33′) and even more in Copenhagen (55° 41′), the course of the sun in the night hours may be perfectly followed by the circling haze of light moving from west to east along the northern horizon.

What I was asking myself following that theological conversation was the question in respect of the latitude where true nights occur on solstic days . . . and from what source the Imam knew so much about all the celestial events depending upon the declination of the sun and the latitude of the observer! It must be remembered that Islam is a religion without any priests and that the Imam, as well as the Muwaqqit, are elected for a limited time only. Their education will not generally exceed the level they obtained in the medressa, a kind of higher Koranic school.

When in European countries it is midnight on the day of summer solstice, the sun's rays reaching from the northern heavens will touch the meridian tangentially at its junction with the Arctic Circle (66.5°N). This point of contact will never occur further southward. The whole of the Arctic zone will then have a sunlit day of 24 hours duration. But as we have already seen, the twilight will extend a further 18° southward to reach the parallel of 48.5°, and this is the northern limit of the true astronomical night. Strasbourg is on this latitude of 48.5°, and on a dial of an astronomical clock calculated for this location (Fig. 1), the black circular area in the

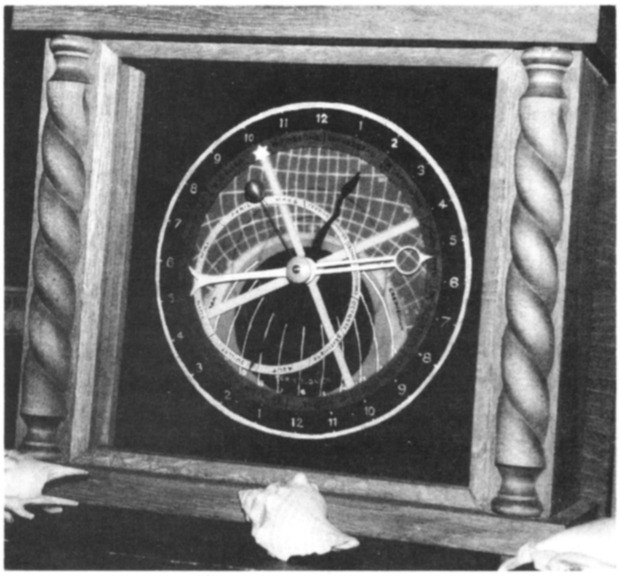


FIGURE 1: Astrolabe Clock with Plate for 48.5° North Latitude

lower part inserted between the slightly brighter (astronomical and civil) twilight areas, is the zone of true astronomical night. Every day that the point of the hand marking the rotating sun crosses the edge of this black area, Strasbourg has the change from twilight to astronomical night. The inner rim of the circular band of the dial which bears the zodiacal signs is the stereographic projection of the Tropic of Cancer. This circle and the black night area are tangential and have only one point in common. At midnight in midsummer, the rotating sun moves along this tropic circle and will touch the black area at this sole point, and this means the sun will not enter the night zone. In other words, from sunset to sunrise on this day, there will be no true night but only twilight in Strasbourg; its latitude is the southward limit of nights with twilight only in the northern hemisphere.

Following the solstice, the declination of the sun slowly decreases until when at zero, the limit of nights of total twilight will have climbed from 48.5° to 72°. On that day the sun will move round the horizon at the north pole, and over all the world it will be the Equinoctial day.

Three months later, on September 23rd, the sun is in the declination of the Tropic of Capricorn, its rays at midnight are tangential to the crossing of the meridian and the Arctic Circle on the opposite side of the globe to ours, whereas the zone of astronomical night will begin north of the parallel 84.5°, and for a short time there will be no sunrise north of the Acrtic Circle.

It is undubitably the case that throughout Islamic countries, a number of astronomers had been actively pondering on these considerations over the centuries; and there is no doubt that even after the Middle Ages, the astrolabe must have remained an instrument of the greatest importance in astronomical research. In his *Traité de l'Astrolabe,* Henri Michel[1] repeatedly mentions Arabian astrolabes containing plates for 72° North without citing suitable examples, whereas Gunther[2] describes two astrolabes of Persian, one of Moorish, two of Indian, and one of Arabian origin.

If one bears in mind that in addition to its scientific value, the astrolabe has the properties of a leisure object, and even a highly venerated toy; and on the other hand, not even at the time of its greatest astronomical importance in Islam, had a traveller such as Ibn Battuta ever approached the Artic Circle. One cannot help, therefore, concluding that the high-latitude plates had no role other than a pedagogic one, in the same way that in Germany at the time of the so-called *Lehrstück von Regensburg,* which moreover had initially been called an astrolabe[3]. Figure 2 shows the outlines of plates drawn for four particular latitudes, all with surprising connections and of pedagogic value.

In spite of centuries-long researches into the extensive Islamic scientific literature, a great deal remains to be done before it is more thoroughly known in the Western world. The names of more than 500 Islamic astronomers have been listed so far, of which almost each one had worked in his own more or less important observatory. In a few cases where the observatory was owned by an interested prince, these are partly preserved and can be visited in present times because the basic elements consist of weather resisting brickwork and marble, sometimes of considerable size and extent.

The uncommon dimensions of these instruments increased the accuracy of the observations. The incentive indeed of this precision, and in fact of the whole very active Islamic astronomy, was the Koran, the Islamic Holy Book; and of the need to accurately determine the hours when it is ordered that prayers must be said[4].

One of the most remarkable observatories had been built in *Maragha* in Azerbaidjan, a rather insignificant place today neighbouring a mountain, where the Mongolian Prince Hulagu, a grandson of the famous

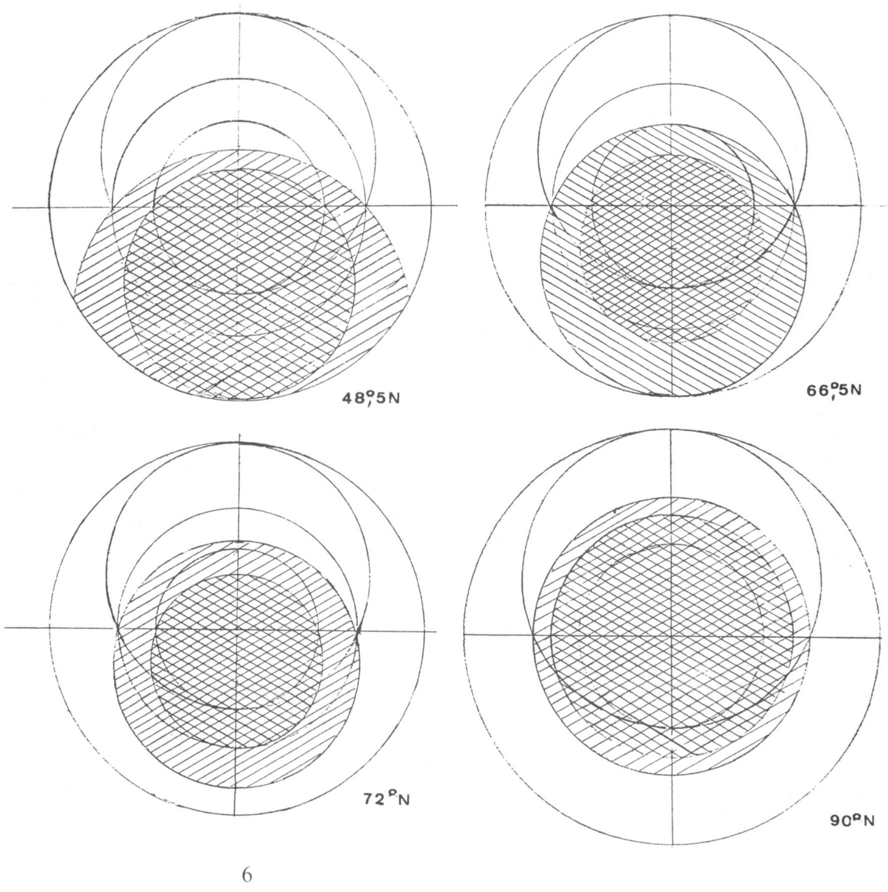


FIGURE 2: Astrolabe Latitude Plates for 48.5°, 66.5°, 72.0°, and 90° North.

Genghis Khan, had ordered its construction for the use of his astronomer Naar Edden-al-Tusi in 1260.

In commemoration of the fourth centenary of the foundation of the Instanbul Observatory, a symposium was held there in 1977. The principal topic of the proceedings was the history of the ancient observatories in Islam. I had been sent an invitation and was thus enabled to make the acquaintance of a number of scientists belonging to the various universities of the Near East and the Islamic countries of the Indian Ocean. One of these, Profesor Vandjavand of the Teheran University, lectured on the recent excavations in Maragha in which he had personally taken part. Little is known of similar but now vanished observatories in *Semasye, Djebel Qasium, or Isfahan.* In Maragha however, the main foundations were dug out, and especially those of the enormous circular observation-tower (Fig. 3), of which the diameter of 24 metres gives some idea of the scale of the buildings' dimensions! An arc of the meridional quadrant of about 40° was preserved in tolerable condition, requiring, with a radius of 20 metres, the height of the building housing it to be at least as much. It is well known that the astronomical tables issued from this observatory were subsequently used all over the Near East and even in the West; but also that in 1335 violent riots broke out in connection with the death of one of the successors of Hulagu, which resulted in the whole observatory being razed by the mob.

But even catastrophic destructions such as this did not mark the end of the astronomic tradition in Islam, for in the years 1624-1628, Ulug-Beg, a reigning prince in Samarkand who was personally interested in science, caused to be erected an observatory containing instruments made from brick which was stated to have been the most perfectly furnished observatory of that time. It may be noted, by the way, that Ulug-Beg was a grandson of the infamous Tamerlane. It was at this time when in Damascus Ibn-al-Shatir made the famous sundial of the Umayyad mosque[5]. Astronomical tables from Samarkand are said to have still been in use in the Royal Observatories in England in the 17th century.

The perennial threat of seismic activity in the region caused the observatory to be built on the slope of a neighbouring mountain. A well preserved trench of 5 metres width was cut in the rocky ground and became the foundation of the lower part of the meridional quadrant (Fig. 4). The extant remains amount to 30° and have a radius of 40 metres, which must also have been the minimum height of the building (Fig.5), identical to the Hagia Sofia in Istanbul. It is very likely the whole construction was clad with the coloured tiles of the period and still visible today on historic monuments in the city. For more certain conservation, this precious part of the quadrant is at present protected in a long roofed hall - but for all that the priceless inlaid bronze arc, with its 30° graduation was stolen a few years ago.

When the planning of the Samarkand observatory was begun, lessons were drawn from the experience gained at Maraghi; and again in 1577, when in Istanbul the construction of an observatory was to be decided upon, these two precedents and their lessons were kept in view. The result was an almost perfect observatory, for which the Seraglio had largely provided the necessary means.

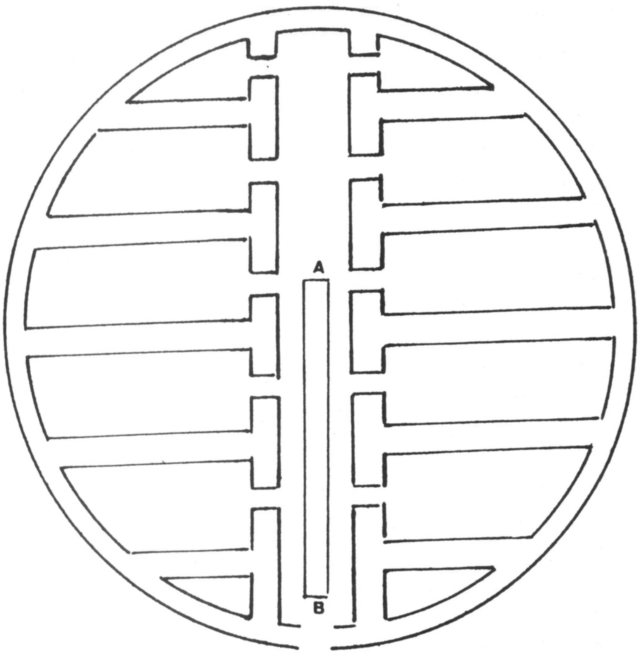


FIGURE 3: The Foundations of the Observatory excavated by Professor Vandjavand, Teheran, 1972. A-B is the Meridian Quadrant Foundations.

FIGURE 4: The Present-Day remains of The Meridional Quadrant in Samarkand.

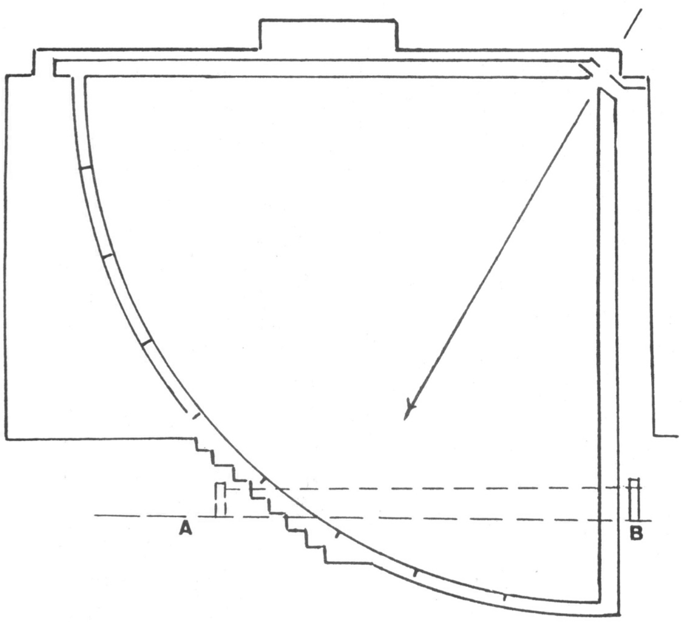


FIGURE 5: Diagram Illustrating that the minimum height of the Meridional Building must have been 40 metres.

There seems to have been some Western influence, and whilst no remains or reports on the monumental brickwork are now known, drawings and paintings from the time show astrolabes, portable quadrants, and all kinds of instruments fit for the measurement of star altitudes (Fig. 6). A feverish activity soon set in and within a very short time, astronomical tables were being issued. But these efforts were short-lived, for in less than a year of the astronomers' work, a series of natural calamities began to spread on both sides of the Bosphorus as earthquakes, conflagrations, plague and famine took their toll; and the people placed the responsibility of these to the work conducted in the observatory, Violent riots induced the Caliph who had caused it to be built, and Taq-al-Din, the astronomer and user of the observatory, to have it destroyed[6].

FIGURE 6: Astronomers at their work in the Samarkand Observatory, according to a contemporary painting.

It may be mentioned in passing, that in the time of Kepler and Tycho Brahe between the astronomers in the West and those in Islam there was a continuous exchange of new ideas on Instruments, especially on quadrants[7].

Following the disappearance of this observatory, nothing more of importance to deserve mention appeared amidst the still numerous private observatories until the days of Sawai Jai Sing II. He was the Maharaja in Jaipur where he ascended the throne in 1691 as a boy aged only 11 years[6]. From his earliest youth he had shown a marked inclination for astronomy rather than for governing, that nevertheless, on assuming power, was not neglected[8]. He was 33 years of age before he began to realize the dreams of his youth: a total of five observatories. The first one in Delhi was erected in 1724, another followed ten years later in Jaipur, then followed by one in Ujjain, another in Mathura, and finally one in Benares; of which the first two, but chiefly the Jaipur example, were to overshadow all those of the past. All are preserved to this day, but except in Jaipur, where in the first years of the present century, restoration work under British guidance was carried out; their general preservation and condition is more or less questionable.

The Jaipur example is by far the most important observatory. On the whole it consists of 18 instruments of which some are multiple, made of brickwork and marble in much the same way as in the previously mentioned examples. Some of the instruments may be innovations, their elements being disposed for dual use, exchanged for each other when continuous observation of the turning universe was required. A complete description of the whole would go far beyond the scope of the present text, nevertheless it will not be inappropriate to have a closer look at some of the special instruments which people sometimes mistakenly take for sundials, whereas the true purpose is in fact very different, although the largest one is sometimes employed in that way.

This is the very conspicuous *Great Samrat Yantra* (Fig. 7), a monumental instrument constructed of brickwork and marble having the form of an equatorial sundial with a style of 30 metres in length, bordered on each side by quadrants of corresponding size. The style is directed to the celestial pole. In fact it is in the form of a staircase enclosed between balustrades bearing marble slabs whose outer edges form precise straight lines bearing engraved scales (Fig. 8). These edges are the geometric axes of the quadrants on their respective sides, of which the upper plane, if extended, would mark the zero of the graduated balustrade. This graduation is proportional to the trignometric tangent of the angle formed with the plane of the quadrant if a straight line were drawn from this edge to the points of the graduated scale. Another graduation of equal precision divides the upper edges of

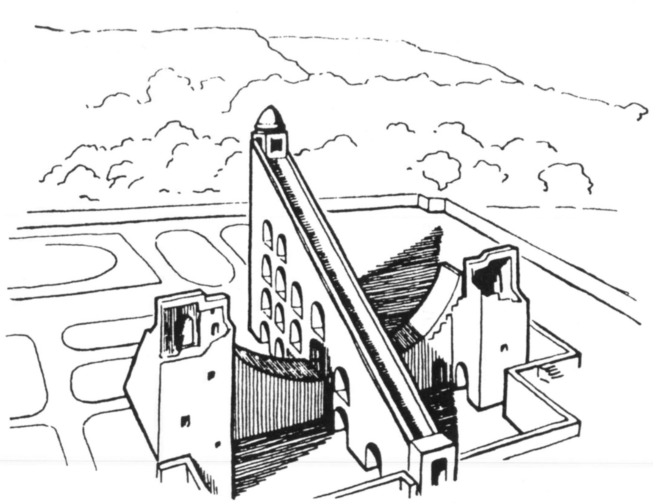


FIGURE 7: A Perspective Diagram of the Great Samrat Yantra in Jaipur.

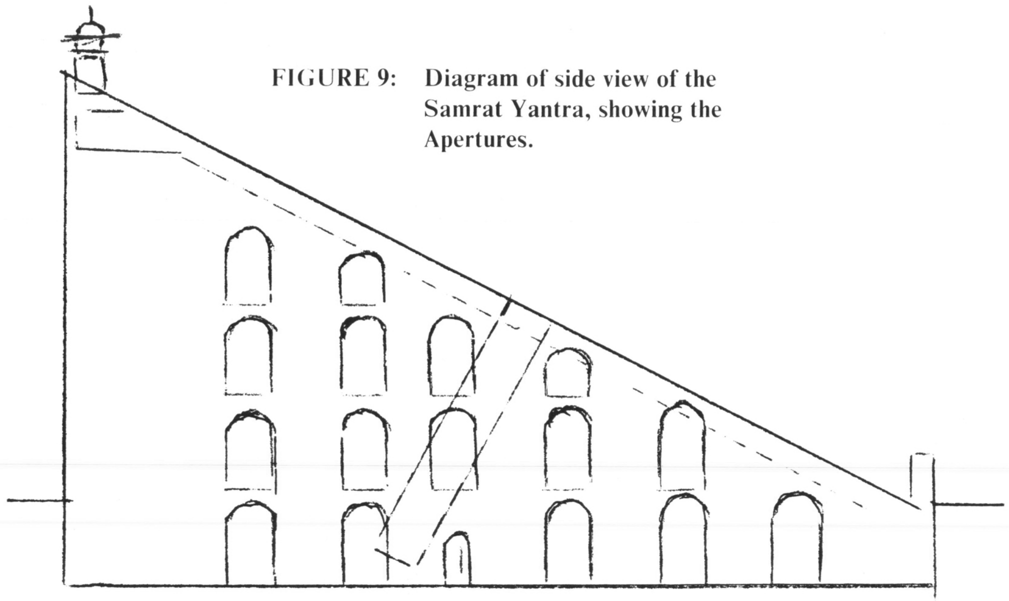


FIGURE 9: Diagram of side view of the Samrat Yantra, showing the Apertures.

FIGURE 8: View of the Staircase of the Samrat Yantra and the Linear Graduations.

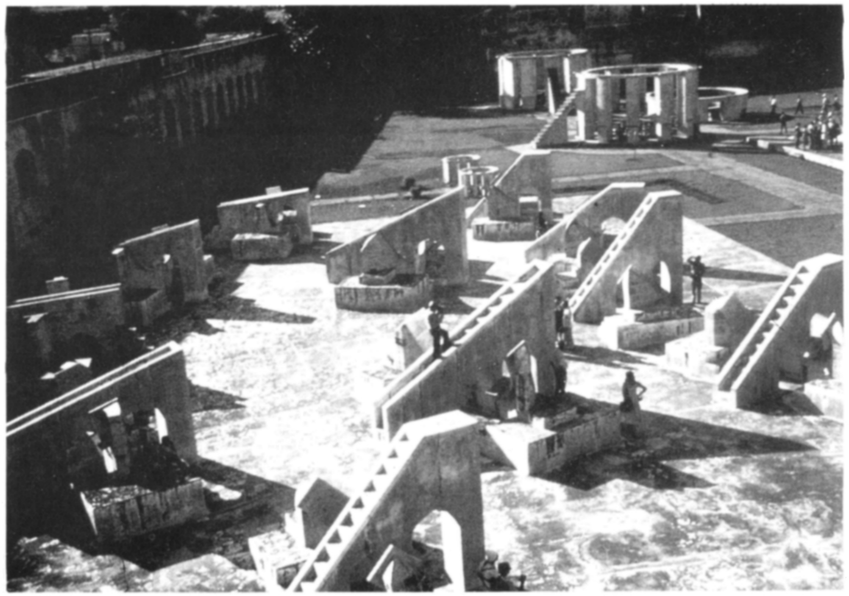


FIGURE 10: The Group of Twelve Rashivalayas Yantra for measuring the Ecliptic coordinates of Celestial Bodies.

the quadrants into degrees only, the foremost role of the Yantrà being to measure the declination and right ascension of celestial bodies. To perform this observation, the astronomer used the staircase descending along the graduations of the quadrant and observed the star in such a manner as to have his line of sight touching the marble edge of the quadrant and the corresponding balustrade edge simultaneously, where an assistant placed some suitable object according to the orders given by the observer.

A few lines of explanation will be helpful to outline the use of the Giant Yantra in the accessory role as a sundial:

Sited next to it, erected on an area of some 600m^2, is a series of twelve smaller copies of the Yantra style and quadrants: they are the *Rashivalayas Yantras.* Four are of a slightly greater size, but none of their axes point to the celestial pole, each has its own particular direction (Fig. 10). Their disposition is disorderly as though some cyclops had thrown some gigantic toys there. The visiting gnomonics apprentice begins to feel uncomfortable as he recalls a saying of Polonius to Hamlet: *Though this be madness, yet there's method in 't!* He tries to understand and attentively looks at the details, everywhere on the styles and quadrants are the fine marble edges bearing the engraved graduations. The yantras appear to be reduced versions of the large one. The angular distances of the group of styles from the style of this latter appear to be similar and about the width of the inclination of the ecliptic on the equator, and when imagining parallels to each style through a point of the style of the Samrat Yantra, a regular cone would be found and divided into 12 equal sectors. What do these axes mean and at which poles are they aimed?

It is at this moment that the spark of intelligence is fired.

Together with the stars the ecliptic makes a complete rotation in a sidereal day during which its pole describes the arctic circle in the sky! The 12 poles of the smaller yantras divide the circle into 12 equal parts. The whole series allows the direct measure of the ecliptic coordinates of the celestial bodies.

The styles of the four greater yantras are aimed towards the opposed points of the ecliptic which mark the beginning of the signs of Aries and Libra, Cancer and Capricorn respectively, is the beginning of the four seasons. The remaining eight styles are directed towards corresponding points and each yantra had its own sign. On a given day, only one observation could be performed on each yantra, and that had to be done simultaneously when the circle of the rotating ecliptic was parallel with the plane of the given yantra. At that moment determined by using the Samrat Yantra in its role of sundial, the corresponding sign was beginning to rise on the eastern horizon. The accuracy required for these rather delicate operations sufficiently explains the monumental dimensions of the Great Yantra.

It is known that the so-called equatorial co-ordinates, ie declination and right ascension are based upon the equator, whilst the ecliptic ones are based on the ecliptic and are called astronomical or celestial latitude and longitude. Their units are also degrees and hours, with the vernal point as origin. Today they are usually deduced from the equatorial values by means of trignometric formulae. Their direct measurement in the Jaipur observatory possibly stands alone in the history of astronomy.

There is the certainty, as we have seen, that the astronomical tables issued for the ancient observatories in Islam were fully equal to those of the Western world. This is a fact which poses the question to architects, astronomers, opticians, and engineers of our own day -what kind of people may they have been, these builders from three centuries and more ago, who with the help of rulers and calculations, dared to to undertake and succeeeded in the realization of monumental instruments of masonry, of which the marble edges required the precision of almost arc-minutes in a rotating universe . . .

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MOONDIALS

BY REAR-ADMIRAL (Rtd) GIROLAMO FANTONI (Italy)

For several milleniums measurement of time has been made by observing and following the apparent movements of the celestial bodies; the "deus ex machina" of this technique has always been the Sun, which, during the centuries, has prompted man to develop a vast range of instruments to measure the time by the shadows of the Sun.

Sundials, however, remain "silent" during the night hours, and our ancestors had to turn also to the stars and the moon to continue to measure time after the setting of the Sun. The techniques that followed, even though they did not achieve the same popularity of the daytime gnomonics, nevertheless achieved a certain level of diffusion. The most common nocturnal dials were the stellar ones; the Moon also gave its small contribution, but the lunar techniques, for good reasons, were not widely diffused and very little known; a short review of these lunar techniques will now be given. Also presented is a new type of "lunar dial" which I have elaborated some centuries too late, rendering it totally useless; nevertheless I think that the fans of gnomonics may find it interesting and amusing.

THE MOON AS TIMEKEEPER

On clear nights, when the phase of the Moon is not too far from the Full Moon (approximately from the First Quarter to the Last Quarter), our satellite can produce shadows like the Sun, and can, therefore, be used to know the hour by observing its position in the sky.

Since the hour that is needed is the "solar hour" and not the "lunar hour", it is necessary, afterward, to compare the position of the Moon to that of the Sun; here, in addition to the limitation due to the phase, we find some other difficulties since the movements of the Moon are among the most irregular of the celestial ones, and are not suited to indicate the passing of time, which requires regular and uniform timekeepers. However in the field of the gnomonic science the historical importance of the techniques devised by our ancestors to make use of the Moon, must be considered.

Briefly these are the main aspects of the movements of the Moon that may interest the gnomonists.

The plane of the lunar orbit is inclined about 5° over the plane of the terrestrial orbit, but these 5° are not taken into consideration as far as lunar dials are concerned.

In relation to the Sun, the Moon moves from west to east, delaying each passage by approximately 48.8 minutes a day, and makes a complete turn around the Sun, called "lunation", in 29.5 days on the average. This turn around the Sun causes the evolution of the "lunar phase" which, during the lunation, goes through the four principal positions of New Moon (NM), First Quarter (FQ), Full Moon (FM), Last Quarter (LQ).

Often the diallists, well aware that they could not have precise measures of the time with the Moon, rounded up to 30 days the duration of the lunation. This means that the daily delay of the Moon is considered to be 48 minutes rather than 48.8 minutes.

In any given moment, to compare the position of the Moon to that of the Sun, it is only necessary to know the number of days that have elapsed from the New Moon (days in lunation, also called the "age of the Moon"). All the techniques to measure time using the Moon demand the knowledge of this fundamental information; once the age of the Moon is known, by multiplying it by 48 minutes the delay of the Moon from the Sun in known, and hence the delay of the lunar hour from the solar one is known.

PASSAGE FROM LUNAR HOUR TO SOLAR HOUR BY TABLES

Exposing a common sundial to the lunar light has been the most widespread practice to use the Moon to determine the hour.

Once the hour indicated by the lunar shadow is read, it is transformed into the solar hour by adding a correction obtainable from a proper table in function of the stage of the lunar phase (age of the Moon). The form of the correctional table (which practically carries out the multiplication by 48 minutes), can vary according to the imagination of the person who designs it. The simplest one is that indicated in figure 1. The first line indicates

d	7	8	9	10	11	12	13	14	15
C	5^h36	6^h24	7^h12	8^h00	8^h48	9^h36	10^h24	11^h12	12^h00

d	15	16	17	18	19	20	21	22	23
C	0^h00	0^h48	1^h36	2^h24	3^h12	4^h00	4^h48	5^h36	6^h24

d = days after New Moon
C = correction to the lunar hours

FIGURE 1

the number of days in the lunation (days after the NM) from the 7th to the 23rd, that is from FQ to LQ, period when the lunar shadow can be used; the second line indicates the addition to be applied to the lunar hour to obtain the solar hour. If the result is more than 12, a subtraction of 12 is made, a simple rule indicates whether the result is an a.m. hour or p.m. hour.

The table would be a little different if the day is divided in 24 hours rather than 12 a.m. hours and 12 p.m. hours.

If the table is extended to cover all the 30 days of the lunation, the result is the table which is shown in the sundial of the Queen's College at Cambridge (Great Britain). Some writers have called this dial "famous" exactly for the presence of the "lunar table"; in this version the first and third lines indicate the stage of the lunation, while the middle line indicates the correction to add to the lunar hour to obtain the solar hour. It should be noted that this is a rather pretentious solution, since it shows the data for all the days in lunation, including those close to the New Moon, when our satellite gives shadows that cannot be used.

An excellent diagrammatic version of the corrective table is proposed by René Rohr ("Les Cadrans Solaires", 1986) (figure 2); this diagram uses the day divided in two periods of 12 hours, a.m. and p.m., and, rightfully so, disregards the periods too far from the Full Moon.

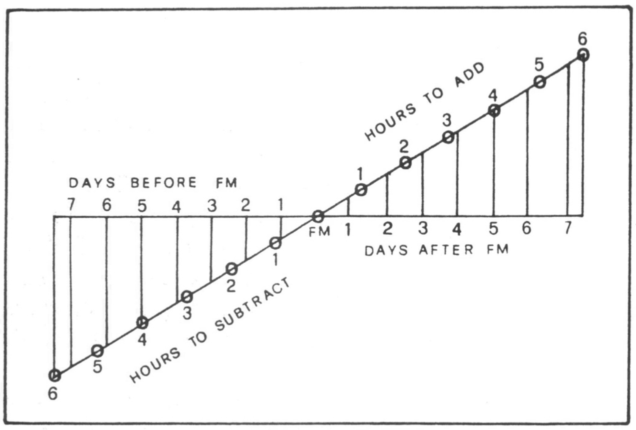

FIGURE 2

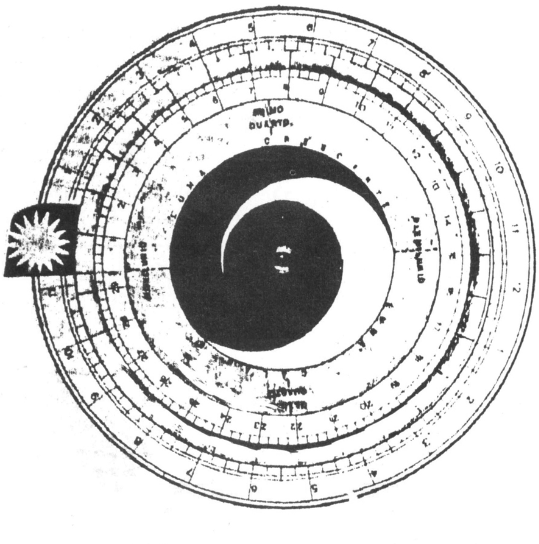

FIGURE 3

The famous reflexed sundial by Maignan in the Palazzo Spada in Rome solves the problem with a circular slide rule, where an external fixed circle shows the hours and an internal turnable circle shows the days in the lunation from 0 to 29.5 (figure 3).

MOODIALS

Besides corrective tables, in the past the diallists devised actual instruments that, exposed to the lunar light, could show directly on the dial the solar hour of the moment.

The simplest of this instruments, proposed by Oronce Finé in his treatise of gnomonics of the XVI century, is practically based on an equatorial sundial (figure 4, taken from an 1587 Italian translation). On the dial there are two concentric circles; the external fixed circle is divided in 29.5 parts, corresponding to the day of the lunation; the internal circle, which turns around the centre of the dial, shows a graduation in hours. By turning the disc of the hours until the origin of the graduation is on the day of the lunation, the lunar shadow of the style marks the solar hours on the hour disc directly.

The French scientist Bion in 1723 described how to design an analogous lunar instrument, using a common horizontal sundial, where as in the Finé's dial, the disc of the hours turns over the disc of the lunar days. This instrument could not have been a masterpiece of precision, not even in theory, since the spacing of the

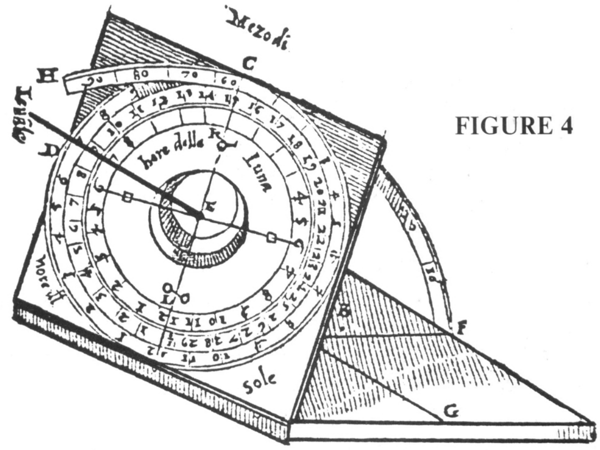

FIGURE 4

solar hours (which in the equatorial instrument by Finé is uniform) here is variable and causes errors when the hour disc is turned with the noon line outside of the meridian.

A NEW MODEL OF LUNAR DIAL (MOONDIAL)

An idea for use of the Moon as a timekeeper can be found in the 1699 book "Cours de Mathématique" by the Frenchman Ozanam. Working on that indication, we think we can propose a totally new lunar dial, which, beside being pleasant and elegant, seems to be sufficiently efficient. It is surprising that our ancestors did not discover it; obviously the Moon did not inspire the ancient diallists enough.

Let us examine this new model assuming that it is on an horizontal plane, but the same construction can be made on planes oriented in any positition, for instance also on vertical declining planes.

Let us consider a common horizontal sundial (figure 5) with the hour lines from 6 a.m. to 6 p.m., with the style rising in point 0, inclined on the plate as much as the latitude (actually the span of the hours can be wider, with hour lines before 6 a.m. and after 6 p.m.).

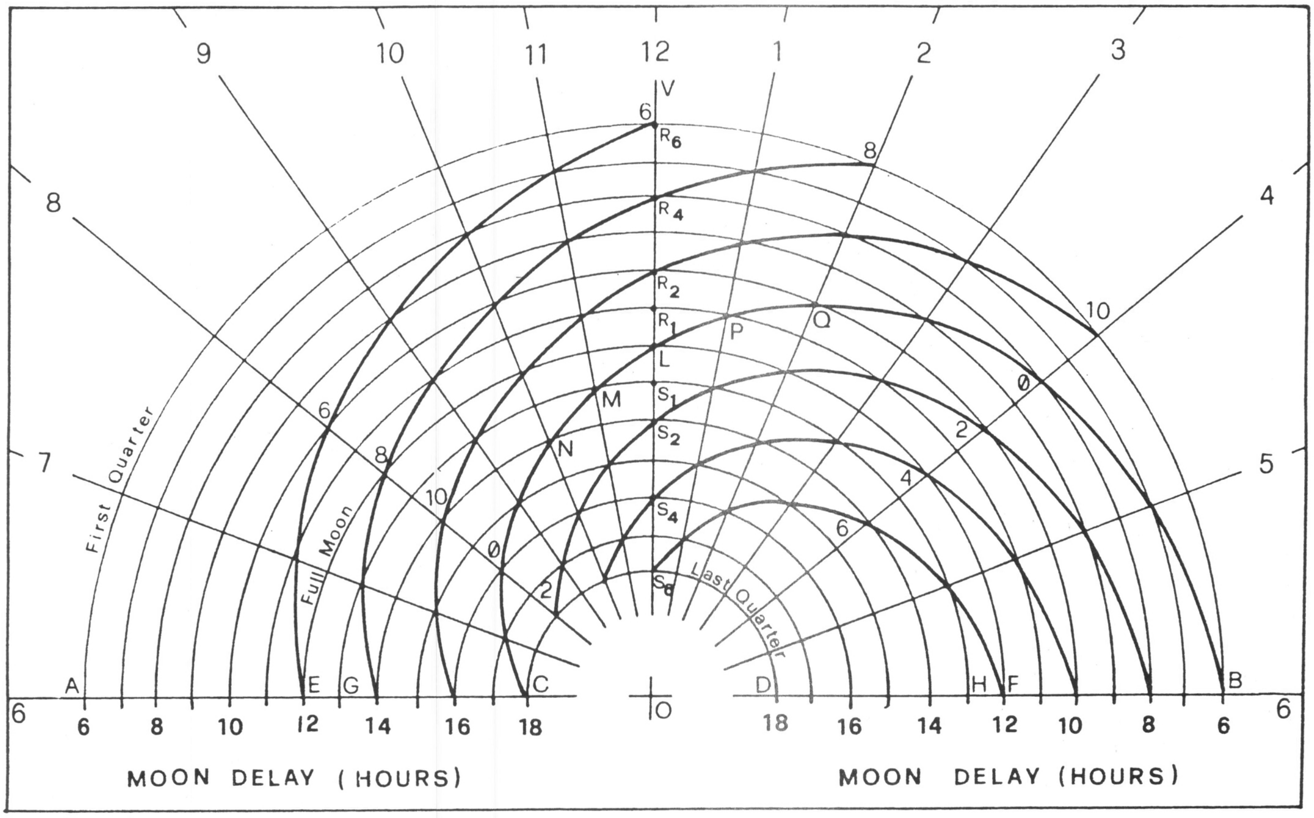

FIGURE 5

With centre in 0 let us draw on the plate two arcs of circle AB and CD with arbitrary radii; they will represent the beginning and the end of that part of the lunation that can be used, that is, respectively, the moment of the First Quarter, delay of the Moon 6 hours (external arc) and the moment of the Last Quarter, delay of the Moon 18 hours (internal arc). Since this arrangement is arbitrary, however, the First Quarter and the Last Quarter can be exchanged.

With other circles, always centred in 0, the space between the circles AB and CB is then divided in 12 equal parts, and, starting from the outside, each arc is assigned the lunar delay of hours 6, 7, 8, etc, until the delay of 18 hours to the arc CD of the Last Quarter. The meridian arc EF, therefore, represents the moment of the Full Moon (delay 12 hours).

Now we want to find the solar midnight hour line shown by the lunar shadow of the style. When the Moon is Full, at the solar hour Ø the Sun is at the inferior meridian, while the Moon, with 12 hour delay is at the superior meridian and casts the shadow of the style on the meridian line OV of the plane. Therefore the point L, where the arc EF of the Full Moon and the lunar shadow of the style at hour Ø meet, is a point of the hour line Ø that we are looking for.

When the Moon is delayed another hour (total delay 13 hours, represented by the arc GH) at the solar hour Ø the lunar shadow will fall on the hour line 11 a.m. and so also the point M belongs to the hour line Ø that we are looking for. Similarly point N, corresponding to the 14 hours delay, belongs to it, and all the other points that can be identified in the same way, in the period following the Full Moon.

Similarly the points P, Q, etc., which correspond, in the period preceding the Full Moon, at the delay of hours 11, 10 etc, can be identified.

Tracing a curve on all the points like Q, P, L, M, N, etc, obtained by the crossing of the lunar delays with the hour lines of the original dial, we obtain a spiral curve that can be called "lunar hour line at the solar hour Ø".

In a similar way, starting from the points from R1 to R6 we can draw the spirals for hours p.m. 11, 10, 9, 8, 7, 6 and starting from the points from S1 to S6 we can draw the spirals for the hours a.m. 1, 2, 3, 4, 5, 6 as shown in figure 5 (for clarity of figure the spirals are drawn only with 2 hour intervals).

The construction is limited to the spirals valid from 6 p.m. to 6 a.m., since the other hours are generally diurnal, and as such, useless in a nocturnal instrument. Of course this interval can be increased by a few hours to take care of situations with a low declination of the Sun or simply for aesthetic reasons.

As a final step, it must be noted that the spacing of the lunar circles by the hours, as shown in the construction, does not have a precise relationship with the movement of the Moon, since it delays 48 minutes a day, and not 60 minutes. Therefore, at this point, the circles of the lunar delays, spaced by one hour, must be erased and replaced with other concentric circles which refer precisely to the lunation. To this end, we will divide the interval between the terminal circles AB and CD in daily parts corresponding to the daily delays of the Moon between FQ and LQ, that is between the days from 7.5 and 22.5 after the New Moon; hence the division should be made in 14 equal parts, plus two half parts at the terminal sides.

The circles obtained in this way will have to be numbered on a scale that will show the number of days that have passed since the New Moon.

The final result is indicated in figure 6. In an analogous way the days of the lunation can be referred to Full Moon rather than to the New Moon.

In the final drawing of fig 6 also the solar hour lines of

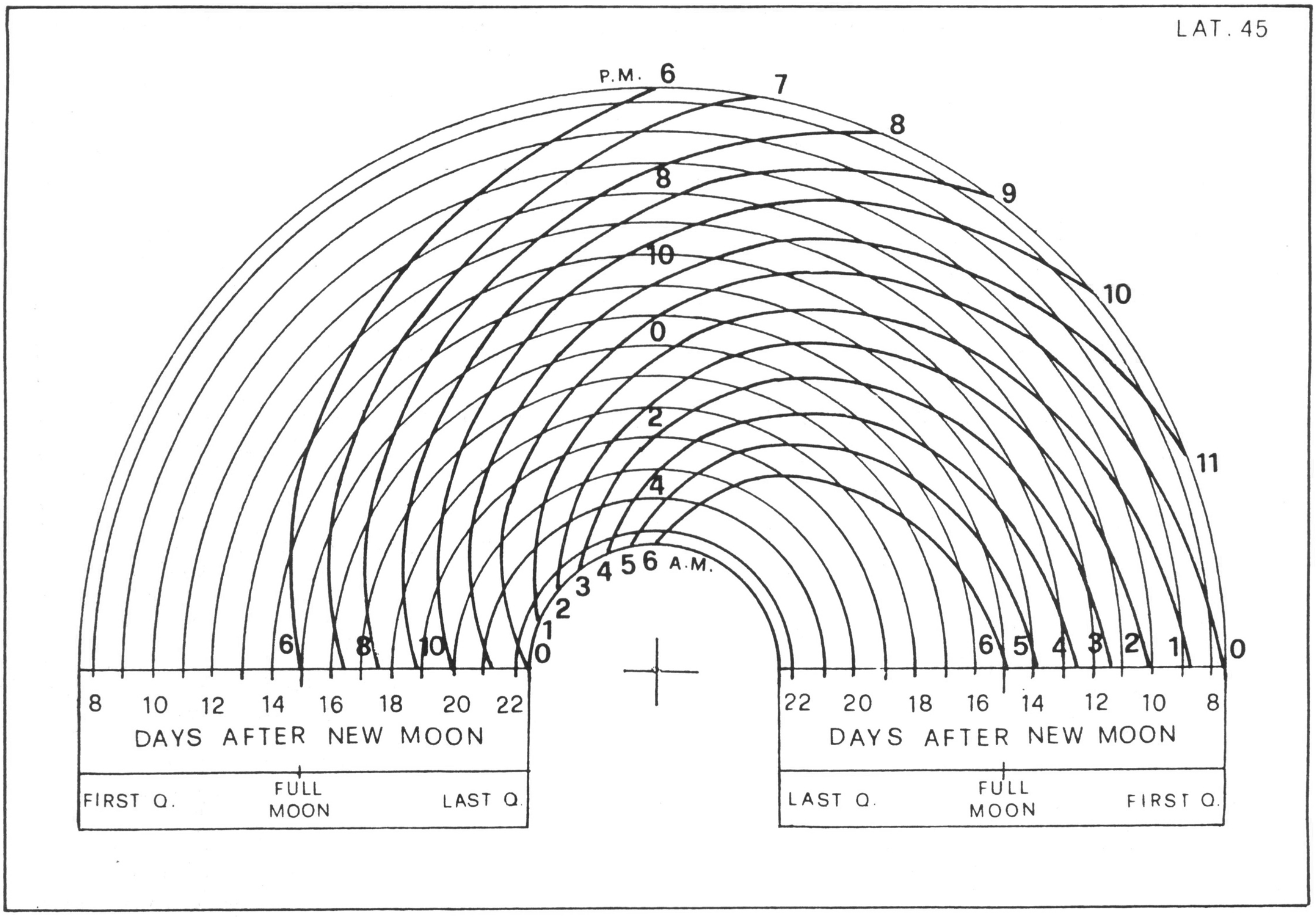

FIGURE 6

the original dial have been cancelled because, when the construction is finished, they become useless. On the other hand the solar hour lines can be left on the final dial, if the instrument should be required to be used also as a solar dial.

In a dial of this type the style is identical to the style of the sundial from which it was derived.

The reading of the solar hour is elementary and immediate. It can be read on the spirals of the diagram in the point in which the lunar shadow cuts the arc corresponding to the stage of the lunation in that moment, counted as "days after the New Moon" (or, also, in an analogous variance as "days before or after the Full Moon").

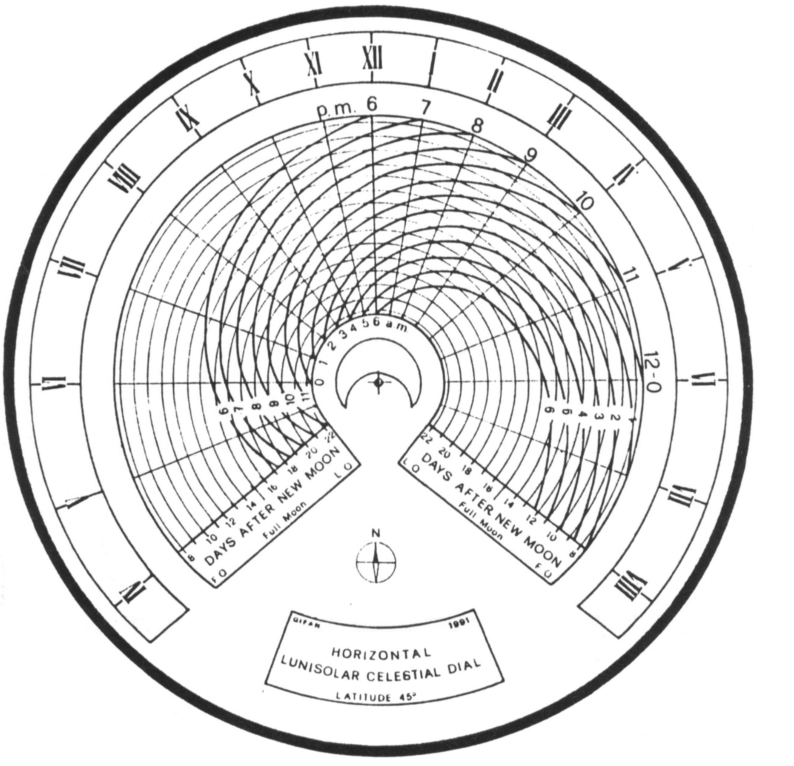

FIGURE 7

Figure 7 shows an horizontal example of this model of celestial dial for 45° of latitude, to be used both as a sundial and a moondial; the solar sector is arranged on the external section, the lunar sector is set inside the solar one, with the "lunar spirals" variable between the hours 6 p.m. and 6 a.m.

A vertical dial for the latitude 51°.5 (London), declining 29° East, is shown in figure 8; also in this example the lunar spirals have been inserted to use the instrument also at night with the shadows of the Moon.

In this last dial it can be noted that in the areas furthest from the substyle, where the hour lines widen, the crossings of the spirals with the circles of the lunation are rather narrow and not very favourable for a good reading. To minimize the inconvenience, during the constuction both the geometrical shape of the curves of the lunation and their spacing can be modified; in our description they have been shown circular and equidistant but, for example, they could be oval or elliptical or with spacings increasing toward the outside. Since the shape and distance of these lines are totally arbitrary, the possible solutions are endless, and each person can choose the one that he feels in the most suitable for the instrument that he wants to produce.

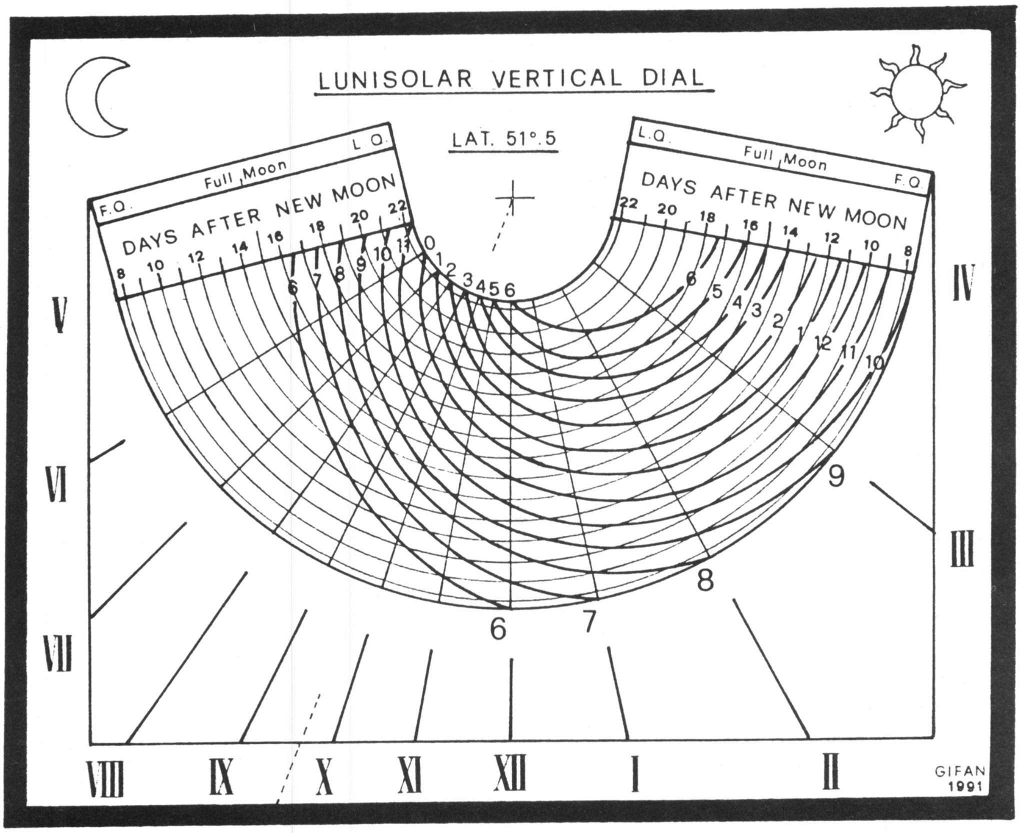

FIGURE 8

G ADAMS SUNDIAL

The photograph is of a G Adams equinoctial dial in the Museum of the History of Science, Oxford, the inventory number being Lewis Evans 193, it is signed "Made by G ADAMS in Fleet Street, LONDON" and is circa 1750-1760. There is a similar example by another maker in the Whipple Museum, Cambridge, catalogue item 216, and another illustrated in *Brass and Glass* page 300, which is in the Royal Museum of Scotland. A correspondent has asked why an equinoctial dial should be fitted with a vertical gnomon offset from the centre of the hour scale, thereby losing one of the great advantages of the equinoctial dial, namely equal hour angular divisions.

The Editor is unacquainted with the finer points of design of this particular instrument, is there anyone out there who can rectify his lack of knowledge?

FOSTER'S DIAMETRAL SUNDIAL

BY FREDERICK W. SAWYER III

DESCRIPTION

The diametral sundial, described in the work of Samuel Foster, a professor of astronomy at Gresham College in seventeenth century London, is a horizontal dial with movable stile. Its hour-points all lie on a finite segment of a straight line so that the shadow becomes retrograde daily at a selected hour. The intersection of the stile's shadow with the timeline marks the time of day. It progresses westward along the straight line until the appointed hour each day, at which time it slows to a halt and reverses direction, retracting its path to the east.

Thus, Foster provides a simple means of recreating the Biblical miracle of Ahaz' dial, whose shadow behaves in much the same way. Note, however, that it is unlikely that Foster had this result as a goal for his research. The diametral dial is simply a special form of the more general elliptical dials he developed, including the earliest English derivation of the analemmatic dial and the original discovery of the circular hour-arc dial often attributed today to J.H. Lambert (1775).

CONSTRUCTION

To make a horizontal diametral sundial at latitude L which is retrograde at acute hour-angle r each day (and also 12 hours earlier or later if the sun happens to be above the horizon), let

$\sin e = |\sin r| \times \cos L$, where $|\ |$ denotes absolute value
$\tan g = -\cot r \times \sin L$
$\tan s = -\cot r / \sin L$

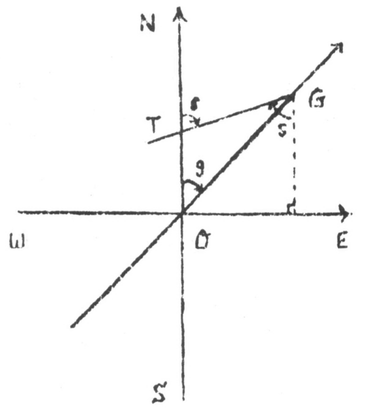

FIGURE 1

Select a point O on the horizontal plane and draw a meridian line NOS, an east-west line WOE, and line OG making an angle g (measured clockwise) with the north ray of the meridian line. The hour-line of the dial will be WOE, with the distance OC_t from O to the hour-point C_t determined as follows:

$OC_t = \cos(t-r) / \sin r = \sin t + (\cos t / \tan r)$

The stile moves in a slot marked by line OG on the dial face; the intersection of the stile and dial face on any given day with solar declination d is the point G_d, where

$OG_d = \tan d / (\cos L \times \cos g)$

The stile itself is elevated above substilar line GT determined as in Figure 1, by point G_d and angle s, or equivalently by the fact that the intersection T_d of GT and NOS is situated so that:

$OT_d = \tan d \times \cos L$ *(similar to the declination scale of an analemmatic dial)*

The stile's angle of elevation above GT, with base at G, is e.

To be certain that the shadow always extends far enough to intersect with the hour-line, the length v of the stile should satisfy the following:

$v > (1 + .4335 \times \tan L) / |\sin r|$

Thus, as an example (Figure 2), for the latitude 51;30 with $r = 60$ *degrees* we have:

$e = 32;37;24$ $g = -24;18;55$ $s = -36;25;02$ $v > 1.7840$

$OG_d = 1.7628 \times \tan d$ $OC_d = \sin t + .5774 \times \cos t$

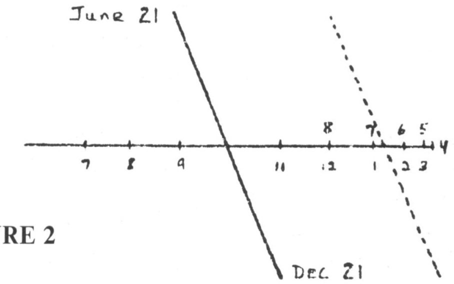

FIGURE 2

The resulting sundial will be retrograde daily at 4pm local apparent time. If we change the signs or r, g *and* s, we have a dial which is retrograde at 8am daily.

Throughout the year, the stile must always move parallel to itself; ie. although points G and T (Figure 1) vary according to the day of the year, angles s *and* e are constant. Alternatively, the stile may be stationary and a number of hour-lines parallel to WOE and centered on OG may be drawn in and associated with some particular date - or one moveable line may be used.

Note that in Figure 2 we have drawn a line parallel to the declination scale *(OG)* and at a distance of -.8920 (ie. $-v \times \cos e \times \sin s$) as measured along the time-line WOE. In this way, we can use a right triangle whose hypotenuse is the stile and which we know is properly placed when its two base vertices fit exactly between these parallel lines and the left vertex is at the correct point for the given date. This configuration is useful if the stile we use is not rigid enough to ensure that the angle s between the substile and meridian does not change as the stile moves in the declination slot. If the stile is rigid enough to preserve the angle, then the parallel line is obviously not needed.

JUSTIFICATION

Begin by considering a horizontal dial face with a vertical rod at its centre and a horizontal stile attached to the rod so that it may move up and down, and suppose that the dial is at the North Pole. Select north-south and east-west lines to correspond to your meridian, so that the shadow of the vertical rod at noon for your meridian lies along ON. Suppose that the horizontal stile is in the plane of the meridian (ie. parallel to ON) and let its height above the dial be *tan d*. The altitude of the sun at the North Pole equals its declination throughout the day, so the shadow of the vertical rod at hour t is OA, and, given the height of the stile, OA has unit length (Figure 3). The shadow of the

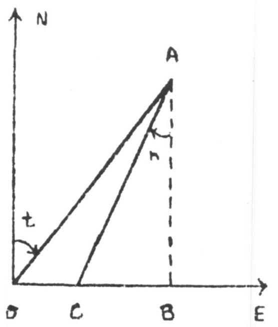

FIGURE 3

horizontal stile is AB, and $OB = \sin t$. If the horizontal style is rotated clockwise through a given constant angle n, its shadow at time t is AC, and

$$OC_t = \sin(t-n) / \cos n = \sin t - (\cos t \times \tan n)$$

since $(\sin OCA) = \cos n$, $OAC = t-n$, and $OC = (\sin OAC)/(\sin OCA)$, this last equation resulting from the sine law and the unit length of OA.

Thus, for any given angle n, the hour-points may be distributed along the diameter WOE (whence the name of dial), and the usual circle arrangement may be ignored. Obviously we need to relate the angle n to the hour-angle r at which the dial becomes retrograde; we will do so presently, but continue for the moment using the angle n.

Suppose now that the dial is moved parallel to itself to the latitude at which it is to be set up. The dial face will be in the equatorial plane and WOE may be selected as the intersection of this plane with the horizontal plane. WOE will serve as the east-west hour-line and, as has been noted, the remainder of the original dial face may be ignored.

Now we determine the placement of the stile. The stile lies in the plane of the equator and the formerly vertical rod OZ with length $\tan d$ is now inclined above the horizon (towards the north) at an angle L equal to the latitude. It is topped by a stile which is perpendicular to the rod and intersects the plane's meridian at point D. When the stile is rotated about the rod through an angle n, its intersection with the plane moves to point G. If we now let T be the base of a perpendicular dropped from the point z to the plane, we have four right triangles OZD, ZDG, ZTG, ZTO which share a common vertex Z. We obtain Figure 4 by rotating these triangles about their bases until they lie in the horizontal plane, the common vertices result in points $z_{1,2,3}$ after the rotation, and we have these equalities of length:

$$TZ_2 = TZ_1 = \sin L \times \tan d \qquad DZ_3 = DZ_1 = \tan L \times \tan d$$

$$GZ_2 = GZ_3 = DZ_3 / \cos n = \tan L \times \tan d / \cos n$$

Given this configuration, simple trigonometry provides the following equations:

$$\tan g = DG / OD = DZ_3 \times \tan n / (\tan d / \cos L)$$

$$= \tan n \times \sin L$$

$$\tan s = DG / (OD - OT) = \frac{\tan L \times \tan d \times \tan n}{(\tan d / \cos L) - (\tan d \times \cos L)}$$

$$= \tan n / \sin L$$

$$\sin e = TZ_2 / GZ_2 = \sin L \times \tan d / (\tan L \times \tan d / \cos n)$$

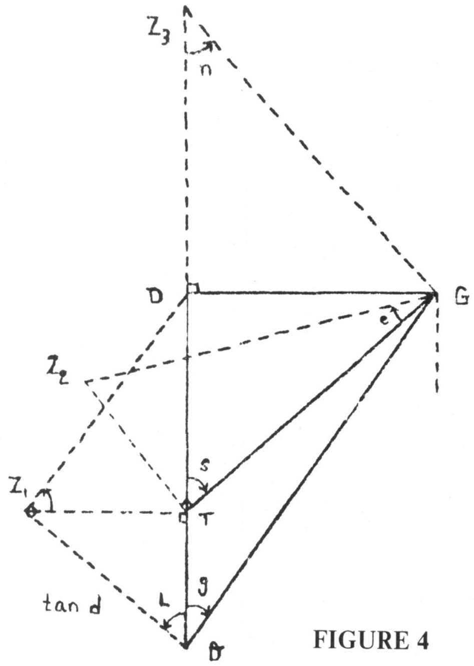

FIGURE 4

$$= \cos n \times \cos L$$

$$OG = OD / \cos g = \tan d / (\cos L \times \cos g)$$

The minimum length of the stile must be the sum of two parts: the distance GZ_2 from the horizontal to the triangles' common vertex, and a length $(\sec n)$ which in the polar case is sufficient to ensure that the end of the stile will cast a shadow at summer solstice noon on the diameter of the original hour-circle for any value of angle n.

Now, finally we need to relate to angles n and r. Consider the point in time at which the shadow of the stile becomes retrograde; for that value of t, the derivative of OC_t with respect to t is zero:

$$d(OC_t)/dt = \cos(t-n) / \cos n = \cos t + (\sin t \times \tan n) = 0$$

However, by specification we have made r equal the hour angle of the sun at this crucial time; by substituting r for t in this equation, we have

$$\tan n = -\cot r, \quad \text{and therefore,} \quad r = n + 90°. \quad (+ \text{ or } -)$$

Given this relationship, substitutions in the above equations to eliminate n produce the defining equations for the sundial laid out in the directions for construction.

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1654 ***'Rectilineal or Diametral Horologiography.*** *Shewing The manner how to describe the Houres upon a finite right line, or the Diameter of a Circle, and to fit a moveable Index unto the Diall so described. Invented and written by Mr. Samuel Foster, Late professor of Astronomie in Gresham Colledge'.*, 4to, London. Edited by John Twysden and Edmund Wingate. Printed by R. & W. Leybourn for Nicholas Bourne, to be sold in the South entrance of the Royal Exchange. Bound with ***Elliptical or Azimuthal Horologiography, Circular Horologiography,*** and ***Elliptical Horologiography.***

SUNDIAL ALIGNMENT BY THE USE OF THE POLE STAR

BY C.M. LOWE

In previous papers the use of optical sighting of the pole star Polaris to align the gnomon of a sundial has been considered. The original proposal by Mills[1] has been commented upon by Taylor[2], who has shown that the accuracy obtainable would in some circumstances be inadequate. I suggest a method which should give improved accuracy. The method relies on knowledge of the angular distance of Polaris from the true pole of the sky and also of the sky and also of the position angle from the pole to Polaris relative to a nearby star.

Fig. 1 is a sketch of the necessary sighting device, which could be made from thin sheet metal. The length L should not be less than 150mm: probably 200mm would be convenient. The height H to the centres of the eye aperture E and the target T must be sufficient to allow the eye to be brought up to E when the device is fixed to the gnomon. The diameter of aperture E should be 2½ to 3mm: any smaller and Polaris will be difficult to see, and anything larger will run the risk of introducing errors due to parallax. The circular target T could be made from a metal disc (such as a washer) carried on a stiff wire. The diameter of T is to be (in millimetres):

$$0.024 \times (L+10)\text{mm}$$

where the extra 10mm is to allow for the distance of the eye behind the aperture E. If glasses are worn, allow 20mm extra. Whiten the back of the target and mark its centre with a black spot.

Fasten the sight to the gnomon (previously approximately). It is essential that the line joining the centres of the eye aperture and the target should be accurately parallel to the style, in both the up-down and transverse directions. The total error should be no more than 0°·1 or about 0·3mm over the 200mm length.

Now wait patiently for a clear starlit night! Locate Polaris and also identify the star β in Ursa Minor. As shown in Fig. 2, β UMi is the brightest star in a small triangle of stars between Polaris and the end star in the 'handle' of the Plough.

The aim is now to adjust the sundial so that β UMi, the target centre and Polaris lie in a straight line with Polaris appearing on the target edge, diametrically opposite to β, as shown in Fig. 2. One way of doing this is to imagine an ordinary (12-hour) clock-face centred on Polaris and estimate where β appears in relation to the hour markings. In Fig. 2, β lies at about 10 o'clock from Polaris (the estimate could be made to half-hour equivalents). Then sight through the aperture to locate Polaris and adjust the sundial to bring the star on to the target rim at a position plus or minus 6 hours from that of β : 4 o'clock as in the Fig. 2 example. It may help to illuminate the target with a torch. The eye will need to be focussed on Polaris and the target will appear out of focus. This is no disadvantage: the star can be centred in the apparent fuzzy target rim. Of course, if the dial is a horizontal one which has been carefully levelled, the only adjustment required will be in azimuth.

After adjustment, it is advisable to wait a few hours until the star field has rotated from the inital position, then check that Polaris still lies on the rim of the target. If necessary, refine the adjustment. The the pole of the sky will coincide with the centre of the target and the style will be parallel to the earth's axis.

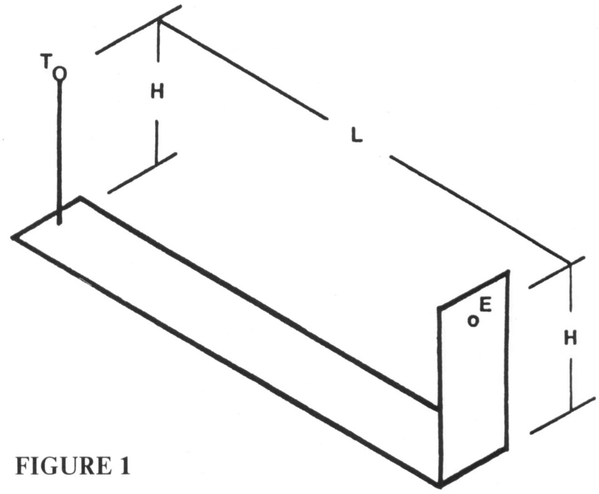

FIGURE 1

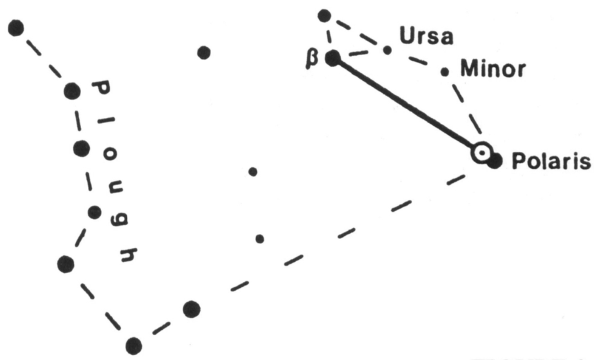

FIGURE 2

The astronomical justification for this method is that the radius of the target subtends the same angle at the eye as the distance of Polaris from the true pole and that the right ascension of β UMi is 12 hours (180°) different from that of Polaris. Because of precession this statement is only strictly true in about the year 2015, but will be sufficiently accurate (error less than 0°·15) for at least 25 years either side of this.

With care it ought to be possible to set the style to an accuracy within about 0°·25. I must admit that I have not set up a sundial in this way, but I have used the method to align the polar axis of a small portable equatorial mounting which carries a camera for stellar photography, with entirely satisfactory results.

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THE AZIMUTH DIAL

EXEMPLIFIED BY THE SCHOOL PLAYGROUND DIAL

BY H.R. MILLS

This particular type of horizontal dial, as is well known, has a vertical style, but it can be derived from the equatorial dial formula tan h = tan H sin φ, where h is the shadow angle, H is the hour angle of the Sun, and φ is the Latitude of the site. It is well known that a vertical style set up at the centre of a horizontal circle cannot properly show the Sun's hour angles, or show the time correctly throughout the year, because of the Sun's changes in declination.

A horizontal dial with a style pointing at the celestial pole, is inclined at an angle ABC = φ is shown in Fig. I. The shadow of the style when the Sun has an hour angle H, passes from C, the centre of the equatorial dial, to the point E on the edge of the dial so that angle ACE = H.

The shadow of the style cast on the horizontal plane passes through the point D, so that the shadow angle h is ABD and BAD is 90°, with tan h = AD/AB and tan H = AD/AC. By division tan h = tan H. AC/AB, but AC/AB = φ so tan h = tan H . sin φ. Hour angles can be spaced correctly at 15° for each hour only if marked round an equatorial circle. So in order to form the horizontal base for an azimuth dial, a circle of radius a is divided into 24 hour lines spaced at intervals of 15°. This circle held in the equatorial plane is then projected on to the horizontal plane to form an ellipse with major axis 2a and minor axis 2a. sin φ, where φ is the latitude of the site. See Fig II. The minor axis should be in the meridian. It will be seen that the projected positions of the hour lines drawn from the centre of the ellipse are not equally spaced as they

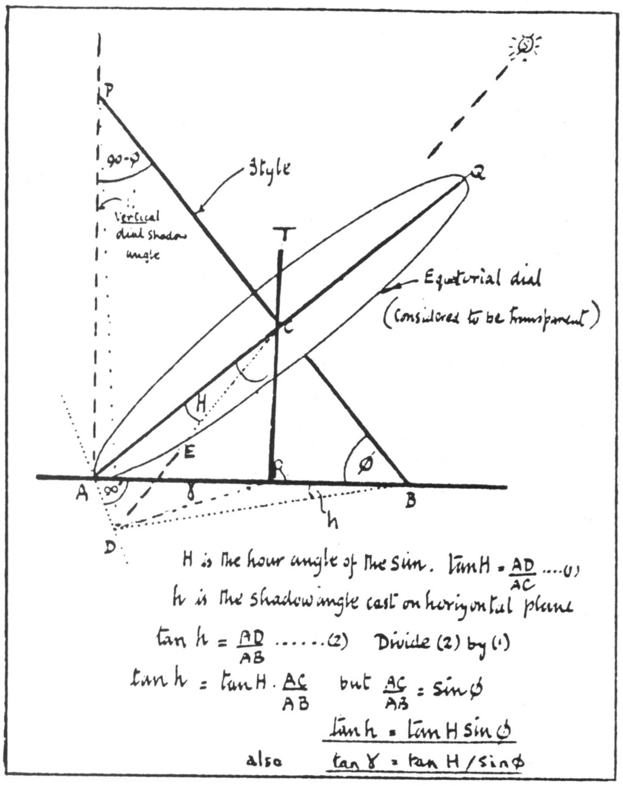


FIG I:

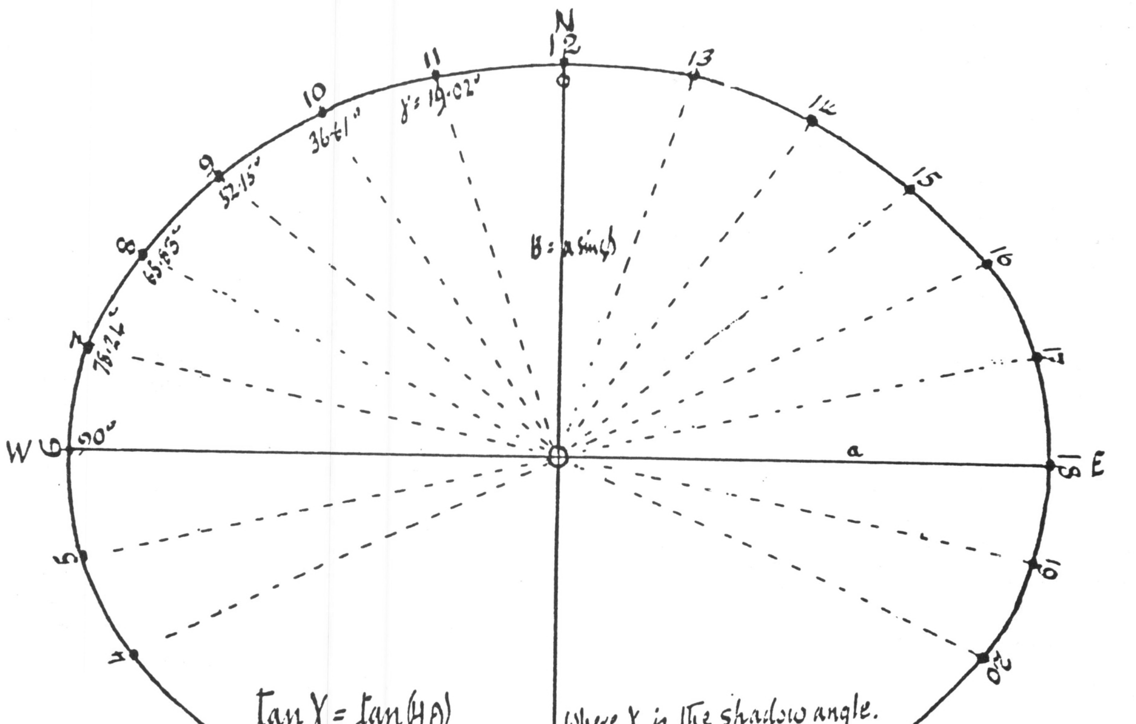


FIG II: Showing the Azimuth angles drawn for the sun when at declination 0°. The points at which these shadow angles cross the ellipse, mark the Hours of the dial.

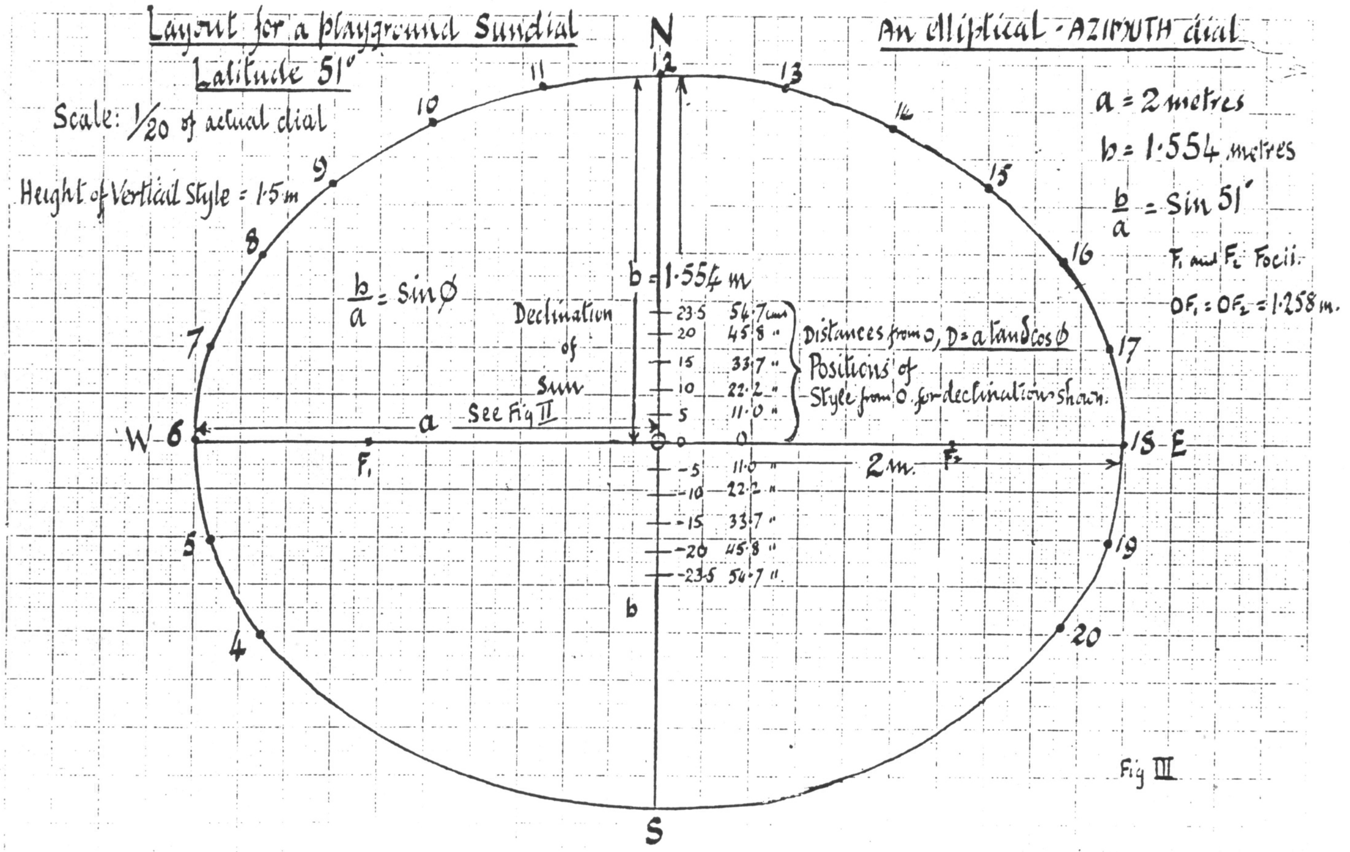


FIG III:

were on the equatorial circle. The sundial angle, or shadow angle h, measured from the North point is given by tan h = tan H/ sin φ, as derived below. These angles are shown in Fig II. The construction and marking of this ellipse provides a useful project for calculators and for understanding the properties of the ellipse. The marking out of the dial on a playground, or in a garden, can be an enjoyable exercise requiring only a few items - some twins, a tape measure, a few wooden pegs, and a small pot of white emulsion paint. It can be accomplished satisfactorily in an hour or so by three or four helpers working as a team, following the dimensions and instructions given in Fig II. It can thus occupy a junior Form with some practical and instructive activity, and a senior Form with some mathematical exercise.

The great attraction of this playground sundial is that a young person or slim adult can stand at the appropriate spot determined by the time of year, and tell the time indicated by his or her shadow falling on the periphery of the ellipse, see Fig III. We again make use of Fig I to derive the formula for the familiar horizontal dial with its style pointing to the celestial pole; but now add to the figure the vertical style RCT which passes through the centre of the equatorial circle and meets the base meridian line AB at the point R.

The following angles can now be shown, see Fig I:

The Hour Angles of the Sun H which is ACD, so that tan H = AD/AC.

The Shadow Angle h, ARD formed by the polar style BP cast on the horizontal plane.

The shadow angle γ, ARD formed on the horizontal plane by the vertical style.

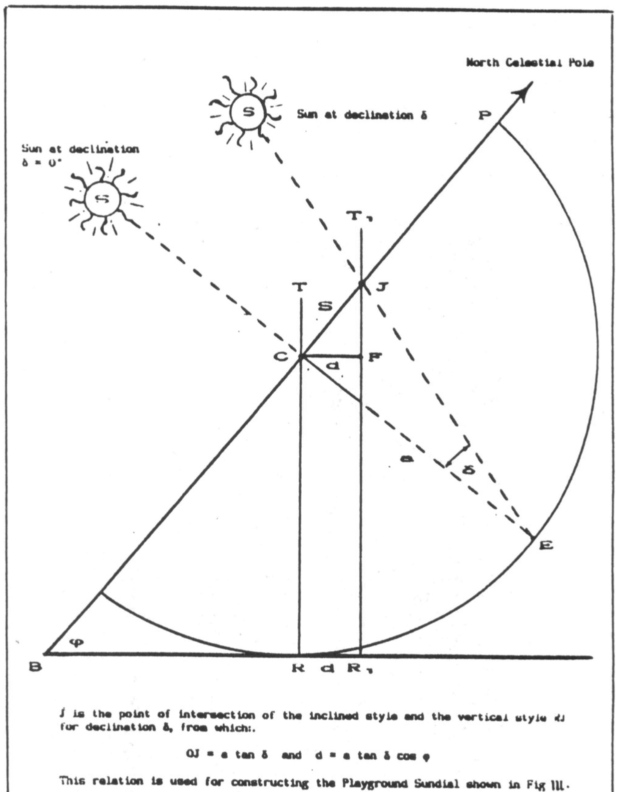


FIG IV:

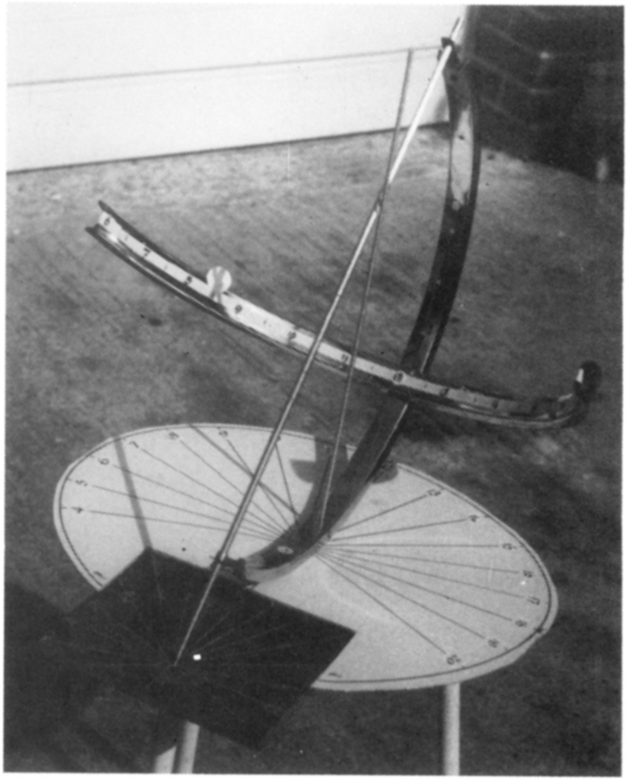
This gives tan γ = AD/AR and by division: tan γ /tan H = AC /AR = 1 /sin φ, so that tan γ =tan H /sin φ.

These angles (γ) are tabulated in column 4 of Table I, but are valid only when the Sun's declination is 0°, ie when the Sun is on the celestial equator. In Fig IV the vertical style TR crosses the inclinded style at the centre C which is at the segment of the style BP that makes a shadow at E on the equatorial rim, only when the sun's declination is 0°. The angle CEJ is the Sun's declination, and the Sun's direction EJ. Consequently for the vertical style RT to cast the correct shadow it must be moved along the meridian a distance given by CF which is equal to CJ cos φ. Also CJ = a tan δ, so d = a tan δ cos φ, which gives the necessary displacement of the vertical style for any declination of the Sun.

Table I shows the calculated times and angle for the Playground Dial, where H is the Sun's hour angle H, measured from the meridian; h is the shadow angle formed by the style inclined at angle φ, and cast on the horizontal dial at the Sun's declination = 0°. γ is the shadow angle cast by the vertical dial CR when the Sun is at declination 0° and tan γ = tan H/ sin φ.

TABLE I

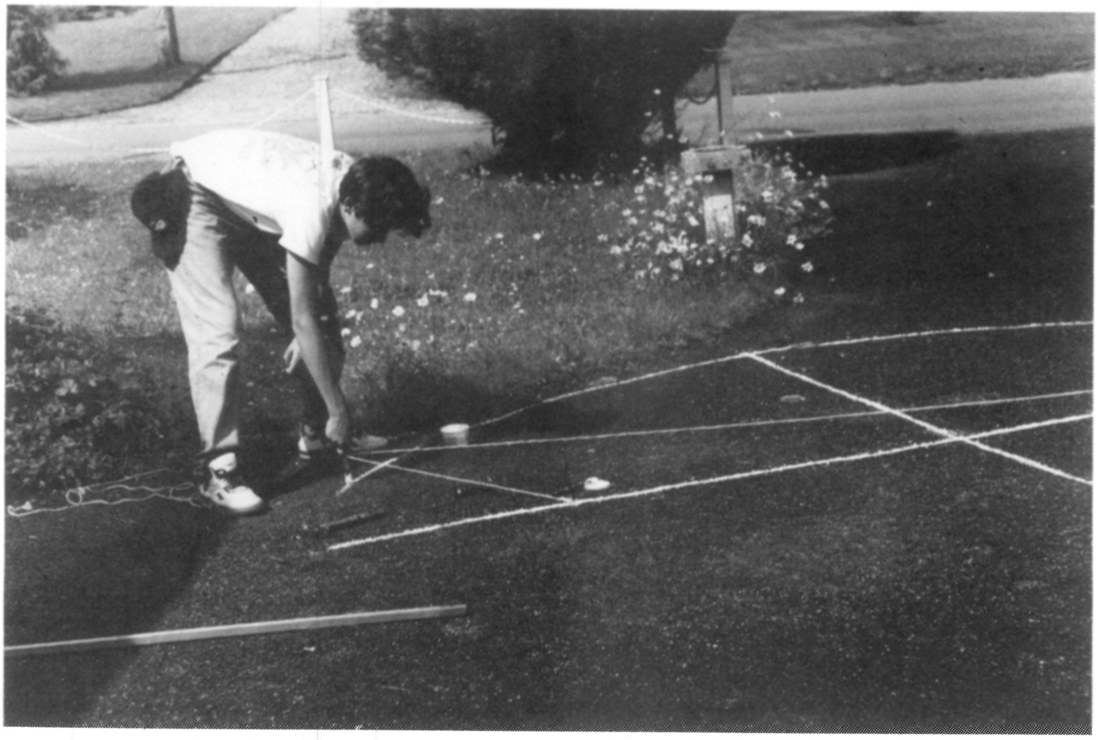
Sun time	H in degrees	h tan h = tan H sin φ	γ tan γ = tan H/sin φ
11/13	15	11.75	19.02
10/14	30	24.17	36.60
9/15	45	37.85	52.15
8/16	60	53.30	65.83
7/17	75	70.98	78.24
6/18	90	90.00	90.00
5/19	105	109.02	101.76
4/20	120	126.60	114.16



1: Photograph showing the cycle wheel rim equatorial dial, A with style PB.

It will be seen that a small cursor, such as a piece of "blue tac", stuck on the equatorial style at J so that CJ = a tan δ, will then trace out on the horizontal dial, curves representative of the time of year or the position of the Sun in the Zodiac. The lines so traced are consequently known as Zodiacal Lines.

The Sun's declination for each day of the year is given in Whitacker's Almanack, or in the Handbook of the British Astronomical Association.



2: Marking our the playground dial using the well known method for drawing an ellipse.

A SUNDIAL DELINEATOR

ALAN MILLS

The fundamental characteristic of the equal-hour sundial is a gnomon pointing at the celestial pole. In practice, a shadow-casting element of this nature may be formed by a taut wire, a sloping rod, or the straight edge ('stile') of a triangular projection. The Sun is so far away that this gnomon may be considered as not only parallel to the Earth's spin axis, but actually coincident with it. It is as if the oriented sundial were transferred to the centre of the planet. Therefore, the direction of the infinitely-thin shadow plane thrown by the wire-gnomon intercepting the effectively parallel light from the distant Sun is independent of the latter's declination. The shadow plane moves through a 15° arc every hour independently of the season of the year.

To be readily visible, this shadow plane must fall upon an opaque or translucent light-scattering surface. A plane at right angles to the gnomon gives the simple equatorial dial, while projection upon vertical planes or the horizontal produces the familiar vertical and horizontal dial patterns. However, there is no absolute requirement that the receiving surface be arranged thus, or even that it be a plane or concave cylinder: these specifications are usual simply because the resulting dials are comparatively easy to calculate and construct. A number of well-known texts explain the graphical and trigonometric techniques that have been evolved over the centuries for this purpose.

However, these classic methods have tended to limit the dial itself to a few rather stereotyped standard forms, although makers have excelled in their decoration. An alternative method of delineating the dial pattern is to experimentally simulate the movement of the Sun around the centre of the Earth, using a point-source lamp to throw a sharp shadow of the proposed dial's gnomon. So long as the latter is set at the correct latitude angle for its final site, and is arranged to be coaxial with the axis of the moving lamp, then the resulting shadow may be plotted upon a receiving surface of any form in any orientation, including those that are too irregular to be amenable to mathematical methods. Of course, the hour lines upon wavy surfaces will not be straight!

Figure 1 shows a practical sundial delineator utilising this principle. It is also portable enough to serve as a valuable teaching aid for explaining conventional sundials, no mains electricity being required. The design is largely self-explanatory and may be modified to suit the constructor, but the keys to its success are:

a) A rigid construction incorporating an adjustable polar axis.
b) A large-diameter disc to both support the moving arm and permit accurate angular calibration.
c) The employment of the tiny 3 volt krypton-filled 'grain-of-wheat' lamp currently used in a number of brands of 'mini-torches'. (Rayovac T1-2 replacement bulbs are available in card packs containing two lamps.)

It is advisable to work in a darkened room, with the delineator clamped or weighted down so that it does not tip over. The polar axis of the instrument is first set at the latitude of the intended site, and then the uncalibrated sundial (or a scale model thereof) placed so that its gnomon is coincident with an imaginary extension of this axis. Finally, the lamp is turned on and revolved on its arm at 15° intervals around the calibrated circle. The resulting shadows are marked out upon the receiving surface to give the corresponding hour lines.

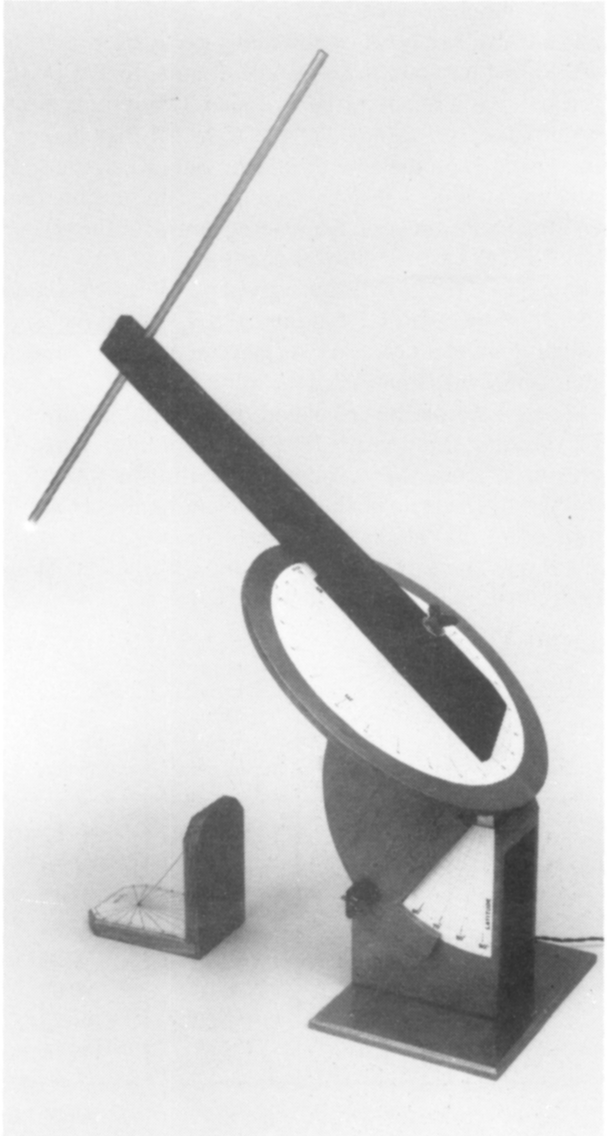


FIGURE 1: The Sundial Delineator. The Lamp Orbits at a Radius of 50cm from the Inclinable Polar Axis.

Should the hyperbolae traced out by the tip of a gnomon at the equinoxes, solstices and zodiacal dates be required ('dial furniture') then it will be necessary to mark an 'equinox' (0° declination) position for the lamp filament in a plane at right angles to the tip of the model gnomon. The tube or rod bearing the lamp may subsequently be raised or lowered by calculated distances for other solar declinations. Thus, displacement by -

$$\text{Length of arm} \times \tan 23.5°$$

will enable simulation of the motion of the real Sun at the solstices.

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SUNDIALS USED FOR NAVIGATION

BY MAURICE J. KENN

Someone recently was overheard to ask: "Of what use is the sundial in the 20th Century?"

One pertinent answer is that the sundial has been usefully adopted during much of this Century for purposes of navigation. It has been used in the air, on the land, and even at sea, especially in those situations where normal navigation by magnetic compass has proved to be unreliable.

A Bumstead "Sun Compass" was, for example, successfully used by Admiral Byrd during his flights to and from the North and South Poles[1]. Also, during the Second World War, the "Astro-Compass" formed a standard item of navigational equipment in the heavy aircraft of the Royal Air Force, of Coastal Command and of the U.S.A. Air Force. This universal instrument included adjustments for declination, latitude and local-hour-angle. It could be used with either sun-shadow measurements or direct-star sightings, in each hemisphere, and is shown in Figure 1.

FIGURE 1: A.M. ASTRO COMPASS Mk II 6A/1174

In 1929, the late Brigadier Ralph A. Bagnold, F.R.S., devised his simple "Sun-Compass" for use with "Sun's Azimuth Tables" when exploring the deserts in mechanical vehicles[2,3]. Later in 1940, he again adopted the instrument for use in the special vehicles of his Long Range Desert Group, which operated deep into hostile territories within and beyond the Libyan Desert. The Bagnold sun compass is currently on view at the Imperial War Museum. A Mark II, hand-held, Howard pattern of this type of instrument is shown in Figure 2.

Other, more complex, versions of the "Sun Compass" for use in the desert (without Azimuth tables) include those by Cole[4]. (British Patent Spec. 537,924) and by Koning[5,6]. The Cole instrument is on view in the South Kensington Science Museum. Nearby, also, is a beautiful,

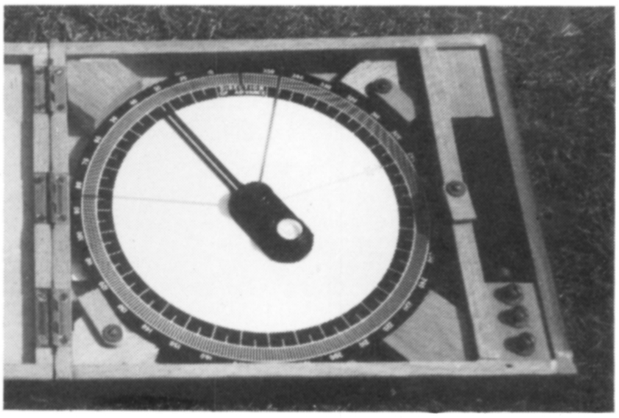

FIGURE 2: SUN COMPASS (HOWARD PATTERN) Mk II W10/VC7815 BRL.

1/4 full-size "Celestial Compass" (in silver) designed by Lt. Col. G. Graydon, R.E., and orginally presented to H.M. King William IV.

An inexpensive sundial intended for use by yachtsmen for the determination of latitude and longitude at sea was developed by Gerald Dunn of Tollesbury in 1972[7,8]. This device called a "Cruiserfix" or "Solar Navigator", was produced in plastic and is shown in Figure 3.

Other varieties of sun compasses have also been developed and include those of de Rijk[9] and Armstead[10].

This brief survey clearly indicates that, when used as a sun compass, the sundial has without doubt been of great value, during the current century.

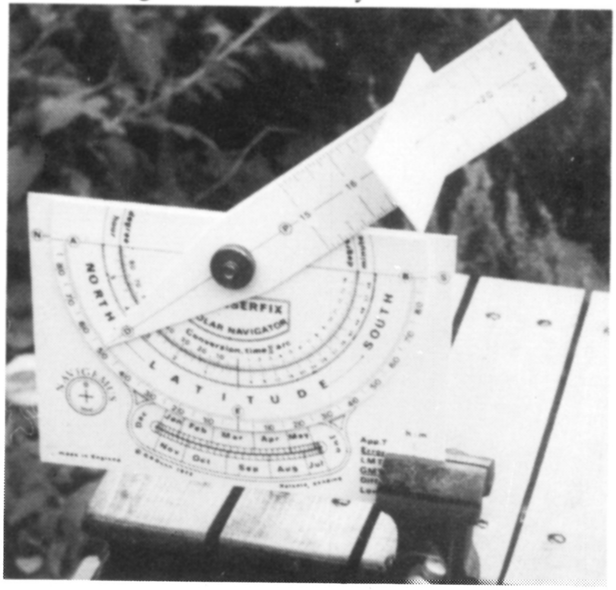

FIGURE 3: "CRUISERFIX", SOLAR NAVIGATOR, BY G.R. DUNN 1972.

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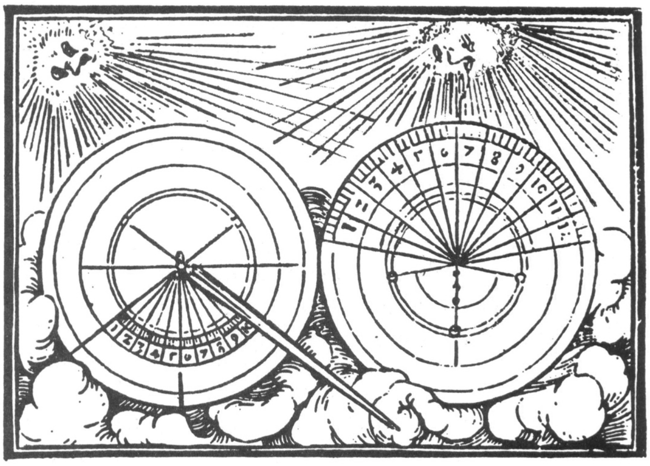
Continued on page 35

THE MIRACLE OF AHAZ

PETER I. DRINKWATER

I have been asked to comment on Holbein's picture of "two dials" illustrative of a passage in Isaiah 38 (repeated from 2 Kings 20), in which (in our received 'Authorized Version') the Shadow on the 'Dial of Ahaz' is said to have gone back 'ten degrees' as a sign from God that King Hezekiah would be healed of an apparently fatal illness. The whole reference is illusiory: the original Hebrew text does not speak of 'degrees' and 'dial' but of 'steps' and a 'staircase'; and modern archeology has established that what is here spoken of was a double staircase (back to back) down which, and up which, the shadows of two walls moved as the day passed. Specifically it is the *rising* shadow of the *declining* sun which is said to go back (as, for the king, the rising 'great shadow' [shadow of Death] goes back).

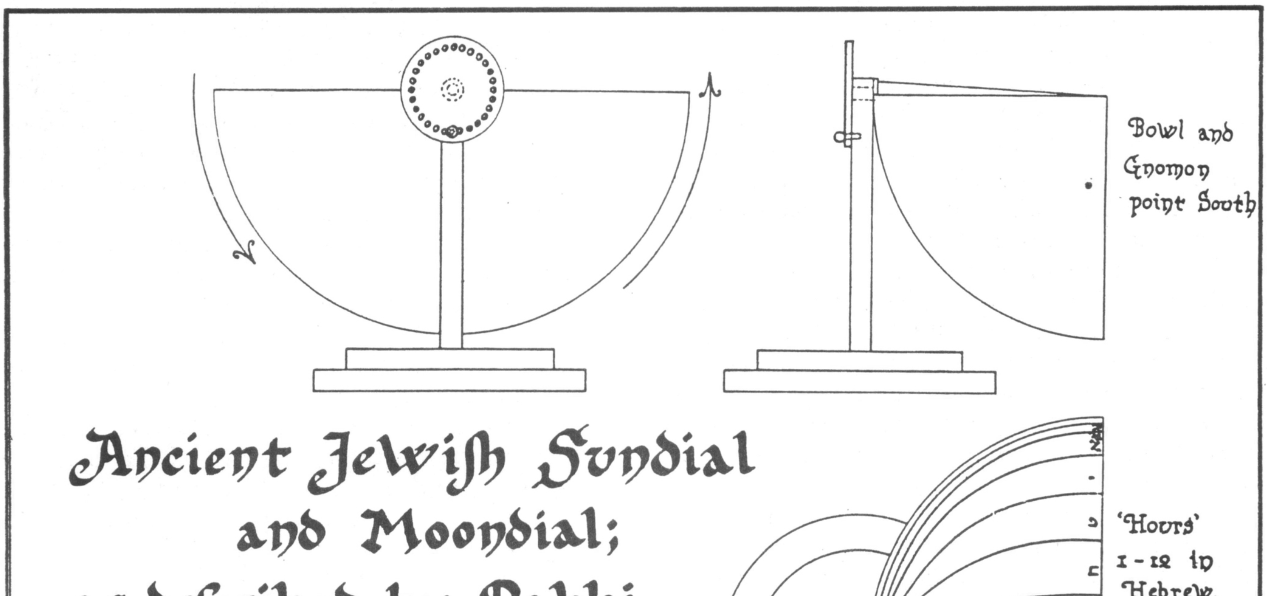
Holbein is not to be blamed for his mistaken representation, he (and other contemporary biblical illustrators) has (/have) merely followed and re-jigged the traditional mediæval MS illustration to this passage, distorted by centuries of transmission, but (apparently) originally depicting two Hemicycles (or rather the same one twice) indicating such a 'going back' of the shadow as the text specifies. The Hemicycle has become the standard, usual, sundial of the Græco-Roman (rather than the ancient Hebrew) world in which the mediæval tradition of biblical illustration has its roots; and indeed it degenerated into the familiar 'scratch dial' found on so many of our old churches. Although it is not a 'dial' of the type originally mentioned in our text, the Jews themselves did, at some time or other possess a version of



1. HOLBEIN'S ENGRAVING TO ILLUSTRATE THE MIRACLE OF AHAZ

the Hemicycle. Childmead's 1650 translation (from the French) of James Gafferel's 'Unheard of Curiosities' contains a long garbled account of an 'ancient Jewish Sundial' described, but certainly not understood, by an earlier 'learned rabbi'; which is quite clearly a form of Hemicycle, in this instance adjustable (rotatable by means of an attached circle pierced with twenty-nine holes and a wooden peg) for telling the hour of the night by the moon as well as that of the day by the sun.

Imperfect transmission of information leads to many errors and illusions, and to the loss of vital facts; and when that we are chasing is (after all) only a shadow, what is one to say or think?



PROFILE: HARRIET WYNTER

Those BSS members who are also interested in early scientific instruments will know the above name quite well, and of course sundials are amongst the earliest of scientific instruments devised by man. It is rare to find a lady in such ethereal interests however, the following account will make the circumstances clear which led her to take up such a career.

As the majority of those who know her are aware, Harriet Wynter is the professional name of Molly Freeman, born Molly Rich. Her parents, forseeing only marriage as a future career for her, sent her to a Swiss Finishing school for the final touches necessary for such an outcome, and where she perfected her knowledge of the French and German languages, plus the art of arranging flowers. Because of the Second World War she was directed to a factory on the Slough Trading Estate then producing electrical instruments for the various branches of HM Services - Taylor Electrical Instruments. Here she commenced by working on the switchboard but progressed until she was the Chief Buyer to the Company. As she says herself, she will never forget the smell of the soluble oil used in the machine shop at Taylors.

She was married after the war to Mr. L.L. Freeman and had two sons. He died in 1965, but earlier Harriet had begun a new career for herself as an Antique Dealer at 22 Ship Street, Brighton. In case it turned out to be a disaster, she did not use her own name but adopted that already on the shop, Harriet Wynter. Like many others at the time, she was forced to learn the elements of the subject as she went along, and had to rely solely upon her own taste and judgement when buying items for sale.

A turning point in her life was reached when one of her customers approached her about writing a book on porcelain, a subject about which she knew little at the time. Nor did she know how to write, and so she refused the commission until she became ill and had to curtail her physical activities. To pass the time she began to study the subject in detail and after eight years produced her first *magnus opus - European Procelain,* published in 1971 and well received by people who were in the same position as she had been when she first started to study.

Moving to new premises at 353 King's Road, Chelsea, she became fascinated by scientific instruments and the relationship between art and science. Her growing reputation led her to being a regular exhibitor at the premier Antique Fairs and eventually to being invited to show at Grosvenor House, then the most prestigious Antique Fair. She was by now a very well known figure in the Scientific Instrument world and was approached by a publisher to write about scientific instruments. This time, with her previous experience behind her, she had no hesitation in accepting the commission, but because of lack of time, asked Anthony Turner to be her co-author so that the book could be produced in time for the 1975 Frankfurt Book Fair. At that time interest in scientific instruments had not developed and in fact the US edition was remaindered, later interest in the subject suddenly expanded and sales of the book suddenly leaped. It is well sought for today and hard to find at twenty times the original price.

Leaving King's Road in 1980, Harriet moved into a Victorian house nearby from which she still conducted her business and used it as a base from which to mount her exhibitions at Fairs, etc. Like others in the past, she discovered that once having written, a Pandora's box had been opened and it is impossible to put down the pen again. Her continuing interest in scientific instruments has led to her publishing numerous catalogues and specialist works about old instruments, and she has commissioned several limited editions of replicas of early instruments that would be unavailable to enthusiasts otherwise, and also provide instruments for practical use when the originals are much too valuable to be handled even for education purposes.

She now regards herself as "sort of retired", however she is about to write a book for Sotheby's on Portable Sundials, of which she has special knowledge.

Readers of the *Daily Telegraph* will, no doubt have seen the outline of her career in the March 1980 issue. Recently she was made a Liveryman of the Worshipful Company of Scientific Instrument Makers, only the third lady in the history of the Company, a very rare honour indeed. This was under her maiden name of Molly Rich. Elsewhere in this issue will be found another facet of her versatility - the poem "What is Time?". These brief details of a remarkable career in a demanding specialization will have to suffice for the moment, no doubt we shall be hearing of further achievements in the years to come. The leaflet enclosed in this issue will give further insight into the interests of this versatile lady.

On behalf of all the members of the British Sundial Society, the Editor would like to congratulate Harriet/Molly on being made a Liveryman of the Company of Scientific Instrument Makers, it is something of which I am sure she is exceedingly proud, and a reward which has been achieved purely on merit.

CHARLES K. AKED

IMPRESSIONS OF THE BSS/ZONNEWIJZERKRING CONFERENCE

HELD AT QUEEN'S COLLEGE, CAMBRIDGE, SEPTEMBER 1991

MRS. A.D. HANNEKUYK, NETHERLANDS

Having filled in the preliminary application form to join the Conference, I really got excited on receiving the programme with "How to reach Cambridge" instructions, location-maps and so on.

We left home in the Netherlands on the evening of 18th September, taking the train to the Hook of Holland, then the boat to Harwich. Next morning we boarded the train to Cambridge, making a stop at the historic town of Bury St Edmunds to visit the Clock Museum at Angel Corner. Unfortunately all the sundials had been removed to make way for a special exhibition featuring American clocks, all that is save one situated outside the front door, with a glass globe containing water which concentrated the sun's rays instead of the usual caster of shadows.

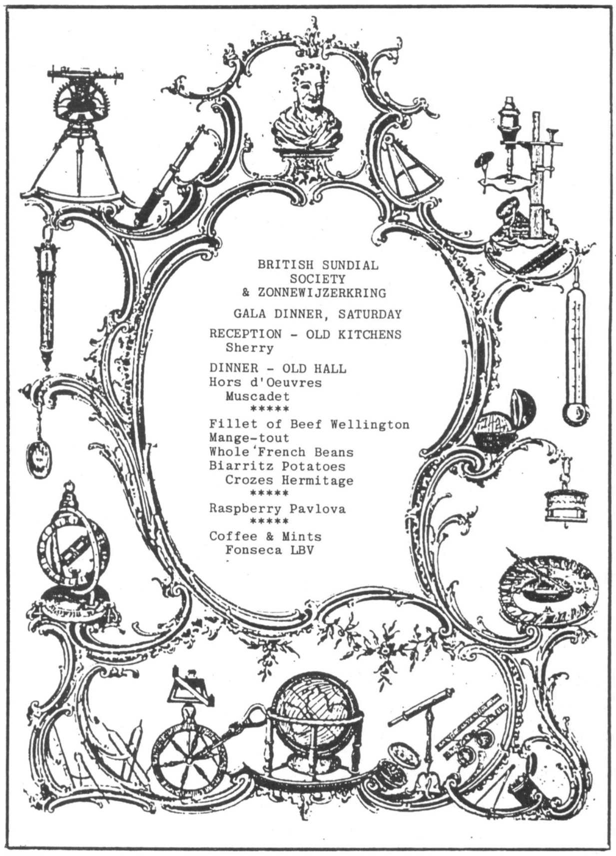
I understand that the "heart" of Cambridge is formed by the many Colleges forming the University, and the numerous churches. Queens' College (two queens, so mind the') was, so to speak a natural venue as it possesses the most interesting and elaborate sun/moondial in the city. The College itself was founded in 1448, its development being clearly visible in the various buildings. This "visible history" all around us added an extra welcome dimension to our stay!

The fourteen visitors, delegates from the Low Countries, stayed in the College since the students were still enjoying their summer vacation, and many of the British participants also. We had our meals, including the famous "English breakfast", in the New Hall (1979), a huge hall which can seat up to 350 diners. As we were only about seventy-five sundial worshippers, the hall swallowed us up in a corner.

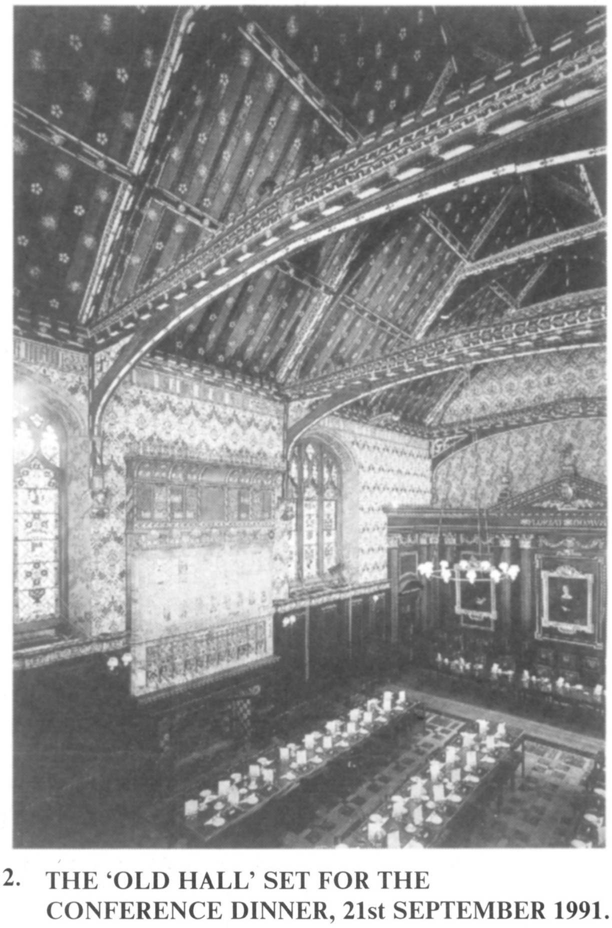
On Saturday evening, preceded by sherry in the "Old Kitchens" of 1449, the Gala Conference Dinner was served in the beautiful and ornately decorated "Old Hall" of the same period. This was a delightful occasion and a most appropriate place to have a "farewell-party". I only wish that all the members of both societies could have seen this magnificent 15th century Hall, with set tables, the candle lit scene and the fire in the enormous hearth of the decorated fireplace.

The Conference lectures were held in the Bowett Room of the Conference Centre. Here several people had placed models, pamphlets, maps, instructional books and other items on display. Following the preliminary welcome to the assembled delegates by Mr. J. Millekamp Chairman of Zonnezerkring; and the BSS Chairman, Mr Christopher St J H Daniel, and the official opening of the Conference; Mr Hans de Rijk gave his address on the split-gnomon dial. With the help of slides he demonstrated how the angle Zenith-Sun-North Pole varies with the solar time. It turned out that this angle is relatively easy to measure with a forked gnomon. In this way he developed a new type of sundial, of which he demonstrated his prototype.

The first morning ended with a visit to the Royal Greenwich Observatory. To the surprise of the Dutch visitors, the Observatory has been moved from Hurstmonceux to Cambridge on a spot adjacent to the University Observatory. One of our Dutch members had tried to visit Hurstmonceux a few months previously, only to find the gates closed and no trace of the Royal Greenwich Observatory to be found. As the observational



1. THE MENU CARD FOR THE CAMBRIDGE 1991 BSS CONFERENCE GALA DINNER.



2. THE 'OLD HALL' SET FOR THE CONFERENCE DINNER, 21st SEPTEMBER 1991.

work is now done in the Canary Islands, the newly installed Observatory does not look as interesting as it used to do in the old days. The computer and calculation work is now done in a large office building. Fortunately the Northumberland Equatorial Refracting Telescope of 1833 still stands in its dome in the University grounds, one can only admire the beautiful work; the old instruments are real works of art. And it is still in use today! Mr Gordon Taylor demonstrated to us his equiangular sundial with its moveable gnonom. As this instrument was made for installation at Hurstmonceux, it is now slightly out of place in Cambridge.

A tour of Cambridge sundials was made on foot in the afteroon of 20th September, the conference members being divided into two groups under the leadership of Mrs Margaret Stanier and Mr Brookes respectively. They are the co-authors of the booklet *Cambridge Sundials* (reviewed in BSS *Bulletin* 91.3, pages 27/28), a copy of this being enclosed in the yellow wallet given to each conference member on arrival on Thursday morning, together with data sheets, writing paper, and a pen engraved "British Sundial Society - Dedicated to the Art of Shadows - 1991 Conferences Edinburgh and Cambridge"!

We were shown about fifteen sundials, some of them just around a corner, where you would not expect to find a dial. I will mention but a few here: Peterhouse, Magdalen College - a modern one with an Equation of Time correction in its design; the Downing site 17-face sundial which saved the lawn from being turned into a car park; the six-faced Gonville and Caius College 'Gate of Honour' monumental sundial encased in scaffolding for repair work; and finally the dial which stole my heart: the ancient scratch dial on one of the buttresses of the church of Little Saint Mary.

The weather throughout the period of the Conference was beautifully sunny, it was a joy to see the City of Cambridge on this late-summer afternoon, with the lovely gardens laid out in the historic college grounds. A must was a visit to King's College Chapel, we have seen it so often on television at Christmas; that to see it in reality was another profound and moving experience.

On Saturday morning two interesting lectures were delivered, the first one by Mr Fer de Vries entitled "Gnomonics". In this he described a mathematical procedure to calculate the declination and inclination of any flat surface, this being the reverse of the normal method of the lines of a sundial on any flat surface, and very suitable for use with a computer-run program. Mr Gordon Taylor followed with his "Theory of Moondials", showing that is practically impossible to realize a moondial because of the many variations in the orbit of the moon. A simple correction table based merely on the age of the moon therefore is not particularly accurate.

The morning ended with workshop sessions where the conference delegates had the choice of the following four areas of dialling.

1. Dial making by computer, Mr Fer de Vries.
   Practical demonstrations of the program mentioned earlier were given.
2. Scratch Dials, Mr David Young.
   The Saxon dials before the Norman Conquest in AD 1066 were better made than those introduced by the French invaders. Its is planned to form a group for this aspect of dialling and to record scratch dials more systematically.
3. Portable Sundials, Mrs Harriet Wynter.
   Delegates brought dials for a group discussion.
4. Education, Mrs Jane Walker.
   I did not learn the details of this session, but throughout the Conference there was news of the introduction of sundial knowledge in British school curriculums. A great idea, see the BSS publication *Make a Sundial.*

Following lunch, delegates made their way to the Whipple Museum of the History of Science, passing the fine two-faced dial on St Botolph's church on the way. This museum has a newly arranged display of the most comprehensive collection of measuring instruments of all kinds, nicely laid out in well lit cases. the catalogue of sundials and related instruments lists 388 separate items!

3. THE GATE OF HONOUR, CAIUS COLLEGE, SCAFFOLDED FOR RENOVATION.

The last speaker of the conference was Mr Jan de Graeve on the subject of Francis Hall's dial installed by the King's Garden in Whitehall, London, in 1669; first described in 1673. It was a multi-faced sundial with over 200 separate dials - "very many dials being new inventions hitherto divulged by None". (It is described in full in BSS *Bulletin* 90.2 June, 1990, pages 19-25, complete with an illustration of the composite monumental dial), **Editor** - but Mr de Graeve added many additional details in his account.

In the morning period Rogers Turner Books had a stall for the sale of their wide range of dialling literature, reading for Dutch members is much easier than writing or speaking in English. The older works were mainly in the French, German or Italian languages.

Now that the Conference is over, I am sure that all the participants can look back on a most enjoyable time. It was a real privilege to take part in the Conference, and to be resident in Queens' College. Many thanks to the College Staff, in particular to BSS organizers Mr Mike Cowham and Mrs Anne Somerville, as well as the lecturers. Speaking on a personal note - it was all just perfect.

CAMBRIDGE 1991 LECTURE
DIALLING LITERATURE
BY CHARLES K. AKED

The great horological historian, Granville Hugh Baillie, produced in 1951, after a lifetime of effort and purchasing books on clocks and watches; a bibliography of time measurement up to 1800. No direct reference to sundials will be found in his book, for the reasons given in his preface:

I have ignored dialling - the art of making sun-dials. Its literature is enormous, particularly in the eighteenth century. It is a simple art, but the older books make it appear complicated. Some small modern books have been written explaining the art simply and clearly and, in comparison with these, the older books are without use or interest.

If this were truly so, then there would, of course, be no reason for me to stand here to talk about dialling literature. It is a little like the assertion that there are no uninteresting numbers in the series zero to infinity, since to find an uninteresting number would then itself be of great interest.

Nevertheless it is curious that a complete bibliography of dialling references has never been attempted by any person. In the case of Baillie I believe that, especially as he left his listing of the last century of horological literature up to 1900 unfinished; that the sheer volume of work necessary to compile such a listing was too much for him to attempt. He had spent fifty years working on his published list, containing a fraction of the references in comparison to the dialling references in those centuries that he covered. Besides, to whom would such a bibliography be addressed since there were very few diallists in England?

Every now and again I have what I consider at the time to be a brilliant idea. One day I thought it would be a good thing if I listed all the dialling literature I had because every now and again I got enquiries about such matters and it is infuriating to know that there is something published but you cannot remember just where. Anyone who has spent a whole fruitless day looking for an obscure item knows what I mean. Unfortunately, in spite of Baillie's words, I did not really appreciate the extent of dialling literature, nor did I have the specialized knowledge to deal with its collation that I possessed in connection with mechanical horology. To be authorative, every item in a bibliography should have been examined personally, together with all editions and compilations, and all the essential details of each collation recorded faithfully. Again Baillie in his preface explains why he could not himself produce his own bibliography in this proper form:

I had hoped to read, or at any rate examine, nearly all the books and manuscripts I have mentioned but, since the war, this hope has dwindled. Travel has become too difficult (Baillie was then in his late seventies), and sending a pound or two to a foreign library for photostats has become a major financial operation. A material proportion of the books and manuscripts are not to be found in any English public library, and the work has been possible only because I have, for many years before the war, collected books on horology. Having seen a remark by an eminent bibliographer that "a bibliography which ignores articles in periodicals is a one-eyed leader of the blind", I have searched diligently for the hiding places of these shy writings.

The rules to be followed in a bibliography ... have been laid down by bibliographers. Very few books on clocks and watches come into this category. What interest they may have is in their contents.

These prefatory remarks apply even more forcibly to works on dialling, so after a short period of heart-searching it was decided to have author, title, (with a translation into English for the foreign titles), place and date of publication, with a few brief remarks where personal knowledge allowed it. Because of the limitations imposed by the word processor used, a first listing with a maximum of one thousand entries was embarked upon. To put this in perspective, the authority Professor Willis I Milham in his book - *Time and Timekeepers*, which was published in 1923, mentions that he thought there might be as many as 300 books and articles *in toto* on dialling. There are probably ten thousand such references since I have uncovered about four thousand without too much difficulty. However one day I happened to look at the date and discovered that several months of continuous application had passed by whilst I was finding and feeding information into the computer without seeing a word in print. I printed out the first one thousand entries and this alone took two days of solid printing and several ribbons at £5 each. The rest remains on disk awaiting a more favourable climate of opinion in regard to these ventures. It is cheaper to distribute the information in disk form than the printed version and a copy can be made at a moment's notice, and continually upgraded.

Even today, in spite of all the advances in computing, it is much easier to consult the written word than to try to glean the information from a screen. It is true that with the right kind of program, it is possible to manipulate the information in many ways, but this also requires that all the information is keyed into the computer in a compatible form. However, at the time I did not have such a program and so I decided upon an alphabetic listing of the authors' names to provide the focal point in locating a given reference, together with a chronological index. It is hardly possible to collate a subject index except in the most general way since most dialling books are based upon the same fundamental basis. So my listing is not a bibliography except in the elemental sense and so I christened it "An Opusculum of Dialling", with the subtitle 'A Preliminary Checklist of Dialling References'; using opusculum in the sense of a minor or subsidiary work. This minor work quickly became a major one.

Commencing with the literature I had myself, it seemed that the limit of one thousand entries was so far away that it was not a practical restriction, and it is well known that angels fear to tread where fools rush in. Of course many of the books themselves had bibliographical lists, and often there are footnotes giving details of obscure items, so like Topsy, things just grew and grew. One of the things which was annoying was that foreign titles were seldom translated into English, fine for polylinguists but not for the average diallist, so I therefore decided to give the English translation wherever possible, not an easy matter when titles may be in Greek, Latin, Dutch, French, German, Italian, and Spanish, and so on. I balked at Scandinavian, Polish and Hungarian titles, however half a loaf is preferable to no bread, so the shortcoming in accuracy of rendition may be excused, as often there is no direct equivalent in any case.

Since dialling has not had a platform of its own until the comparatively recent formation of Sundial Societies, most of the articles that have been published are to be found in all kinds of both learned and popular journals, especially archeological journals dealing with ancient examples. Often these obscure pieces can only be discovered by serendipity, as for example when searching for other things. A search of all the newspapers published in the period of Queen Anne's reign produced only a few mentions of sundials, almost impossible to find except by pure chance or the most minute examination.

One of the earliest writers to compile a list of dialling works was J Alexandre in his *Traité Général des Horloges* of 1734. (General Treatise of Clocks). His catalogue is a useful listing of the older dialling treatises. Houzeau and Lancaster in their monumental work *Bibliographie Générale de l'Astronomie* list about one hundred entries prior to 1886 under section 34 headed "Gnomoniques"; whilst Löschner in his *Sonnenuhren* mentions a total of 77. Herman Bush of Hull published a bibliography in the *Horological Journal* in serial form from June to October 1878 which included some dialling works, from which Löeske in Germany produced his *Die gessamte Literatur über Uhrmacherei und Zeitmesskunde,* (The Complete Literature of Horology and Time Measurement), which contains just over one hundred entries on dialling. Professor Willis I Milham has already been mentioned and he gives a very good dialling bibliography in his book. However Tardy in France with his *Bibliographie Générale de la Mesure du Temps* (General Bibliography of Time Measurement) is the largest listing with about 336 entries under the heading of "Gnomoniques" in the first edition of 1947, with an addendum in the later edition of 1980. The dialling references are mixed up with the general list of entries and so are not easy to consult with the constant going back and forth from list to entry. Furthermore, Tardy's accuracy leave much to be desired.

One of the characteristics common to dialling and horology is the constant copying of texts over and over again. One may be deluded into thinking that some statement is correct because several works corroborate the information. This is only natural if one writer has taken his words from another. Again one might be led into thinking there are several works because selected parts of a title may be used and authors' names given in the Latin or other form. In fact most of the early dialling titles are so long that they are rarely rendered in full since they would require many lines of text, and thus be impossible to use in a large bibliographical listing.

What then is the use of a bibliographical listing? It is merely the pointer to the original references. If for example, it is required to know the printer or publisher of a particular work, or some other detail, it is necessary to consult the original work or one of the sources mentioned earlier. Such information is of little interest or use to a diallist unless he is a book collector with more interest on these as books rather than the contents. The researcher will need no reminding that accuracy dictates consultation of the original sources where this is possible, many of the more modern references consist of subjective analyses and observations, more or less biased by the knowledge of the investigator or his personal opinions. No two researchers see the data in the same light.

Again most of the older books are of more interest for the mode of presentation and illustration rather than the treatment itself. If in Latin, or the Gothic text of older German books, they will be beyond the understanding of most diallists today. Even the older English books are terribly difficult to read unless you are familiar with the older presentation of the written word and the many abbreviations employed, and as the older authors specialized in making simple things difficult, these too are not for the modern dialler except for being made aware of the mode of presentation in former days. There was no standardization of mathematics as we know it until the seventeenth century when William Oughtred introduced algebraic signs and shortened means of presenting formulae. Mathematics was not taught as a university subject, nor such things as dialling although many famous men followed these subjects in their student days, such as Christopher Wren who had private tuition from famous mathematicians such as William Oughtred in his home. Yet surprisingly universities often had sundials upon which some student had practised his growing skill in the application of his mathematical knowledge to a practical objective. Oughtred himself wrote a number of pamphlets on sundials and wrote a paper whilst a student at King's College, Cambridge, entitled "Easy Way of Delineating Sun-Dials by Geometry" but did not publish it until about fifty years later. It was translated by Christopher Wren into Latin when he was at Wadham College, Oxford, as *Horologiorum Sciothericorum in Plano.*

Naturally the mathematics in the older works may be extremely difficult to follow by the modern reader unless he is prepared to study it closely. Of course the expansion of scientific dialling from the sixteenth century onwards was dependent upon the progress of mathematics, and it was only after 1500 that dialling works began to make their appearance in any number. Many dialling books were printed over and over again, sometimes covering many decades or even as much as a century, appearing long after their author had departed this world.

Until the advent of printing in Europe in the mid-fifteenth century, and in England about 1470 by Caxton at Westminster for pamphlets, nearly all the information on dialling was either locked up in the surviving artefacts themselves or in manuscript form. Louise Perron, in a book entitled *Essay on the abridged history of timekeeping comparing the division of time by sundials and clepsydras since 740 BC* published in 1830, attempts to cover this ground. Of course modern diallists today do not consider the water clock, but before the invention of the mechanical clock the clepsydra was the important complement of the sundial in providing time through the night or when the sun did not shine. Instruments using the stars for determining time also are dependent upon clear skies but in the birthplaces of astronomy where these instruments evolved, clear skies are the norm. When the use of these instruments spread to Greece and later Italy, water clocks became essential to complete the time measurement system because of occasional days when the sun could not break through.

From the scrolls written before the birth of Jesus Christ and later texts which formed the Bible, come the oft-quoted references to the Miracle of Ahaz involving the return of the shadow on a sundial, and quotations such as "Are there not twenty-four hours in the Day", these dating possibly to about 750 BC.

About AD 150, Ptolemy of Alexandria produced his Almagest, his great work on astronomy, in which he propounded that the earth was the centre of the Universe and the Sun revolved around it. Fortunately for diallists this concept is still perfectly satisfactory, and so we are the few members of the human race still sticking to Ptolemaic principles. There are references to sundials in this work.

The sundials introduced to Britain by the Romans seem to have left no written record at all, probably merely because such records have vanished. A few examples of actual dials have been found. The Venerable Bede who worked circa AD 672-735, refers to timekeeping and the methods of achieving it in his famous "History of the English Church and People". One would have thought that Bede might have mentioned the Cross at Bewcastle with the famous sundial which by general concensus and little actual proof, has been accorded the date of AD 670. However absence of evidence does not prove anything although some modern writers have tried to employ this method.

Moving on to the Norman Conquest, we have the evidence of Saxon dials immediately prior to this event such as that at Kirkdale, which is credited with having the largest section of the Anglo-Saxon language of the time carved into it. It shows evidence of the transition from Scandinavian runes to what was to become the foundation of the marvellous English language and it is not easy to decipher, however it records the names of two men who are the first known in English dialling, namely, Brant and Haward, and these names are recorded in "The Anglo-Saxon Chronicles", the history of Britain up to AD 1154. Elizabeth Okasha produced a little work entitled *Handlist of Anglo-Saxon non-Runic Inscriptions* in 1971 (published in Cambridge), which deals with the Anglo-Saxon words found inscribed on early sundials of English provenance.

Surprisingly, in view of the great impact of the Normans in their enormous building programme after the Conquest, and the large number of churches built by them, there is little recorded of their dialling activities. These invaders left behind a legacy of scratch dials which have puzzled many diallists since they were so at variance with the Anglo-Saxon dials preceeding them and no one ever succeeded in producing a time system into which they would fit. It is now accepted that these primitive devices were merely event markers for the use of church masses and not time markers. Yet not one single word has been found on these remarkable markings at the time when they were being cut into church walls all over England, and we are at a loss when we find many of these cut in close proximity into the same church wall.

If we move on to AD 1391 we meet Geoffrey Chaucer, one of England's greatest writers in the medieval English language who wrote *A treatise on the Astrolabe,* addressed to his little son Lowys. Anyone who reads the preface to the edited version by the Reverend Walter W Skeats cannot fail to be impressed by the scholarship and the research into how this important work was written and how it was produced to make it available to learned men. There are about twenty copies of the manuscript known, and not surprisingly, in view of the fact that each copy had to be made by a scribe, generally who was quite ignorant of the subject, each copy has its own peculiarities, and Chaucer's manuscript has been reproduced over and over again even in modern times.

Chaucer commenced this as a result of being asked by his son Lowys if he might learn something about an astrolabe, the father sent him a small astrolabe constructed for the latitude of Oxford. Believing that the Latin treatises were too difficult for a child, Chaucer "Englished" the more important parts and modified these to make it easier for a child to understand. He himself makes it clear that he has only taken his knowledge from others, and in fact he made great use of a Latin translation of the Arabian astronomer Messahala who wrote at the end of the eighth century a manuscript with the title *Compositio et Operatio Astrolabie,* of which there are many copies in University libraries. This then was the pattern of most dialling works, the extraction of relevant information from previous texts arranged to suit the tastes and abilities of the new compiler.

A most fortunate discovery was made in AD 1485 when a manuscript copy of the long-lost work of Vitruvius was discovered in a monastery. The original had been written in 90 BC and it was a comprehensive treatise on architecture in ten books, in which Chapters 4 and 7 of Book IX deal with the subject of gnomonics. It is the only contemporary work describing the dials of the ancient world and some of the described dials have never been identified among those surviving to today. It is curious too that when he describes the "Tower of the Winds" in Athens, then newly erected, he mentions such things as the bronze weather vane on the pinnacle of the roof, yet not a single word is included about the sundials cut on the eight marble walls of the tower, although these were a complete departure from the normal hemispherical sundials then in use. The weather vane was a brand-new invention, the water clock was unique amongst the many to be found in Athens, but it seems a strange omission to leave out mention of this and the dials which seemed a new innovation also. When I visited the site I would have assigned a later date to the dials except that I discovered one previously overlooked which was a composite one cut into the circular wall of the water reservoir. As this was in the shadow of a Roman building erected about one hundred years later and overlapping the foundations of the tower, it would have been completely useless to cut such a dial where no rays of the sun could penetrate; so I had to agree with the late Professor de Solla Price that the dials must have been part of the original tower erected about one hundred years before the birth of Christ. There is a magnificent article in the National Geographic Magazine of April 1967 by Professor de Solla Price on the subject of the Tower of the Winds, which if I had been aware of its existence, I would not have attempted any research into the subject. In fact he was not pleased with me until he found that my work, which agreed with his findings, was quite independent and written in complete unawareness of his article. But who would expect to find an article including references to sundials in a book devoted to geographical articles?

If we look at Oronce Finé's work "Of the Sundial and Quadrant" which was published as part of his *Protomathesis* of 1532, the title page "Solaribus Horologis et Quantribus Libra Quatuor" is dated 1531. The later edition of 1560 is the date generally quoted for this work when it appeared as a separate book, by which time Finé was dead, and it was only a few years ago that I realized that the illustrations used in this work, for which Finé was highly praised, were not in fact the original but copied. I persuaded Mr Drinkwater to produce an English version of part of this work a couple of years ago, which was published and a copy given to each of the delegates to the first British Sundial Society Conference held at Oxford March 1990, so I will leave my listeners to consult that for more details of the work. Suffice to say that Mr Drinkwater discovered several substantial errors in the work, none of which had been commented upon in the last four centuries. The most obvious was that of Proposition VIII in which Finé made a real botch of a composite dial, and which Mr Drinkwater brilliantly restored to the correct appearance.

England rather lagged behind Europe in the art of dialling and indeed depended on the Continent for both literature and diallers. Henry VIII employed Nicholas Kratzer for his astronomical and dialling interests, and Kratzer never learnt to use any other than his native German. Hans Holbein the Younger, a wonderful artist greatly esteemed by Henry, immortalised Kratzer by portraying him with some of his portable dials; the same instruments may be seen in the large painting in the National Gallery known as "The Ambassadors". There is a manuscript by Kratzer in Corpus Christi College, of which he was made a member, Ms number 152, circa 1520, which contains several drawings of sundials. Those of you who possess the 1900 edition of Mrs Gatty's *The Book of Sundials* can inspect some of the sample pages of Kratzer's text which are included. In spite of the eminence of Kratzer, he does not appear to have made new contributions to dialling and he himself stated that he obtained his information from an old manuscript in a Carthusian monastery. His work was described much later by Robert Hegges. Kratzer may be regarded as the first of those who later called themselves mathematical practitioners, who combined making instruments with instructions how to use these and teaching the principles of dialling to fee-paying pupils. Often, upon the retirement of the practitioner, he would use his course notes penned and amended over the years to produce a book. The pupils usually set out to compile a collection of notes themselves although often resorting to the copying of a well-known dialling work. Possibly this was as much to gain knowledge as to save the expense of purchasing the work. Hundreds of such dialling compilations must have been made by pupils, most of which have perished. Those that survive can usually be traced back to a particular author. Some mathematical practitioners insisted that their book be purchased as one of the conditions for taking the course.

In 1531, Sebastian Munster had produced his famous work on dialling under the title of "Dial arrangements for plane, wall, annular ring, cylinder and different quadrants", from which Finé had either extracted some of his information or had possibly made use of the same original material, complete with the errors. Munster was a professor of mathematics at Basle University, and again he derived his information from earlier sources, importing errors in the process. Whether the two ever collaborated is not known, but although Finé contributed little of his own to the dialling text, he produced some outstanding engravings for the period, and these are still used today for illustrative purposes.

The latter half of the sixteenth century saw the publication of many books on dialling, of course these mostly originated on the continent of Europe, mainly in France, Italy, and Germany. One of the well-known works is that of Johanne Stöeffler, "The Explanation, Making and Use of the Astrolabe", the first easily understood work on the astrolabe. It was written in the universally used Latin text for learned works. Although Chaucer's work is in English and written for a child, most of us today find difficulty in understanding it.

By the end of the sixteenth century the Jesuit Christopher Clavius produced a series of dialling works, mainly published in Rome and with Latin text, culminating in his *Gnomices de Horologiis* which was by far the largest book on dialling produced in the seventeenth century, published Rome 1612.

The first dialling book printed in England was written by Thomas Fale and entitled *Horologiographia.* The Art of Dialling: teaching an easie and perfect way to make all kinds of Dials upon any plane however placed . . ., first published in London in 1593. The woodcut figures were produced by Jacobus Hondius, the fourth and last edition appeared in 1652. It is a highly prized book today.

With the proliferation of those making instruments and portable sundials, and those who actually delineated sundials to order, more and more treatises appeared in England. Among these may be mentioned Samuel Foster, Edmund Gunter, and William Leybourn; the latter produced many dialling books, commencing with *The Art of Dialling* in 1669. Originally a printer, Leybourn gave this up to become a mathematician and dialler. His treatment is performed in three ways, geometrically, arithmetically, and instrumentally; thus catering for all modes of delineating dials. Apart from the vagaries of the presentation of the text then popular, Leybourn's treatises are very clear, by 1700 his work had reached 191 pages and included mechanical dialling as well. Alas the paper for these editions is less than good and my copy is browned in places. This edition includes the supplement describing the ill-fated Pyramidical Dial designed by Francis Hall, singularly unsuited for placing in a garden where the public could enter and had already destroyed earlier stone dials weighing five tons.

One could list further outstanding dialling books for the next few hours, however those who are interested in knowing more of these had better purchase a copy of my listing, when available, for the actual cost of printing.

All the earlier encyclopedias contain sections devoted to dialling, and excellent treatments are to be found in *The Encyclopaedia Britannica* and Abraham Rees' *The Cyclopaedia;* or, *Universal Dictionary of Arts, Sciences* *and Literature* ... which contains excellent engraved plates showing all the usual dials. This latter which first appeared in 1820, has had the dialling section reprinted twice in recent years by the publishers David and Charles.

Again those interested in such areas as Scratch, Mass, Canonical or early Anglo-Saxon dials must search in archeological or country journals. The main interest is in the information about the examples and siting, most of the theorising is of no value whatsoever since most of the effort is directed towards trying to fit these sad relics into a modern time system which did not exist at the time they were cut into the stone. Quite often a well cut example illustrated only 50-100 years ago cannot be found today, sometimes even the church itself has disappeared. Examining a mass dial recently, I found that what was quite clearly delineated 20 years ago had vanished and someone had crudely scratched the remaining lines deeper and spoilt the whole thing. At St Peter's, Tankerton, the stone of the porch had been dressed quite recently and the ancient scatch dial almost obliterated. Not even the most ancient mass dial has the slightest protection afforded to it and I marvel that some are supposed to be almost a millenium in age. If you examine the old engravings of Bewcastle Cross, and then look at the actual cross, you are disappointed at the degradation which is taking place.

Engravings are, of course, the only source of some long-lost dials, for example that at Settle in Yorkshire. The majority of old sundials today are but the bleached skeletons of what once were maintained by regular painting. Paint cannot survive more than about 10 years of exposure to the elements. An inspection of the Corpus Christii sundial will reveal that much of the paint is peeling from the stonework and this was specially treated and repaired before the restoration of only a few years ago.

Of course it is of little use in preparing long lists of dialling works if one cannot obtain copies of the books or articles themselves. Unfortunately the material is scattered far and wide with just a few concentrations of dialling works such as the notable collection gathered by Gunter in Oxford and now in the library of the History of Science Museum. This is probably the most substantial collection in conjunction with the other dialling works acquired by the museum from other sources. Most of the universities have early manuscripts on the subject of dialling, and the British Museum Library contains much unresearched material. It is a very wearying task to deal with these old manuscripts and generally it is much better to obtain microfilm copies so that they can be studied at leisure, as and when the mind feels in the right sort of mood. I have never found conditions to my liking in any library, and it is inhibiting under constant surveillance to be handling documents many centuries old, conscious of their fragility and importance.

There is another way out, of which I am indebted to Frederic Sawyer III for the information. University Microfilms International have a list of dialling works which can be supplied as xerographic copies on acid-free paper and binding in the original format and soft or hard binding. The cost is about four pages to the dollar, minimum charge 20 dollars per book, plus despatch costs. This is not particularly cheap but naturally cheaper than purchasing the appropriate book, even should it be available. For example the first edition of Fale in 1593 would cost about £50-60 in replica, whereas the original might cost £1,000 or more. Theatrum Orbis Terrarum of Amsterdam also reproduced a number of early printed books in facsimile in their series "The English Experience", for example number 465 is the *Description and Use of His Majesties Dials in Whitehall Garden*, published in London in 1704. Nevertheless, no matter what method is used, the collecting of sufficient dialling books to form a modest library is going to mean a fair outlay of expenditure. Unless you are an historian or bibliophile, the older works are best left to the scholars; and it will be more satisfying to collect the modern works, of which there have been a fair number published in recent years. They are clearer in exposition, more certain in their principles, more comprehensive in coverage of the history of dialling, and filled with illustrations of actual dials, often in beautiful colour plates. They vary from quite inexpensive to costly massive *opus majors*, so it is a question of deciding what it is you wish to do and purchasing works to complement this requirement. Dialling is such a vast and varied field that the specialization is an absolute necessity to preserve one's sanity. As Jean Henri Lambert, the famous mathematician, stated in one of his mathematical works, "It is not easy to find a science which presents so many forms and can be applied in so many different ways as that of gnomonics". But even he would have been surprised to find that lasers and computers were being used as aids to dialling today, and the commissioning of so many public sundials at a time when devices are available to measure time within a fraction of a nano-second. Such is the tremendous capacity of dialling to meet new challenges, and the new literature on the subject has improved in order to keep in touch with modern readers.

I fear that I have rather over-run my allotted period for speaking, so if I have not touched upon some particular aspect which might have interested you personally, I can only plead that the subject is so far-reaching that no single person can encompass it, nor condense it to be all-embracing within the space of an hour. The British Sundial Society was formed so that these gigantic tasks can be broken down into parts with which one person can deal with adequately without having to feel oppressed by the immensity of the task. No one need fear that if all the knowledge, by some miracle, could be computerised; that there would be nothing left to do. Dialling and its literature is an ever-expanding field with no limit in sight after several thousand years. In the BSS *Bulletin* we have the literary vehicle to take us into the 21st century, with no shortage of material to fill the waiting pages for the foreseeable future. Through it we may share our knowledge and record it for posterity and future diallists. The British Sundial Society *Bulletin* is kept in all the major copyright libraries.

CHARLES K. AKED

British Sundial Society members may obtain an example of the Singleton Helix Sundial (this has been displayed at BSS Conference) at the members' privilege price of £30 + VAT and carriage.

All enquiries to Mr. J.S. Singleton, Foundry Road, Land Road Estate, Newbury, Berks., RG13 2AD, from whom further information can be obtained.

CAMBRIDGE 1991 LECTURE
GNOMONICS
BY FER DE VRIES, NETHERLANDS

At a certain place with latitude φ, a flat surface is located on which it is desired to make a sundial. To do so it is necessary to know the orientation of the surface given by the inclination and declination of the plane.

Here I shall describe a method by which these two constants may be found, but before this can be done, it is desirable to outline in what way all kinds of lines may be calculated for any given values of inclination and declination for a sundial. It will become clear that both these problems may be resolved using the same precedures, in the course of which I shall try not to bore you with too many formulae, these are given separately at the end of this discourse.

DEFINITIONS:

It is first necessary to define the declination and inclination of the sundial plane. For that purpose a gnomon of length g is placed perpendicular to the dial, directed to one point in the sky, the coordinates of which point, relative to the horizon, are called the declination and inclination.

There are three possibilities:

Azimuth and Height
Azimuth and Zenith distance
Azimuth and Nadir distance of that point.

In the Netherlands the system of Azimuth and Zenith distance is normally employed, and this is used in my formulae. Both the Germans and Austrians use the system of Azimuth and Height, whilst the Societat Catalona de Gnomonica uses the system Azimuth-Nadir distance, but in principle there are no differences.

For the Azimuth, the zero origin may be chosen either north or south as is desired, I choose south in my calculations.

On a sundial there may be many kinds of lines, for example:

Lines for solar time, lines for date, Analemmas as defined by British usage, Babylonian, Italian and Antique hour lines, Islamic prayer-time lines, and many more.

Nearly all these lines depend upon the declination of the sun according to the day of the year. Only those lines for indicating the hours, with corrections for longitude are independent of the declination of the sun, but these lines may be calculated just as if they were. For that reason I calculate all the lines as though they were date-dependent, thus I require just one point as the shadow casting device, and this can be the tip of the gnomon.

On any sundial there are only two types of lines: straight or curved. A straight line can be drawn if two points only are known, a curved line requires at least three points to be known. Once a procedure to calculate a point is established, it is possible, by repeating the process, to calculate the required points for any given complete line.

No matter what the type of line it is desired to calculate, the required point can always be transformed into a particular position of the sun given by the declination and hour-angle of the sun. For that particular position of the sun it is required to calculate the coordinates x,y of the shadow-point.

So the first problem reduces to the following:

IN	φ i d g	(constants of the sundial)
	δ t	(the position of the sun)
OUT	x y	(coordinates of the shadow point)

With the help of standard coordinate system transformations, the problem may be solved, and it will become clear from the following that five transformations are necessary for a full solution.

The position of the sun is chosen relative to the equatorial plane.

In the equatorial plane a Cartesian coordinate system is selected x0, y0, z0. It is simple to transform the values δ, t of the sun's position into this coordinate system.

The system 0 is transformed to the horizontal plane by rotation about he x-axis, with the angle 90° - φ into the new system xl, yl, zl. Rotation about the z-axis with angle d transforms system 1 into the new system x2, y2, z2, a further rotation transforms system 2 into the system x3, y3, z3. System 3 now gives the sun's position relative to the plane of the sundial. System 3 can readily be transformed into the desired coordinates x, y.

To summarize:

Transform the position of the sun into the coordinate system 0
Rotate through angle 90° - φ into system 1
Rotate through angle d into system 2
Rotate through angle 1 into system 3
Finally transform system 3 into the coordinates of the shadow-point.

Using this procedure it is simple to determine if the calculated point gives a real or imaginary shadow. In system 1, if the value $z < 0$, the sun is below the horizon and there are no indications on the sundial, if the system 3 the value $z <= 0$, the sun is on the wrong side of the dial, and again no shadow will fall on the dial surface.

With this procedure all the lines on a sundial may be calculated, and it is valid for all points on the earth's surface. [The lecturer demonstrated a small example of such a dial at this point, it also illustrated the next step].

By means of additional steps in the procedure, it is also easy to calculate a mirror dial, or to calculate the lines for a submerg dial. On the same dial model is a submersible dial, placed in water it indicates correctly. The concept of submerged dials was learnt from Mr Schilt, Switzerland.

At a sunny moment, of which the time and date is unknown, the coordinates of the shadow point on the dial are measured carefully. I now wish to calculate the date and time for these coordinates.

This second problem may be expressed:

IN	φ i d g	(constants of the sundial)
	x y	(coordinates of the shadow point)
OUT	δ t	(position of the sun)

The identical procedure, as in the first problem, is used but in reverse, from bottom to top.

Transform coordinates x, y into system 3
Rotate with angle -i into system 2
Rotate with angle -d into system 1
Rotate with angle -(90°-φ) into system 0
Transform system 0 into the position of the sun, δ, t.

Because the operation is reversed, the negative values of the rotation angles are necessary.

Normally I do not use this procedure, but it works well and it is required for the solution of the final problem.

At a sunny moment of which I know the date and time, the coordinates of the shadow point are again measured.

The final problem may be expressed:

IN	φ	g	(constants of the sundial)
	δ	t	(position of the sun)
	x	y	(coordinates of the shadow point)
OUT	d	i	(declination and inclination of the sundial)

The two earlier procedures are used as far as possible, 1 is utilized to find the coordinate system x1, y1, z1, and coordinate system x3, y3, z3.

It is necessary now to introduce two formulae:
The first to calculate a sundial is x3 = x 1. cos d - yl. sin d;
the second is zl = z3. cos i -y3. sin 1

In the first equation d is the only unknown, in the second i is the only unknown. From the solution of these two equations, the required declination d and inclination i of the dial plane is obtained. However there remains a slight problem, two answers are obtained for each angle; but repeating the procedure with other input values, the erroneous values change, whilst the correct values remain constant.

On a final note, this method of calculation was learnt from Mr Thijs de Vries. Ten years ago an article on this subject was submitted by him and published in *De Zonnewijzerkring.*

THE FORMULAE - SOME DEFINITIONS

A gnomon of length g is placed perpendicular to the dial plane, the tip of which is used to cast the indicating shadow. The calculated points are measured in x-y coordinates, the foot of the gnomon being the origin of the Cartesian grid.

The coordinates are:

Horizontal sundial	Other sundials
+ x axis points east	+ x axis points right
+ y axis points north	+ y axis points upwards

The dial plane is oriented to the horizontal plane by:
the inclination i of the plane $0° <= i < 180°$
the declination d of the plane $-180° <= d <= 180°$

The inclination of the dial plane is the zenith-distance of the tip of gnomon, or the angle between the horizontal plane and the back of the sundial plane.

The declination of the dial plane is the direction (or azimuth) which the gnomon is pointing.

south = 0°, west = 90°, north = ± 180°, east = - 90°.

For a horizontal sundial, with i = 0, the declination of the sundial is unknown, then choose d = 0.

The location of the sundial is determined by the latitude φ. $- 90° <= \varphi <= 90°$.
North-latitude is positive, South-latitude is negative.

PROCEDURE 1 (To calculate lines on sundial)

IN: φ g i d
δ t
OUT: x y

x0: = sin t . cos δ	Translation δ , t into
y0: = cos t . cos δ	x0 , y0 , z0
z0: = sin δ	
R: = 90° - φ	Translation x0 , y0 , z0
x1: = x0	into x1 , y1 , z1
y1: = y0 . cos R - z0 . sin R	rotation around x-axis
z1: = y0 . sin R + z0 . cos R	through angle 90 - φ

If zl < 0 then point is imaginary and the sun is below the horizon.

R: = d	Translation x1 , y1 , z1
x2: = x1 . cos R - yl . sin R	into x2 , y2 , z2
y2: = x1 . sin R + y1 . cos R	by rotation around z-axis
z2: = z1	through angle d
R: = i	Translation x2 , y2 , z2
x3: = x2	into x3 , y3 , z3
y3: = y2 . cos R - z2 . sin R	by rotation around x-axis
z3: = y2 . sin R + z2 . cos R	through angle i

If z3 <= 0 then the point is imaginary, the sun is not above the dial plane.

x: = x3 . g / z2	Translation x3 , y3 , z3
y: = y3 . g / z3	into coordinates x , y

In this procedure it is seen that x3 = x1 . cos d - yl . sin d.
This result is required for use in Procedure 3.

COMMENTS:

Knowing x1 , y1 , zl it is possible to calculate the height and azimuth of the sun. With input δ = 90° and t = 0, it is possible to calculate the height of a style parallel to the earth's axis (v : = arcsin [z3]) and coordinates x , y of the intersection point of the style. If z3 = 0, there is no intersection point.

PROCEDURE 2 (Reverse of Procedure 1)

IN: y g i d
x y
OUT: δ t

LS: x . x + y . y	Translation x , y
h: arctan (g / LS	into x3 , y3 , z3
z3: sin h	
y3: = z3 . y / g	
x3: = z3 . x / g	
R: = -i	Translation x3 , y3 , z3
x2: = x3	into x2 , y2 , z2
y2: = y3 . cos R - z3 . sin R	by rotation around x-axis
z2: = y3 . sin R + z3 . cos R	through angle -i
R: = -d	Translation x2, y2, z2
x1: = x2 . cos R - y2 . sin R	into x1 , y1 , z1
y1: = x2 . sin R - y2 . cos R	by rotation around z-axis
z1: = z2	through angle -d
R: = - (90° - φ)	Translation x1 , y1 , z1
x0: = x1	into x0 , y0 , z0
y0: = yl . cos R - zl . sin R	by rotation around x-axis
z0: = yl . sin R + z1 . cos R	through angle -(90°- φ)
δ: = arcsin z0	Translation x0 , y0 , z0
t: = arccos (y0 / cosδ) and	into δ , t
t: = arcsin (x0 / cosδ)	

In this procedure we see: z1 = y3 . sin (-i) + z3 . cos (-i)
and: z1 = -y3 . sin i + z3 . cos i
These equations are required for use in procedure no 3.

PROCEDURE 3 (To find the inclination and declination of the sundial)

IN: φ g
δ t x y
OUT: i d

$x0: = \sin t \cdot \cos \delta,$ — Translation δ , T into x0 , y0 , z0
$y0: = \cos t \cdot \cos \delta$
$z0: = \sin \delta$
$R: = 90° - \varphi$ — Translation x0 , y0 , z0 into x1 , y1 , z1 by rotation around x-axis through angle (90°- φ)
$x1: = x0$
$y1: = y0 \cdot \cos R - z0 \cdot \sin R$
$z1: = y0 \cdot \sin R + z0 \cdot \cos R$

$LS: = x \cdot x + y \cdot y$ — Translation x , y into x3 , y3, z3
$h: = \arctan (g / LS)$
$z3: = \sin h$
$y3: = z3 \cdot y / g$
$x3: = z3 \cdot x / g$

It is now possible to solve the following equations which will give the declination d and inclination i of the sundial.

$x3: = x1 \cdot \cos d - y1 \cdot \sin d$ (only d is unknown - see procedure 1)

$z1: = z3 \cdot \cos i - y3 \cdot \sin i$ (only i is unknown - see procedure 2)

Two answers are found for d and for i, but by repeating the procedures with other values δ , t , x , y , it will be seen that the unwanted answers will change, but the required correct answers will not.

(These methods were made known to me in 1981 by Mr. Th J de Vries, member of "De Zonnewijzerkring"). This is the Netherlands Sundial Society, the pioneering group which founded the modern study of gnomonics in Europe through mutual research and the publishing of information in their *Bulletin.*

Editor's Note: Mr. De Vries lecture was illustrated by slides and models which cannot be shown here.

WHAT IS TIME?

TIME is forward only motion
So we can't arrive before we leave.
But as we move through our own cycle
Time enrobes us in its sleeve.
Like shading on an eternal graph,
Dependent for life upon the sun,
Faster than sound we can fly
Through science just begun.
All the while moving inexorably
To the date inscribed in the cemetery.

We build our caesium clocks,
Record the passing days,
Spectators of Time's progress
Through the sun's declining rays.
Unmerciful, anonymous Time,
Recorded in rocks and trees,
Inescapable, omnipresent Time,
Time's drum beat rolls relentlessly.

We try so hard to make a mark,
Resisting our mortality,
But all that most of us will find
Is lingering obscurity.
Ruins of cities mark our passing,
Foundations of those which are to come,
A few great generals get recorded,
But mankind only soldiers on.

Learning new tricks but never changing,
In the continuum of history;
Consume the seasons, eat next year's fruit,
Devour the forest, pollute the water,
Lead the children, what divine right have we?
More and more when less is more. No wonder
Time regards us quizzically.

Against the background of Time's passing
Man's lifetime is a *scène de theatre,*
Love and hate, success and failure,
Just *Existence a la* Jean Paul Sartre.
Applaud the actors as they are leaving,
Fresh faces smile and keep on coming,
Time remains, just like a river,
Flowing gently, and irrevocably
Ever onwards, on and on.

HARRIET WYNTER

(Lines written in the Archiginnasio Library, Bologna, 14th September 1991).

Continued from page 23

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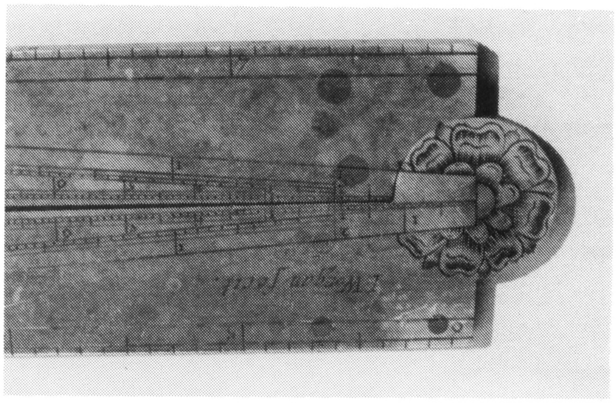
LETTERS TO THE EDITOR

JOHN WORGAN

I was interested in the recent article (*Bulletin* 91.2) about a sundial by John Worgan, being the property of a lady in Australia. The illustration of this dial shows quite clearly the quality of Worgan's work. A most interesting feature of his work, is that wonderful English Rose design that can be seen at its centre. I have examined two other sundials by him and both had this striking feature. One may be seen at the Royal Scottish Museum, Chambers Street, Edinburgh. The other was offered for sale at a recent Scientific Instrument Fair.

Another instrument of his, a sector is shown in the accompanying photograph. This clearly shows his small but neat signature, very similar to that in the Australian dial and of course that wonderful rose design. Another similar sector was recently offered for sale by an American dealer, and yet another from the Time Museum collection (America) was sold at Christies, but in this case it did not have the rose design. A circumferentor by him is in the Museum of the History of Science, Oxford, again with that rose motif. In all cases the signatures are very similar.



The rose design was not peculiar to Worgan. It was used by several English makers working towards the end of the seventeenth century. Three others that I have come across are Edmund Culpeper, Richard Glynne, and Richard Whitehead. They were all Mathematical Instrument makers but they also made and sold various types of sundials.

Little is known about John Worgan but Joyce Brown records in *Mathematical Instrument Makers in the Grocers Company*, 1688-1700:

Son of William of Colford, Gloucestershire, Yeoman, deceased.

9 November 1669. Apprenticed to Nathaniel Anderton.

6 December 1682, free of Walter Hayes.

1693. Fetter Lane against Cliffords Inn back gate.

1700. Last noted, Fleet Street.

(Under the Dial of St Dunstan's Church, Fleet Street, London, 1688.)

In 1688 he advertised in John Love's book on surveying:

"Such persons as have occasion for the instruments mentioned whatsoever, may be furnished with the same, at Reasonable Rates by John Worgan, Instrument-Maker, at his Shop under the Dial of St Dunstan's Church in Fleetstreet, London."

E.G.R. Taylor in *Mathematical Practitioners of Tudor and Stuart England* records that he flourished 1866-1714, specailising in Surveying Instruments and Dials.

I hope these few notes will encourage BSS members to look out for his instruments and help them to appreciate the fine quality of his work.

M.J. COWHAM

THE ANALEMMATIC DIAL

I, like Mark Lennox-Boyd, had been frustrated at not finding an easily understandable proof for the analemmatic dial in the literature, and therefore was delighted to read his proof in *Bulletin* 91.2. In so doing I happened upon a rewarding simplification which made it even easier for me, and perhaps too for others to understand.

In my revised construction, I have shown the line of the sun intersecting the equatorial gnomon at W, at a declination D. I first reminded myself that the plane ELW is at right angles to the equatorial plane ABC and that, for any given value of H, the position of EL is independent of the declination (a most useful property of equatorial dials). At hour H, the bearing, or azimuth plane of the sun at zero declination is EGLP; thus a vertical gnomon EG will cast a shadow through P on the ground.

However, when the sun is at declination D the azimuth plane for the same hour H is WQLP. This means that if we still wish to use P as the hour mark, we must move the gnomon from EG to WQ.

We now draw VW parallel to GQ and can easily see that the required gnomon displacement GQ for declination D is given by:

$$GQ = VW = EW \cos \varphi = a \tan D \cos \varphi$$

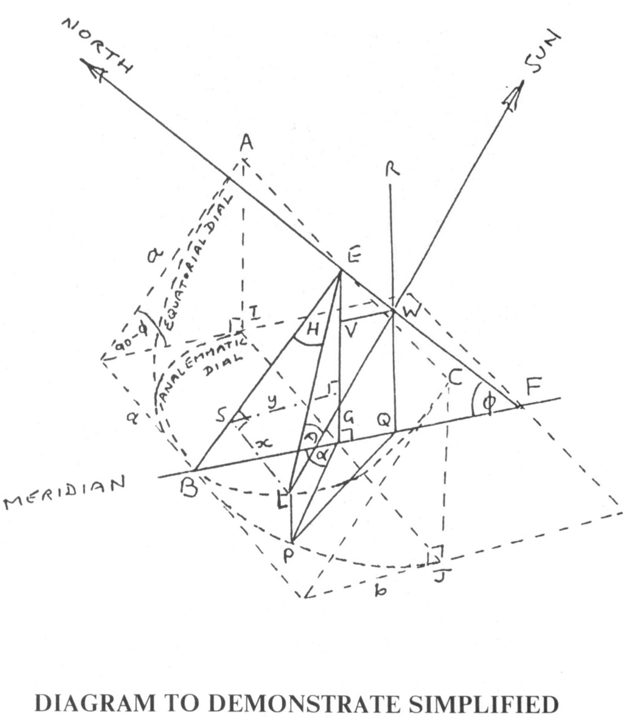


DIAGRAM TO DEMONSTRATE SIMPLIFIED PROOF OF ANALEMMATIC DIAL

To briefly recap on the other two necessary formulae: In orthographic projection, the dial IJB is seen to be in a semi-ellipse, with axes 2a and 2a sin φ, and:

$$\text{Since } x = a \sin H \text{ and } y = ES \sin \varphi = a \cos H \sin \varphi$$

$$\therefore \tan \alpha = x/y = \tan H/\sin \varphi$$

where α is the angle between GP and the meridian.

I thank Mark Lennox-Boyd for enlightening me with his article and hope that my own further simplification may be of use to others who still find the trignometry of this dial confusing.

To end on a lighter note, if the analemmatic gnomon is a fixture such a tall building, we could make a dial by displacing each hour mark parallel to the meridian by the amount GQ. This would produce a series of parallel semi-ellipses, one for each chosen declination. I offer this concept, free of charge(!) to any budding town planner seeking a novel layout for a housing estate.

How useful it would be if you lived, say, at No 10 (am) Capricorn Crescent, to be able to regulate your clock by the Town Hall clock tower when it occluded the sun on 21st December. Who needs the clock when you have got the tower!

JOHN MOIR, LONDON

PORTABLE EQUATORIAL DIAL

Thank you for your letter dated 24th September 1991. I have enclosed a photograph of my portable equatorial dial - its price is £700. It is handmade in brass and can either be mounted or operate as an entirely independent portable dial. It measures 6½in x 5in. The equatorial plate showing the hours is toothed, gearing a minute hand. It can usually operate to the nearest minute. The Equatation of Time and GMT/BST can be pre-set into the dial to avoid having to convert the observation of the sun's time.

I hope the photogaph and information is helpful.

ALEX MONROE, WANDSWORTH

Editor: Mr. Monroe's address will be forwarded on request.

A BIFILAR SUNDIAL

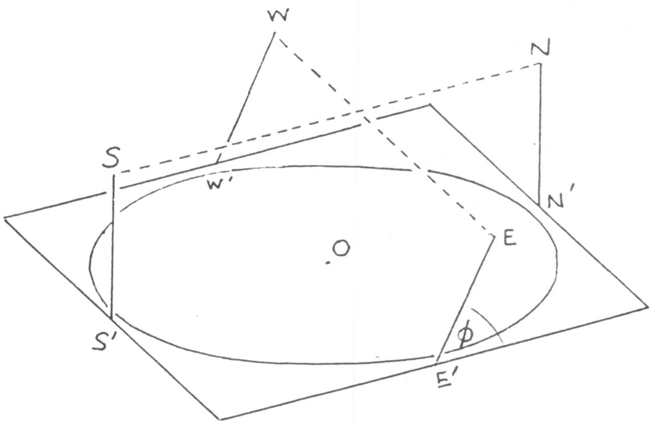
In the *Bulletin* 91.2 F.W. Sawyer described an interesting and ingenious equant sundial. Another horizontal dial which is equant is the bifilar dial.

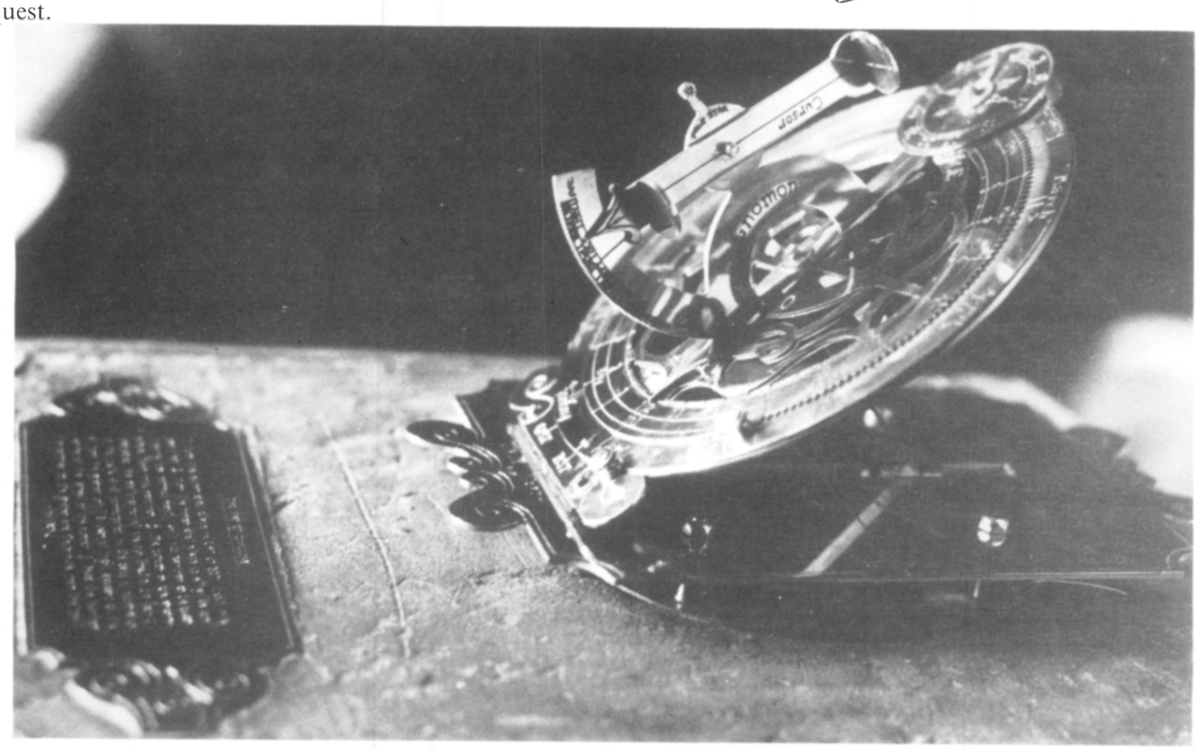
The gnomon consists of two horizontal wires (the broken lines in the diagram); one wire SN pointing north is supported by vertical rods S'S and N'N of equal length; the other WE pointing east is supported by rods W'W and E'E of the same length as S'S and N'N but inclined at an angle Ø (latitude north) to the north-pointing horizontal and in a vertical plane parallel to the plane S'SN'N.

On a circular disc with centre O radii are drawn at equal intervals of 15° and numbered with the hours. The disc is mounted on the baseboard with its centre at the point of intersection of lines S'N' and W'E' about which it can turn. The time is indicated by the position relative to the numbered radii of the point of intersection of the shadows of the two wires.

If the disc is placed so that the noon radius lies along ON' the dial will indicate local solar time. As the radii are equally spaced, the disc may be rotated to allow for the difference in longitude between the dial and Greenwich and to allow for the equation of time, when the dial will indicate G.M.T. A further rotation through 15° will enable the dial to indicate B.S.T.

J.G. FREEMAN





DIAL-ECTIC

BY CHARLES K. AKED

A recent delightful note from our member Ms Joanna Migdal included the word "dial-ectic" in connection with a meeting of the BSS Educational Group. As someone who has played with words for a considerable period of time, the application of this word seemed so apposite that the temptation to committing plagiarism was well-nigh irresistible. This set me to thinking about the use of "dial" as a prefix, just another of those mental byways that appear when proceeding along the main route of a project, byway being used in the sense of an area, field of study, etc, that is very obscure, or of secondary importance. This process is the main dissuader of those who have honest intentions of producing an important addition to literature, but yield, almost imperceptibly, to the blandishments of unseen temptations just around the corner of a small opening just in the way ahead; generally never to be seen again. What has been published in the past is but a mere trifle of that which has been envisaged in the minds of potential authors until diverted in a similar fashion, or ground down by the sheer drudgery of producing a literary text from a shamble of material garnered from a multitude of sources.

The ordinary domestic dictionary may list about fifteen words commencing with "dial", most of which are some reference to the actual art of dialling. It is more instructive to turn to the main Oxford English Directory where words with the prefix of dial . . . cover almost four pages.

Under "Dial", at the start of the listing we read:

Also dyale, dyel, dyal, diall. presumably a derivative of the Latin *dies* a day, through medieval Latin adjective *dialis* daily, represented in Du Cange by *diäle = diurnäle* 'as much land as can be ploughed in a day', and *dialiter* adverb daily. Outside England, however, *dial* is known only from a single Old French instance in Froissart in which the *dyal* in clockwork is said to be 'the daily wheel *roe journal* which makes a revolution once in a day, even as the sun makes a single turn around the earth in a natural day'. This would answer to a medieval Latin *rota diälis:* the transition from 'diurnal wheel' to 'diurnal circle' is easy.

Dial 1 An instrument serving to tell the hour of the day, by means of the shadow of the sun upon a graduated surface: a SUN-DIAL.

This is a very loose definition of a sundial since we normally use the shadow of the gnomon to indicate the time by the sun. Evidently lexicographers also suffer from blind spots. No doubt the shadow of the sun could be used on a cosmic scale, but hardly by mortal man.

The weakness in the ensuing analysis of the use of the word "dial" is indicated by the quoting of its employment from the date AD 1430 viz: LYDG *Chron.Troy* l.v 'For by the dyal the hour they gan to marke'. By this time the mechanical clock was in use in many parts of Europe and by parallel comparison the term dial on a clock had been forged through being linked to the sundial since they similarly indicated hours (during sunlit hours for the true dial). After about AD 1270 there is an ambiguous period in which the word "orloge", or some derivative, was used indifferently for a whole host of devices from sundials to sand clocks, clepsydrae to mechanical clocks; causing great obfuscation (I was going to write "confuscation" but this is not a word to be found in any dictionary) amongst horologists searching for the origins of mechanical timekeeping.

The start should surely have commenced with ancient Egyptian and Arab sources, followed by the Greek and later Roman sources, in particular Vitruvius's *De Architecture Libri Decem;* where the literary material is unsullied by contamination from the world of mechanical time measurement; although to be strictly factual the present copies are all derived from the manuscript copy discovered in a monastery in AD 1486. The original was written circa 90 BC, Chapters 4 and 7 of Book IX dealing with gnomonics. The treatment is surprisingly modern. However several of the types of dials described by Vitruvius have never been discovered as actual specimens.

However, to continue with the dictionary examples:

c 1440 Promp. Parv. 120 Dyale or dyel or an horlege (dial or diholf of an horlage). 1530 Palsge 213/2 Diall to know the houres by the course of the sonne, *quadrant.* 1535 Coverdale 2 Kings xx, 12 The shadowe wente backe ten degrees in Achas Dyall.

This last seems promising in returning to ancient times but actually is merely what was then a modern rendering of an obscure or ambiguous term in the original Biblical texts, and so adds nothing to our understanding.

1552 HULOET Diall set upvn a chymney or wall to knowe what it is a clocke by the sunne, *scioptericon.* 1593 Shakespeare 3 Henry I, I, ii. v. 224 'To carve out Dialls quaintly, point by point, Thereby to see the Minutes how they runne.

Sadly this latter quotation has become a dial-ling cliché with so much use.

1647 WARD *Simp. Cobler* 39 Where clocks will stand, and Dials no light. This clearly distinguishes between the two but also shows how mechanical clocks and sundials continued to exist in harmony in spite of the various difficulties in reconciling their different rates of indication. As the Equation of Time was not known then in a quantifiable form, mechanical clocks were corrected daily to divide the period of one crossing of the meridian by the sun to the next into twenty-four hours, and so there were variations in the duration of the hour with season, but nothing like that of temporary hours.

1719 YOUNG *Busiris* v. i. How, like the dial's tardy moving shade. Day by day slides from us unperceiv'd. 1720 GAY *poems* (1745) Here to sev'n streets, sev'n dials count the day. Obviously this is a reference to the monumental dial in the Covent Garden area.

1799 VINCE *Astronomy iv, (1810) 56 A clock or watch . . . may be regulated by a good dial. 1876 B TAYLOR Deukalion* I. vi. The hour shall miss its place, And the shadowe recede on the dial's face. (Another reference to the Miracle of Ahaz).

Dial can also be used in a figurative sense eg:

15123 DOUGLAS AEnis I. Prologue 347. Venerable Chaucer . . . Hevinlie trumpat, horleige and reguleir, condit and diall. 1854 J. FORBES Tour Mont Blanc, Introduction 11, The stately march of the glacier is yet a stage more slow, months and years are but the units and

Continued on page 4

EDITOR'S FARE

This current issue of the British Sundial Society *Bulletin* is the ninth since it first appeared. My first thoughts on the subject of providing a forum for dialling information was to have a newsletter of four pages issued two or three times a year, the first subscription was based upon this and set at the very modest sum of £7.50 per annum. One of the reasons for a small newsletter was so that the available dialling material would not be exhausted rapidly, no one had any idea that the material is virtually inexhaustable.

The BSS Committee (as it was then) had no estimate of the possible size of the membership but its founders were content to proceed on the assumption that if we attracted 50 members, the project was viable. The original proposal to form a group under the auspices of the Antiquarian Society came to naught since few AHS members expressed interest, and the far greater number who wished to join a sundial group were not in the Society and made it clear they were not prepared to pay the AHS subscription, whose journal was almost completely devoted to mechanical clocks and watches, in order to receive only a few newsletters a year in return. So it was that the British Sundial Society came to be founded on an independent basis.

The first issue had 24 pages, corresponding to about twelve pages of the present printed issues, but already twice the content as envisaged for two years. Thanks to a very low price for photocopying, with no VAT as the *Bulletin* was registered as a book with the copyright libraries from the start, the BSS Committee managed to finance the publication of three similar issues in the subscription year, or about eight times the material thought possible, plus the far heavier cost of postage made necessary. The rapid increase in membership enabled the cost of printing an individual copy to be reduced but the task of despatching these became a very large committment.

The use of a dot matrix printer at the start did not give good results when the text was photocopied. As a result the matter was debated at the first Annual General Meeting held at Oxford, March 1990, when the members voted to raise the subscription to £12.50 to allow the *Bulletin* to be printed. Some members indeed would have gone for a far higher sum to allow an expensive glossy version to be published, however a halfway house compromise was made by the BSS Council to avoid making it difficult for those on limited budgets.

The immediate benefit of the printed page was the great improvement in clarity, with the greater advantage of being able to use halftone illustrations, plus the condensing of the text to get twice as much on each page. Thus the first printed issue of the BSS *Bulletin* contained 32 pages, equivalent to 64 of the previous typed text, and equal to five times the material envisaged for a whole year initially. The disadvantage was the increase in the postage necessary for the increased weight, and the postal rate has risen twice in the short time the Society has been in existence, now forming a considerable proportion of the cost of supplying the *Bulletin* to BSS members.

The size of the *Bulletin* was increased to 40 pages and three issues a year rather than issues of a smaller size four times a year, mainly because of the despatching costs. Four issues a year cannot be supported on the BSS finances and present level of subscriptions unless a substantial rise in membership takes place, and/or a sponsor is found. Nevertheless BSS members are currently enjoying (with all deference to the original of such journals - Der Zonnewijzerkring), the best quality and largest journal on gnomonics in the world. Finance is the sole factor which limits the size and quality of the publication.

What has rather astounded the Editor is the extreme erudition of many of the authors who submit dialling articles and their grasp of the details of the subject, plus their ability to pass on the results of their cogitations. To be truthful the original committee did consider that the BSS might become a rather ethereal debating society for a small number of aficionados and were prepared to run the Society at an academic level. The rapid rise in membership in the earliest days took the Committee members quite by surprise. Fortunately it has been found possible to cater for all levels of interest in gnomonics, and indeed increase the areas of interest available and not forseen in the founding days. One continually meets fresh surprises, for example the current interest in Mass dials which was not indicated in the replies to the questionnaires sent out in the early days, the indicated results of these were most ably analyzed by Mrs Anne Somerville. Nor was the great interest in computer programs for dialling envisaged, yet these are now recognized as a great step forward in arriving at exact solutions with very little work, and the absence of tedious mathematical calculations with many opportunities for error. Furthermore the cataloguing of the entire total of sundials in the British Isles would be virtually impossible without inputting the data into a computer.

The Editor naturally welcomes articles and letters from members. It is helpful if these are submitted in typed double spaced text with wide margins and space both at the top and bottom of each single-sided sheet to allow for editing and corrections. Black and white photographs are preferred, or line diagrams, but colour prints which are sharp and of good contrast are acceptable. Diagrams should be competently produced and labelled, reproduction processes rarely improve the final quality. Submitted manuscripts will be acknowledged and have to take their place in the publication queue. Because of the present printing schedules and since only one person is dealing with publication matters, it is not possible to supply proofs to authors, but authors who require extra copies of the *Bulletin* which contain their article may obtain these on request - free of charge - maximum 5 free copies. Should anyone require a large number of a particular issue, this can be arranged at cost plus despatch charges, providing the request is made before the printing date.

Suggestions from members on possible improvements to the *Bulletin* are welcomed by the Editor as long as no increase in cost is incurred. For example some members suggest colour illustrations, it would be marvellous to be able to incorporate these, the cost, alas, is far beyond our meagre resources.

One of the desirable items is that of a collective index. As the number of issues rises, it becomes increasingly difficult to locate items in spite of the contents listing in each issue. If there is a professional indexer in the great

Continued overleaf

A PROTEST SUNDIAL

BY MILUTIN TADIĆ, YUGOSLAVIA

The sundial illustrated here was unveiled on 6th September 1991 in the City of Sarajevo, Yugoslavia. It is cut into a granite slab measuring 93 x 66 x 3 cm. The basic structural details are:

$$\varphi = 43°51'N, \lambda = 18°26'E, A = 97°30'$$

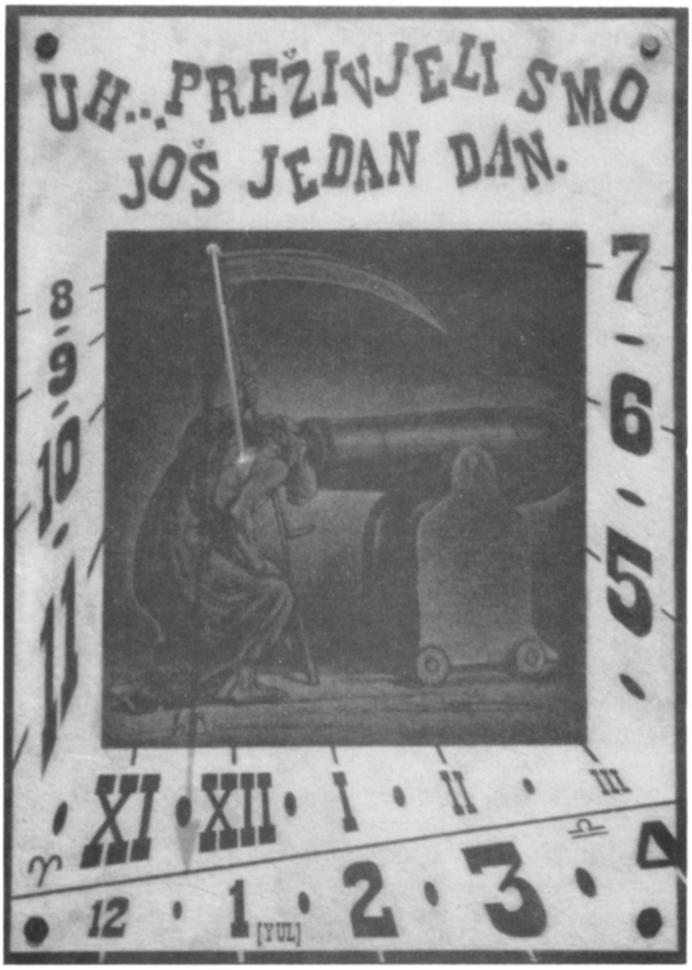
It has been created by the sculptor Stjepo Gavrić (College of Fine Arts) and Doc, Milutin Tadić (Faculty of Natural Sciences and Mathematics). The sundial is constructed conventionally. The astronomical content is standard: included are dials for Central European time and daylight saving time, plus a projection of the celestial equator.

The artistic composition is characterized by the unique inclusion of slightly modified sketch of the former Berlin Wall ("Oh... we survived one more day"), and a satirical drawing by the famous French painter and caricaturist Honore Daumier (1808-1879). Daumier produced this well-known painting showing Chronos as a symbol of Time peering into a barrel of a loaded cannon in 1846, when the circumstances in France were almost similar to those at present in Yugoslavia.

If there can be all kinds of sundials, wall, park, monumental and memorial, then the protest sundial can take its place too. We call this sundial in Sarajevo a "protest sundial". The creators of this sundial call it thus as an acerbic comment upon the present gloomy everyday life in Yugoslavia.

The sundial was built under the patronage of "Radio Sarajevo Program 202".

Editor's Note: Here is another aspect of the diversity of dialling, that of political comment. I am sure I express the feelings of the BSS membership when I say that I hope that the turmoil in Europe will end and that all the vexed questions of borders and nationalism can be amicably settled without recourse to armed struggle. War is such a futile and costly means of settling matters. Perhaps, since sundials were regarded as the legitimate spoils of war two milleniums ago, this new dial is also an indictment of the distinct lack of progress in the affairs of Mankind.



PHOTOGRAPH TAKEN 23rd SEPTEMBER AT THE AUTUMNAL EQUINOX

Continued from page 39

outdoors who would like to compile such an index, the Editor would be more than pleased to hear from him/her.

One day it is hoped to reprint the first three *Bulletins* in the present style, it has been considered, with the verdict that money is best spent on the publication of new material at present. Meanwhile all the issues published to date are available from the Secretary at £5.00 a copy post free to British members. Overseas members must pay the extra postage costs. David Young's address in listed on the back cover, and he is the only one who can supply the early issues by photocopying from the master copies. The copies are actually at cost, or lower, of printing, it is a service to enable everyone to acquire a full set of Bulletins should they so wish. When the present stocks are exhausted, it will no longer be possible to acquire the earlier issues direct from the BSS, it is too expensive to print a small quantity only of each issue.

Finally remember that the BSS *Bulletin* is the mouthpiece of the members, if you want to make comment, the correspondence columns await you. The most successful journals are those with a healthy input of "Letters to the Editor". If you want to have a good old moan - do so, if you want to tell someone how much you enjoyed their article - why be shy, it may be just the moral boost the author is seeking. Just keep to the point, be pithy, and above all constructive. Few people produce better results merely by being subjected to criticism.

CHARLES K. AKED

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