The British Sundial Society

ISSN 0958-4315

BULLETIN

No. 91.3

OCTOBER 1991

HONORARY OFFICIALS OF THE BRITISH SUNDIAL SOCIETY

BULLETIN 91/3 - OCTOBER 1991 - CONTENTS

Page

DIALOGUE
BULLETIN OF THE SCIENTIFIC INSTRUMENT SOCIETY

Issue No 29 for June 1991 is a most excellent journal, with quite a number of interesting items for those interested in gnomonics. On page 22, a beautiful instrument for laying-out dials made by Matthaeo Popell is illustrated, it is thought that it was probably a presentation piece. A number of astrolabes are shown, plus a diptych dial by Tobias Volckmar. About twenty pages are devoted to the SIS Visit to the Netherlands 13-17 May 1991, a fascinating tour of the Netherlands scientific museums. A report on the 'Images of Time' exhibition held in Amsterdam 28 November 1990 to 27 November 1991 is given, this exhibition had a number of early sundials. There is a catalogue available for the exhibition, edited by Anthony Turner (Dutch and English text versions). There are about six hundred members of the SIS, the journal is issued four times a year, the subscription rate for UK members is £20.00, but there is a joining fee of £10.00 (which must deter some potential members). Contact Mr. Howard Dawes, Executive Secretary SIS, PO Box 15, Pershore, Worcestershire, WR10 2RD. Overseas members' rate $40 plus $15 because of the increased postal charges. It is a vigorous and active Society.

PUBLICITY

The British Sundial Society has a fair amount of free publicity of late, the outstanding item being the almost one-third page article in *The Independent* newspaper of Saturday 27 July 1991, page 4 of the main section, written by William Hartston and made prominent by the very large illustration of the sundial in the Plymouth city centre. Under the heading of "Sun seekers with their eyes on time" and "Consuming Passions - The British Sundial Society (Established 1989)" there is a pot-pourri of facts and fiction. One or two people have telephoned the Editor to ask if it was really true, as stated in the article, that sundials read correctly only twice a year! It all depends on what you are looking for, but take comfort, very few mechanical clocks read correctly at any time, although even a stopped clock will indicate absolutely correct time twice in a twenty-four hour day; and even our standards derived from atomic clocks drift about the odd nano-second from time to time. Nevertheless, thanks Mr. Hartston, for the publicity for the British Sundial Society you have engendered.

In *The Daily Telegraph* of Wednesday, 31 July 1991, on page 14, was the mention of our member Robert Mills in the feature "August Night Sky" thus:

Modern astronomy provides ever-increasing quantities of data for scientific evaluation, and it is upon the results of research into the statistics of stars and galaxies that theories of cosmology are formulated. Cosmologists offer no theories involving the wondering mind in the physical universe - that is not their business - but as Robert Mills, a gifted teacher whose book on simplified mathematical astronomy was mentioned in these columns, said at the exhibition meeting of the British Astronomical Association; "There is more to astronomy than meets the eye"... The ingenious devices for simple observation exhibited by Mr. Mills do much to help the star-gazer understand, as he says, the what and how of that which is seen, but it is only the mind behind the eye which can attempt the why.

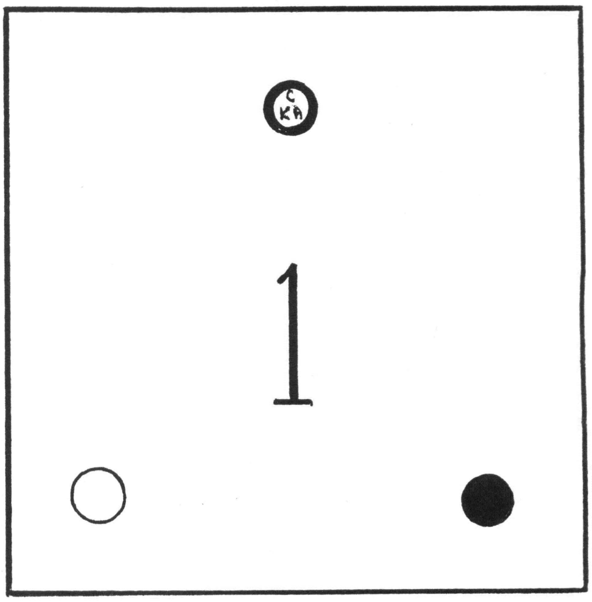
The Chairman of the Society, Mr. Christopher St. J.H. Daniel has also given two short talks on radio about sundials, for Radio Scotland and Pebble Mill in August; and in September he gave a lecture for the Canterbury Festival - "The Shadow of Time" in the Dominical Priory.

All these happenings bring in a few more enquiries about membership, the majority being surprised that a society exists for sundials, and many of those who have been interested in sundials for some time are even more surprised that so much can be written about them (so too is the Editor).

A HOLOGRAPHIC SUNDIAL

In the February 1991 issue of the *Bulletin*, No 91.1 on page 2, a report was given on a holographic sundial devised by Kristina Johnson and Rob Penland. Some further details have been provided by Mr. Ian Elliott of the Dunsink Observatory, Dublin. The devisers have named their new type of sundial the holographic sundial (surprise, surprise!) or holodial. Not being diallists, they claim it is the first gnomonless sundial. The first gonomonless sundial occurred over two thousand years ago when some vandal removed a valuable iron rod from one of Berosus's hemispheriums the original hollowdial?

However the additional information is that the new holographic sundial can exhibit nearly 20 minute accuracy from 8 am to 4 pm and the hologram is constructed by placing a two inch by two inch piece of Kodak 649F photographic film in an altitude-azimuth plateholder and exposing stencilled numbers and dots using a hellium-nean laser split into two beams. The time of day is read directly off the hologram. See attached figure and marvel at the artistic concept.



TWENTY MINUTES PAST ONE, OR THEREABOUTS

All you old-fashioned craftsmen might just as well gnash your teeth in the face of progress, throw away your stone and slate slabs, your chisels and scribers; the virginal brass plates awaiting the firm touch of the engraving tool in the master's hand, etc, etc. A dial can be ready within an hour with the local chemist's express developing service.

CLOCKS

Each monthly issue of *Clocks* contains "The Sundial Page" written by our Chairman Christopher St. J.H. Daniel, and the July contribution is entitled 'King Harry's dials' and encompasses the exhibition held at the National Maritime Museum, Greenwich which was open 1st May to 1st September 1991. The magazine devotes more space to dialling than any other horological journal.

THE CLOCKMAKER

In writing of this magazine, the BSS Editor must declare a vested interest since he also edits *The Clockmaker*. The early issues (it commenced publication in May 1990) contain articles reprinted from a number of old periodicals, generally at a 'popular level'. The magazine is intended for constructors and is mainly for those interested in making mechanical clocks and related devices. An article which will appear in a forthcoming issue is by the late Noel C Ta'Bois, an instrument intended for the delineating of sundial hour lines. The instrument is built from Meccano parts, as was usual with Noel's prototypes, since he wished to verify his designs before embarking upon an instrument of traditional materials. The article might well have disappeared into oblivion except that our member Alan Partridge drew it to my attention. As *The Clockmaker* is only available on subscription, ie. it is not on sale in bookshops, if any BSS member is interested in obtaining the issue of *The Clockmaker* which contains this article, please write to the BSS Editor - address on inside rear cover and arrangements will be made to make these available. The early issues are still available from:

TEE Publishing, Edwards Centre, Regent Street, Hinckley, Leics, LE10 0BB.

For those prepared to wait some time, the article will be published in the BSS *Bulletin* at some future date. At present there is so much to publish on the subject of dialling that all articles must take their place in the queue.

WILLIAM GILBERT OF COLCHESTER

Until the invention of the magnetic compass, there was no means of orientating dials quickly, so portable sundials were in the form of ring dials or pillar dials depending upon the sun's altitude rather than its angular position to indicate the time, and turned to the sun's position to read off the time. Thus there was no requirement to know the precise direction of the meridian. As to the invention of the magnetic compass, like many others, it is shrouded in mystery. Tradition has it that the knowledge was discovered at the end of the 11th or beginning of the 12th century at Amalfi in Italy, which then was a city state depending upon seafaring. There were a number of early writers upon the magnetic compass, including the Englishman Roger Bacon in 1267, however the first epistle of magnitude was by his friend Peter Peregrinus in 1269 who wrote a famous letter expounding the mysteries of magnetism. The passages in this letter are translated and analysed in *Bibliographical History of Electricity and Magnetism* by P.F. Mottelay, published in 1922, pages 45-54.

The man most responsible for the birth of science as far as electricity and magnetism is concerned is William Gilbert of Colchester, Physician to Queen Elizabeth I. His monumental work, written in Latin, is entitled *De Magnete ... [On the Magnet, Magnetick Bodies also, and on the Great Magnet the Earth ...]*, first edition published in 1600. It is [the English translation] just as readable today as when first written, for Gilbert's approach shook off much of the previous shackles of scientific thought, for example he was fully committed to the earth rotating round the sun in the sixth book of his great work. Such copies of his work that are found in Italy will often have this offending section taken out as it was against the teaching of the Roman Church.

The heading to Chapter XVII of Book III of *De Magnete* therefore looks very promising - "On the Use and Excellence of Versoria: and how iron *versoria used as pointers in sundials, and the fine needles* of the mariners' compass, are to be rubbed ..." *Versoria* is the term invented by Gilbert for what we would now call pivoted magnetic needles. The reference to sundials, however, is but fleeting, as part of the first paragraph repeated here in modernized English shows:

Versoria prepared by the loadstone, subserve so many actions in human life that it will not be out of place to record a better method of touching them and of exciting them magnetically, and a suitable manner of operating. Rich ores of iron and such as yield a greater proportion of metal are recognised by means of an iron needle suspended in equilibrium and magnetically prepared; and magnetic stones, clays, and earths are distinguished, whether crude or prepared. An iron needle (the soul of the mariners' compass), the marvellous director in voyages and finger of God, one might almost say, indicates the course, and has pointed out the whole way round the earth (unknown for so many ages). The Spaniards (as also the English) have frequently circumnavigated (by an immense circuit) the whole globe by aid of the mariners' compass. Those who travel about through the world or who sit at home have sundials ...

That is the end of the matter of sundials. The rest describes how the needle called versorium or needle indifferently by Gilbert, is magnetized by the use of loadstones, pieces of naturally magnetized iron ore. He describes the needle in general, calling it iron (but it must be of steel to retain the magnetism), but does not give precise details of making it although he mentions the upright pin upon which it turns, and is careful to point out that the north seeking end must be made a little lighter to compensate for the dipping of the needle when magnetized, ie. so it may remain horizontal. By the time Gilbert wrote his treatise, Nuremburg makers of portable dials had been incorporating magnetic compasses into their instruments for a considerable period, hence it was of a commercial nature in which Gilbert would probably find no scientific interest.

THE HAMPTON COURT SUNDIAL OF JOHN MARR, 1631. (PART 4)

A.R. SOMERVILLE

All theise propositions and manie more (the hower of the daie onelie excepted) may bee knowne by ye
43 great concave, although ye sunne doe not shine, onelie by knowing either the daie of ye moneth, or place of ye Sunn, and sometimes the hower of ye daie.

THE DAIE OF THE MONETH BEING KNOWN TO FINDE THE HOWER OF SUNRISINGE AND SUNSETT, & LENGTH OF THE DAIE AND NIGHT.

If the moneth bee uppon the west side of ye margent the howerline that passeth by anie daie thereof sheweth ye hower of sunnrising, and the parallel of that daie being followed to the east side of ye margent, the hower line that passeth by that intersection sheweth the hower of sunnsett. And if the moneth bee uppon the east side, the howerline yt passeth by anie daie thereof sheweth the time of sunnsett, And the parallel thereof followed to the Horizon at the west sheweth the hower of Sunnrisinge. And in either of theise the hower of
44 Sunnsett being doubled maketh the length of ye night.

Moreover the daie of ye moneth beinge knowne, the parallel thereof cutting ye Ecliptique line sheweth the place of the Sunne, and ye howerline passing by that intersection sheweth ye right ascension. The arch of ye Equinoctiall conteyned betweene the howerline passing by ye daie, and the howerline of six, sheweth the ascensionall difference. The Parallel of ye daie at the meridian line sheweth the declination of the Sunne. And that same parallel cutting anie howerline, sheweth both the Azimuth and Almicanter of that hower.

And cutting anie Azimuth sheweth both the hower and Almicantor of that Azimuth. And
45 cutting anie Almicantor sheweth both the hower and Azimuth of that Almicantor. Likewise the Jewdaicall howers maie bee inserted with anie of theise, And soe manie and diverse propositions and theire converses may bee found, wch depend only uppon the mutual intersection of theise lines one with another.

ALSO IT MAIE BEE DESIRED TO KNOWE WHAT DAIE OR MONETH THE DAIE SHALBEE ENCREASED OR DECREASED ANIE POSSIBLE TIME REQUIRED.

Example

When the daie is at the shortest it maie bee desired to knowe when it shall bee encreased one whole hower.

To knowe this, marke well what howerline passeth by the intersection of the Tropique of Capricorn ♑ with the horizon at ye West, Now theise hower lines being each of them one degree asunder (as hath been said) therefore count from
46 the said hower line 7 1/2 degrees more the measure of halfe the time desired (because 7 degrees and a halfe is the measure of halfe an hower) and the hower line passinge by that distance, shall (uppon the circular segment) cutt the daie fo the moneth desired. And thus doeing the daie shalbee found to bee increased one whole hower uppon the 15 daie of Januarie, and two whole howers uppon ye second daie of ffebruarie etc.

OF THE STARRS IN THE CONCAVE, AND FIRST TO KNOWE WHAT STARRS ARE UPPON THE MERIDIAN.

In this case wee are not to deale, but with one quadrant of the meridian, and that is from the Zenith to the Horizon at the North wch Quadrant wee distinguish by two severall names the upper parte and the neather parte thereof. The upper parte is what wch is conteyned betweene the Zenith
47 and the Pole of the north, and the neather parte from the pole to the Horizon.

And because that all the shaddowes have a contrarie position to theire bodies in respect of ye subject wch causes them, Therefore in this diall the center thereof representeth not ye Nadir but ye Zenith, whenso it cometh, that that parte heere (of the Meridian) wch wee call the upper parte, to wit from the Zenith to ye Horizon is reallie in this place the lower parte thereof and that wee call ye lower parte thereof is in this diall the upper parte.

But to finde ye thinge required observe what starrs shall fall to bee in a straight line with the plaines of the East or West dialls, wch you may both speedilie and easille (with your eye) perceave, I saie that those starrs soe found are (at that instant) uppon ye meridian.

48 **AND SOE HAVINGE THOSE FUNDAMENTALL GROUNDS SAID TO FIND THE HOWER OF THE NIGHT BY YE STARRS.**

Hee that will understand to doe this conclusion, must first have somuch acquaintance of ye Spheare (wch maybee easilie obteyned) as to knowe the constellations by eyesight and bee able to judge wch bee the Starrs of them, that hee hath present use of, and then hee may proceed thus.

But because in this proposition theare is no regard at all had to the declination of the sunne or starrs, but onelie to theire right ascension, therefore they maie bee supposed to bee alwaies in the Equinoctiall circle, and in the selfsame points thereof wheare theire right ascensions are found to bee.

And forasmuch as theise starrs heere described have noe nicessitude of settinge or risinge but doe continuallie move about the pole of the world
49 above ye Horizon, thereby it commeth to passe that all of them may bee seene of us, both uppon the upper parte of the meridian & uppon the neather parte thereof. Soe then if the right ascension of the sunn and starrs bee equall, then the starr will come to the upper parte of the meridian with the sunn at 12 a clocke at noone, and then wee cann make noe use of it. But it will likewise come to the neather

parte of the meridian with ye sunn at 12 of the clocke att night, and soe it sheweth ye hower to bee twelve.

But if the sunne bee departed from the starr (I mean in respect of their right ascensions) then I call the arch of the Equinoctiall conteyned betweene the points (of the starrs right ascension and the sunns right ascension) the arch encreasing and the remainder of ye whole Equinoctiall circle I call ye arch decreasing.

If the arches encreasinge and decreasinge bee
50 equall one to another, that is to have ye sunne and starr opposit, or 12 howers distant, then that starr will come to the meridian at 12 of the clocke at night. If the arch encreasing bee less then 12 howers, soe much as it is less in time, soe long shall that starr come to the upper parte of the meridian after 12 of the clocke. And soe much as this arch encreasing is more than 12 howers so much before 12 shall that starr come to the meridian, The like may bee knowne both waies by the arch decreasing.

Example of this

The eight daie of October I desire to knowe at what hower of the night the starr called Benenaiz (wch is in the end of the Great Beares taile) wilbee uppon the meridian. The same daie I find the right ascension of ye Sunne & of that starr to bee equall that is each of them is 13 hrs and 32 minuts.
51 Therefore I saie yt (accordinge to ye rules formerly delivered you shall finde that starr uppon the neather parte of the meridian, at 12 of the clocke a night.

And uppon the 5th of Aprill you shall find the arches encreasinge and decreasinge equall, that is to have the sunn and ye starr at 12 howers distance, wch may bee easilie found havinge the points of both theire right ascensions in the Equinoctiall circle of the concave. And uppon the 8 of Januarie, havinge ye arch encreasinge found to bee 6 howers and 28 minutes it sheweth that it wilbee uppon ye neather parte of the meridian at 5 of the clocke and 32 minutes in the evening, And ye next morning after it wilbee uppon the upper parte of ye meridian at 5 of the clock and 34 minutes.

Soe hereby it is manifest that this arch encreasinge (if it bee less then 12 howers) is ye true measure of time that the starrs shalbee uppon the lower parte of ye meridian - before 12 of the clocke
52 at night And if it bee more than 12 howers the excesses thereof is the time yt it cometh to the upper parte after 12 at night. And ye arch decreasinge being less than 12 howers is the measure of time yt it commeth to the nether parte of the meridian after 12 at night.

Soe havinge anie one of theise starrs uppon ye meridian the hower of ye night may be found and that is the most this diall cann promise for this particular. But in a plaine Horizontall diall the matter may bee soe handled that ye hower of ye night may bee readilie and preciselie knowne both by theise starrs and the starrs of the southerne constellations also, what respect or position soever they have to ye meridian.

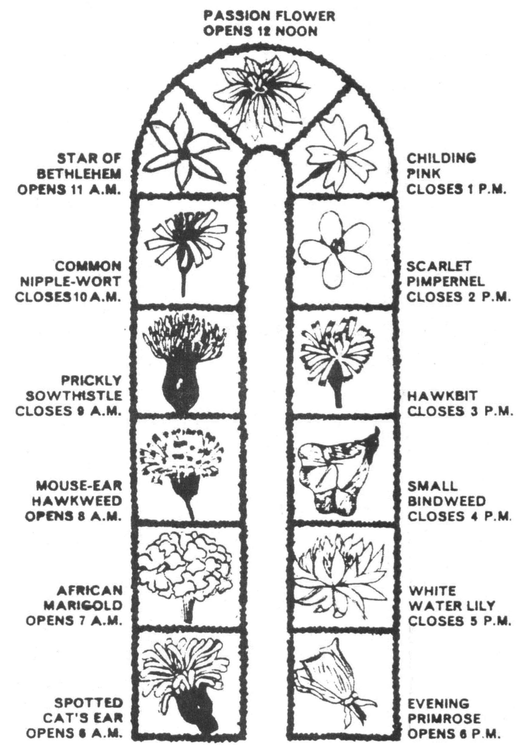
And thus much for ye description and use of the great concave & the margent thereof.

To be continued.

FLOWER POWER

SUNDIALS are not the only form of time-telling by the sun. A popular and decorative means in European nineteenth century gardens was by a series of flower beds laid out to form a "clock face", each individual bed being devoted to a specific daylight hour. Much depends upon the latitude and the openness or otherwise of the garden site, however on a sunny day in the summer season, the flowers in the attached diagram will open at the approximate times shown, at intervals of about an hour, to give the indication of time within about half an hour. Naturally the flower opening times are synchronized to local solar time, and so the usual Equation of Time, Longitude, and addition of one hour, corrections are necessary if you wish to check clock time in summer.

Unlike the sundial, the flowers will attempt an indication even without direct sunlight, but the observer is likely to be misled since some flowers steadfastly refuse to open if the light is not strong enough. It is thought that the flower "dial" fell into disuse because of the labour in preparing the flower beds and because it is useful for only a few months in the year at most. Most of the flowers shown in the adjoining diagram are in fact weeds, and the need for a pond for the water lily is another disadvantage. However a smaller version of the flower "dial" with a sundial as a central feature could be an attractive addition to the garden, perhaps with the plants placed in urns.



TREASURES OF THE CHURCH

As there was little outlet for publication of articles on sundials in horological literature up to quite recently, one often finds such articles tucked away in fairly obscure magazines. Prior to the Second World War, the Reverend T.W. Cole published a number of small pamphlets on the subject of what he termed "incised dials", now generally referred to as "scratch or mass dials", at his own expense. In August 1935 he had an article on this subject with the above title published in *The Church Assembly News*, 1935, pages 176-177.

The custom, which lasted over a thousand years, of cutting or incising sundials direct on the stonework of churches, has given us a permanent and most valuable record of the successive attempts made by English churchmen from Saxon days until the eighteenth century to tell the time by means of the sun. The entire history of English sciagraphy, or the art of marking the hours by shadows, is thus told on church walls.

For the first five hundred years or so, the sundials incised or carved on church walls (on the south side, of course) were usually quite small, about the size of one's hand, and although placed at about eye-level they are today decidedly inconspicuous after so many centuries of weathering, to say nothing of lichens. After the fifteenth century sundials gradually became bigger and were incised increasingly higher up on the wall until in the eighteenth century they became highly finished and prominent such as the one on the parapet of St. Sepulchre's, London, or that at St. Katherine Cree dated 1706.

The fact that eighteenth century sundials were painted as well as being incised suggests that their predecessors, the medieval dials, were similarly treated. The medieval practice of lime-washing the exterior of churches would lead us to suppose that dial-makers of that period must have been alive to the advantages of black hour-lines painted on a white background. In such cases the lines that we now see incised on church walls would be merely skeleton outlines, or graffiti, of once fully painted dials. All that remains of these medieval dials nowadays is a hole for the pointer (which has long since disappeared) and the few hour-lines radiating therefrom scratched on the stonework sometimes with an encircling line sometimes not.

DIFFERENT TIME SYSTEM

In looking at dials made before the fifteenth century, we have to remember that a time-system widely different from our own was then in vogue, namely the ancient method inherited from the Palestinian Jews of the first century (see Mark, XV, 25, 33; Acts, II, 15 and elsewhere. This system merely divided the stretch of daylight into equal parts and the sundials of the period were correspondingly planned on this primitive principle, a horizontal line left and right of the pointer hole being scratched for the shadow at sunrise and sunset, a vertical line downwards for the midday shadow (sext or the sixth hour) and two further sub-dividing lines for midmorning (terce or the third hour) and midafternoon (none or the ninth hour), see illustration of Saintbury dial.

EARLY ATTEMPTS AT ACCURACY

These lines which on Saxon dials were sometimes carved in relief instead of being incised would give sufficient guidance for the timing of the chief services and for the rest any lines could be added to suit the requirements of the individual village. These early dials are consequently characterised by a lack of uniformity, in fact most dials made from the Saxon times to the fourteenth century can easily be recognised by their incomplete set of hour lines, i.e. in their not having the full number of twelve as in later dials.

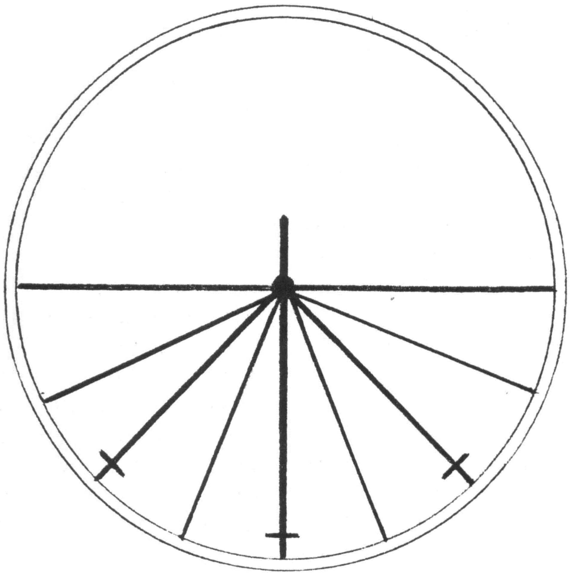
A notable period in the making of sundials began in the second half of the fourteenth century, when mechanical clocks came into use, and dial makers made pathetic attempts to redesign their dials so as to record clock-time. A big number of such experimental dials are still to be seen, and can easily be recognised by their possessing twelve equally-spaced hour-lines, some dials indeed being further distinguished by these lines being marked with Roman numerals in the new clock notation. But all such sundials must have been, on the whole, indifferent timekeepers however assiduously the pointer was adjusted (presumably by being bent downwards at varying angles to suit the successive seasons).

Up to the present about 1,400 churches have been recorded as possessing one or more of these medieval dials. They are to be found in every English county except Lancashire and London. For some counties the records are almost complete as for instance for Worcestershire where the diocesan advisory committee took an official census about a couple of years ago (1932), and for Somerset, which heads the list with over 140 churches, Wilts, Hants and Gloucestershire, where local antiquaries have been specially assiduous in searching for and recording medieval dials. Fairly good lists have also been made for other counties but there is still plenty of scope for further discoveries, specially, say in Dorset, Bedfordshire, Cambridgeshire, Lincolnshire and Leicestershire. In general, medieval dials become fewer as we reach the northern counties.

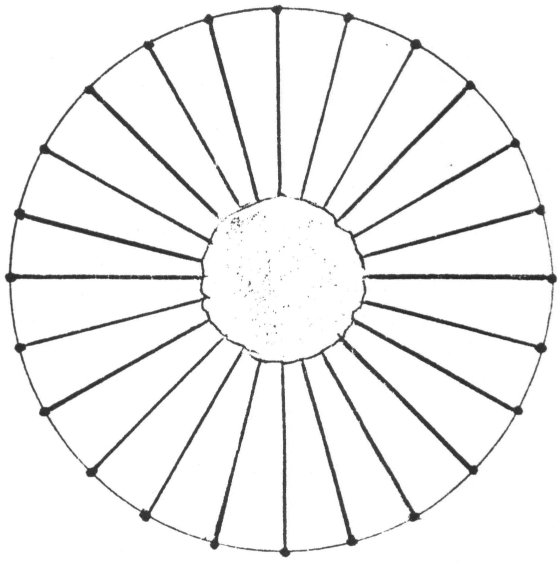
FIRST SCIENTIFIC DIALS

Following these medieval dials, the next development in incised sundials came about through the discovery, due to the increase of astronomical knowledge in the fifteenth century, that a true sundial could be made by slanting the pointer at an angle to suit the latitude of the church, and by spacing the hour-lines at calculated intervals. Very few early examples of this scientific type have as yet been noted, but there are possibly a good many awaiting discovery or recognition. The most interesting to date is the dial on the porch of Litlington church, Sussex (see illustration) which is cut in the manner of the old medieval dials but with the lines spaced at gradual intervals on the scientific principle just mentioned. Other early trial-dials of this kind are at Barfreystone, Kent and Charwelton, Northants.

As yet no systematic attempt has been made to compile a list of the post-medieval incised sundials, but such an



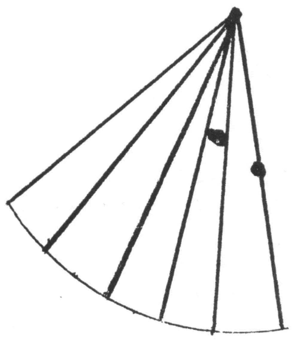
SAINTBURY CHURCH, GLOUCESTER



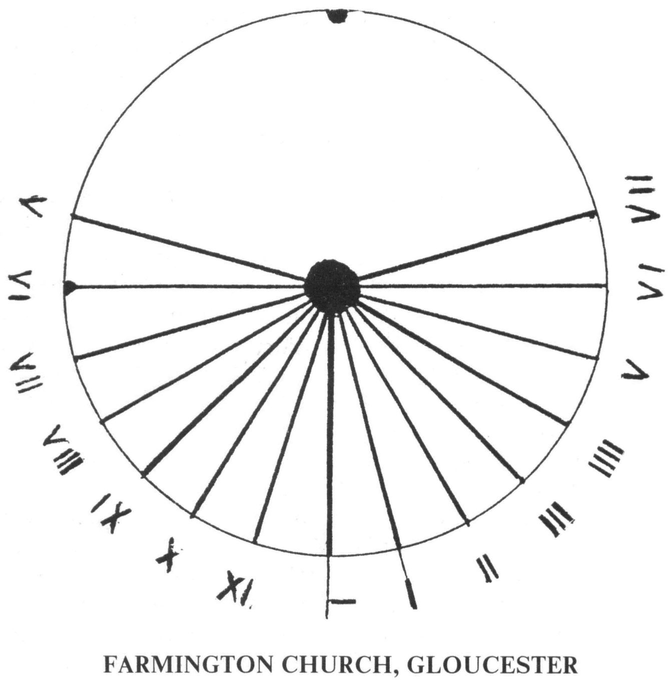
NORTH LEACH CHURCH, GLOUCESTER

ILLUSTRATIONS FROM "TREASURES OF THE CHURCH - SUNDIALS"

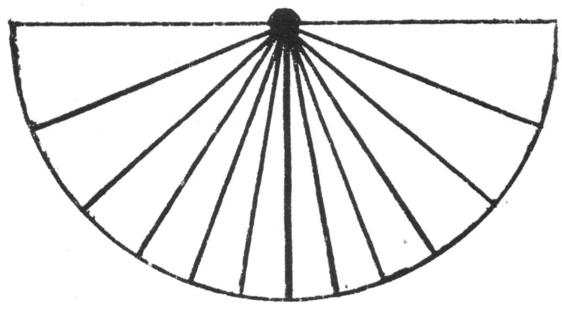
BY T.W. COLE



COLN ROGERS CHURCH, GLOUCESTER



FARMINGTON CHURCH, GLOUCESTER



LITLINGTON CHURCH, SUSSEX

inventory would be most valuable not only as a help towards their permanent preservation but also as affording together with the existing list of medieval dials * a complete series which could be arranged chronologically to show every evolution of the church sundial and also certain collateral developments, some of which show considerable ingenuity.

AMATEUR DETECTION

Finally, the subject is one, fortunately, not limited to the expert. The only qualification required in the discovery of these ancient sundials is an alert pair of eyes. Further there is the added zest of that a dial might be discovered in a most unlikely position, owing to a stone on which a dial is incised being reused in another position. For instance, at Churchill, Worcestershire, a medieval dial is inside the church on a reused stone just behind the pulpit. At Bodenham, Herefordshire, a dial is on the north porch, on stonework shifted from the south side of the church. At Pirton, Worcestershire, a very old dial, possibly Saxon, is over the inside of the north door, where it was fixed after being found among debris under the church floor. At Stowell in the Cotswold a most interesting dial now forms the inside sill of a window. Everyone therefore who visits old churches has a chance of making a new discovery and in this will perform a useful function in so far as the recording of a dial is the chief help towards preventing any inadvertent destruction.

SUNDIAL LITERATURE PUBLISHED BY T.W. COLE

1. *Scratch-Dials on Churches.* Interim List, Wimbledon, 1934. * This is the list referred to in the article - original price being $4\frac{1}{2}$d, post free, now about £5 to £10.
2. "Treasures of the Church Sundials", *The Church Assembly News*, August 1935, pages 176-8. This is the article reproduced here, but the original photographs are produced as line drawings of the dials only.
3. *Classification of Church Scratch-Dials,* Wimbledon, 1935.
4. *Origin and Use of Church Scratch-Dials,* Wimbledon, 1938.
5. *Scratch-Dials and Medieval Church Sundials.* Relation to scientific sundials. Saxmundham, 1938.
6. *Church Sundials in Medieval England.* Prize Essay. Saxmundham, 1947.

Entries 1, 3, 4, and 5 were small pamphlets, and these are quite scarce today, originally they were sold by the Hill Book Shop, 87 High Street, Wimbledon. The last article has not been seen by the writer. The Reverend Cole entered the living at Saxmundham, hence the change in the place of publication.

The late Professor David Torrens obtained copies of T.W. Cole's pamphlets, the following is a letter from T.W. Cole to him:

at THE RECTORY,
STRATFORD ST. ANDREW,
SAXMUNDHAM, SUFFOLK,
May 5th 1939.

Dear Professor Torrens,

I have pleasure in inclosing booklet as requested and also the change from your too liberal remittance (David Torrens had sent a shilling - 5p postal order).

May I send for your kind acceptance a previous one I wrote as this contains a list of scratch dials although that for Ireland only covers a couple. I don't know whether this is representative or whether the paucity is due to my not having fuller reports.

The blue booklet, however covers my later reflections on these puzzling dials, and they seem to lead to the conclusion that in England at least, the folk of medieval days were content with merely rough divisions of the day and that the hour as a definite unit of time was not measureable and so not in vogue. I have tried to find out any medieval instance where an hour as a unit of time has been mentioned e.g. in worker's pay. But up to the present I have drawn a blank. If you should have studied the period and know of anything that might throw light on the question I should be very much indebted to have a note of it.

Yours very truly,

This letter is reproduced with the original style and punctuation, as is the article replicated here.

Cole carried on from where Dom Ethelbert Horne had left the subject, but apart from extending the list of dials to other counties, did not advance the subject greatly. He added a few extra dials to the list in manuscript, unfortunately Torrens, who normally added piquant comment, made no entries in his copies of the pamphlets. Although Cole was supplied with examples from Normandy, he never associated scratch dials with the French. Since there was a tradition of dialling extant before the Norman invasion, and only after this event did dialling in England apparently revert to a more primitive form which evidently met a religious requirement without serving the general secular demand, it is surprising that Cole did not look to the Continent for a solution. In 1985 the writer was corresponding with M. Jean Laviolette in respect of his article on such dials in France, from which it was apparent that the so-called Anglo-Saxon scratch dial was imported with the Norman invaders. See "From the Clock of Solomon to the Canonical or Scratch Dial" by M. Laviolette in *Clocks,* Volume 8, No. 3, pages 23-28, September 1985.

To look for payment by the hour in those days would be a waste of time as men hired themselves out by the year for as little as 7s 6d, and as the twenty-four hours of the day were the master's prerogative, the hourly amount would be too trifling to record. The passage of time was immaterial to most workers since the only reward at the end of the day was to be able to eat and rest in preparation for the next day's toil. Sunday and Saint days provided the only release, and daylight and darkness regulated the period of working. Much has been written about the poor accuracy of the scratch dials as time indicators, but if looked upon as indicators for people to attend a church service, whose precise time of commencement was of no importance at all in a country church, it is obvious that the dials were quite good enough for the purpose. As in the less developed parts of the world today, people just turned up with plenty of time to spare and awaited the moment of summoning with patience. Most people accepted the time service provided in the absence, or ignorance, of anything better. With all due respect, therefore, T.W. Cole merely kept the subject of scratch dials in front of those who were mildly interested in these strange relics of an almost forgotten past.

Pioneering work in the field of scratch or mass dials was done by Dom Ethelbert Horne of Downe Abbey in Somerset. In 1917 he published his first little treatise entitled *Primitive Sundials, or Scratch Dials,* containing a list of those in Somerset, followed by the same text entitled *Primitive Sundials, or Scratch Dials,* but with the list of Somerset dials omitted, published in 1929. Both these books are very rare today and expensive to obtain, the first edition is much to be preferred. He was really drawing together the threads of isolated articles which had appeared in archaeological journals, plus details of the dials visited by himself or his collaborators. His work left us with the conclusion that these dials were the work of our rude Anglo-Saxon forbears who had suffered a mental decline under the influence of their French masters. The true Anglo-Saxon dial previous to the Norman invasion, whilst not constructed on scientific lines and only showed the time of day in a most cursory fashion, shows a skill in the sculpting, incising, and working of stone far above that required for the marking out of a true scratch dial, the latter would not be far beyond the competence of most of us today, whereas the production of a dial such as at Kirkdale would be far beyond our immediate untrained hands to perform. Neither Horne or his successors mention that the two types of dial could be found on the same building, so there was no requirement to explain why such a retrograde method should be adopted so universally. The lavish building and rebuilding programme of churches and cathedrals by the Normans, and their desire to obliterate, what was to them, the rude and uncouth Anglo-Saxon practices and traditions, has eliminated much of what might have come down to us, distorting the picture now presented. In remote areas of insignificance, the old dials remained, or perhaps, as at Kirkdale, were hidden under a layer of lime plaster. Here the priest's entrance has several scratch dials cut into the stone, and must have been placed there after the main dial was erected just before the Norman invasion of 1066, apparently a backward step if the main dial was still displayed.

Also prior in the field of publication to Cole was Arthur Robert Green, who had his book *Sundials - Incised or Mass-Clocks* published by The Society for Promoting Christian Knowledge (SPCK). The book was printed in England and published in New York and London in 1926. It has been reprinted in recent years (1977), and whilst it suffers from a number of weaknesses in the treatment, and Green's biased opinions; it makes interesting reading. Much of the information and reasoning is based upon the published work of Professor G. Baldwin Brown and the Reverend Daniel Henry Haigh, both of whom used imagination where factual information proved to be shortcoming. Green attempted to apply scientific analysis to the dial forms he recorded, without really achieving anything worthwhile. It is unfortunate that the frontispiece in his book showing what would be an excellent dial over the door of the church of St. John at Sherborne, has an electric cable running just above and turned down at right angles to run parallel to the noon line. It demonstrates the unsympathetic way in which these old dials were regarded in the past.

On 26th April 1926 Green sent a letter to *The Times* on the subject of preserving mass dials and preventing such philistine treatment, the Editor was sympathetic but refused to publish it. The letter was again sent on 25th February 1985, when the Editor once more declined to publish it. The only other contribution made by Dr. Green seems to be the account "The Anglo-Saxon Sundial at Pirton" in the *Transactions of the Worcestershire Archaeological Society,* New Series, Volume IX, pages 21-24, published in 1932.

The letter to *The Times* is worth repeating here as it is one of the few glimpses into the contemporary thinking about mass dials, it was dated 12 April 1929.

Croyland, Nr. Romsey, Hampshire.

To the Editor of The Times, Sir,

The interesting correspondence on mass-clocks in your paper and in the *Guardian* will I trust lead to some active steps being taken to preserve these little time-markers from the destruction which has overtaken many hundreds and Mr. T.W. Cole is to be congratulated for bringing the matter forward. The unfortunate fact remains that the country Rector or Vicar is frequently (there are notable exceptions) quite uninterested in his church from an archæological point of view and until he can be roused from this indifference and induced to take an interest in the subject, mass-clocks and many other objects of national and historical interest wil continue to suffer from neglect, misunderstanding and destructive restoration.

Mr. Cole's suggestion that the Bishop should include mass-clocks in the list of questions which he asks incumbents before his visitation is excellent and I hope will be acted upon, but it should not be limited to rural dioceses for I have recently found these dials on some city churches, e.g. on York Minster and there are others on churches in Salisbury and Southampton and no doubt there are others on churches in large towns; they only require looking for.

A list of mass-clocks in every diocese is the first essential, for if they are not known to be present obviously they are liable to defacement in many ways, such as re-tooling or plastering. [Re-tooling is the removal of the weathered surface of stone to improve the appearance]. Is there any means of preserving a mass-clock from the action of the weather? A small wooden frame, with a door, fixed over the mass-clock, either with or without a piece of glass, would give some protection and would also serve to point out that there was some object present which needed safeguarding.

That excellent little book "The Protection of our English Churches", published by the Central Council for the Care of Churches, 2/6 [12½p and a high price for 1929] gives the following advice for the preservation of stone work. (Mass-clocks are not mentioned). "In the case of some of the softer limestones coating with lime-wash is the best preservative and is always a safe and simple method, especially if the surface is inclined to porosity. Chemical preservatives should only be used under skilled advice".

In the attempt to preserve a stone with a dial incised on it by means of limestone care would have to be taken not to apply too thick a coating, otherwise the lines and holes would be entirely obscured, but even if that should happen, the dial would not be damaged, it would only be covered up. A careful application would leave the lines visible.

I should be interested to know the name of some person who can give skilled advice about the use of chemical preservatives.

The Reverend Fairbairn asks about "hole-dials". In most hole-dials the hole is much too shallow to have held a peg and I think that the holes in these cases would take the place of lines and when the shadow of the gnomon fell on a hole, it would indicate a certain time. There are quite a number of mass-clocks in which the shadow of the gnomon, instead of falling exactly along the lines, cuts across them at an angle, and in such a case the end of the shadow reaching a hole would be a more accurate means of telling the time. Mass-clocks are found on the south sides of churches and so are low side windows and sometimes these are found in close proximity. Some archæologists who think that low side windows were used for outward confession have associated the external approach to the window with time. If there is any foundation for this idea then it is possible that the visiting friar might have placed a peg in the hole of a mass-clock, if the hole were deep enough, to indicate the time when he would receive his penitents.

In conclusion I would commend these insignificant but fascinating little markings to the care of the Diocesan Advisory Committees feeling sure that if they will interest themselves in their preservation a great deal can be accomplished.

Arthur Robert Green.

Author of "Sundials, Incised Dials or Mass Clocks". [Published in 1926].

A note was sent to A.R. Green by the Editor of The Times dated 26th April 1929, on the standard E form of the time:

The Editor of The Times regrets he has been unable to find room for the enclosed communication as he had hoped, and he now returns it with his compliments and thanks.

The letter is written closely, in excellent calligraphy, on two sheets of paper. What disappointment or regret at the non-publication felt by Green is not recorded. In those days it was regarded as a feat to have a letter printed in The Times, but it is to be feared that a few more punctuation marks in the text would have been necessary before publication. The writer re-submitted the letter on 25th February 1985, with precisely the same result but with a much quicker reply and rejection within three days. Perhaps it will be third time lucky.

It would seem, on the face of it, that T.W. Cole based his own work mainly on Dom Ethelbert Horne and that of Dr. A.R. Green, and in fact Cole corresponded with Green, as witness the letter dated 9th April 1935 sent by Cole from his home address - Normanhurst, 8 Routh Road, Wandsworth Common, London SW18.

Dear Dr. Green,

I have pleasure in inclosing a copy of a further little pamphlet I have done - though I am afraid you will not agree on some of the findings.

Anyhow I hope it may stimulate yet further interest in the subject. I have been surprised at the wide interest in these matters, largely due to your work and lecturing it.

Yours very truly,

T.W. Cole

Another worker in this field, also basing his studies on Horne, Green and Cole, was F.N. Fisher, who contributed an article "Derbyshire Scratch Dials" to *Derbyshire Archaeological and Natural History Society's Journal* of 1935, pages 31-43. It adds little new to the subject and amounts to extending the listing of the dials in Derbyshire. Of 150 churches with medieval features inspected closely, only seventeen were found to have scratch dials. Since dials are often found in quite unsuitable positions, including being placed inside the church by re-using existing pieces of stone in rebuilding work; there is no means of telling how many dials have been removed or obliterated in the past. Those now left only tell us of the survivors.

Once so common, these dials have left no mark in the written records of the church, not a single comment upon them in ancient British records has ever been found. The answer to their origin seems to lie on the Continent, and in particular, France, based upon even earlier practices.

An article which may have spurred T.W. Cole into writing his own may be found in the January 1935 issue of the *G.L.M. Review,* Issue No. 21, pages 11-13. The author is not named but is evidently A.R. Green, as it makes use of some of the photographs from his book, and seems intended to publicise the work to encourage sales. These were the days when a book could remain in print for decades. The article is entitled:

GNOMONICS - THE ORIGIN OF SUNDIALS

One can only beg that the reader will not "abandon hope" on the score of the title, which is certainly perturbing in its severity, accept apologies for its use, and rest assured it will not be repeated.

"I never noticed it" is probably more often said of the dialling to be found on ancient buildings all over Great Britain than of any other of the many links we have reminding us of the past.

But let us begin at the beginning and trace back the history of dialling on the walls and monuments, or from the instruments which have been discovered, for the 18th century sundial to be seen in so many manor gardens was by no means the first word in time recording. The origin of dialling seems to be lost in antiquity. Charles Lamb once said that the sundial is so ancient that Adam could not possibly have missed it in Paradise. However one may be reasonably sure that the shepherds of old stuck their staffs in the ground and marked with longing eyes the progress of the shadow over the dial they would make to represent their day's work. Probably the earliest known recorder of the sun's movement was the crossplane, used in the time of Thotmes III, 1500 BC, a simple device, which by marking the length of shadow in the mainplane (which was turned to the east in the morning and to the west in the evening) divided the day into watches, a division of time which was similarly adopted later by the Romans for military purposes.

Perhaps the earliest recorded references are those in the Old Testament which tell us of the days of Ahaz, who reigned over Judah 742 BC (Isaiah 38, 8). Other references so recorded are of shadows indicating the use of Sundials and are found in Job 7, 2, II Kings, 20, 9-11. Two hundred years later Diogenes referred to the invention of the Gnomon by Anaximander of Miletus.

In 340 BC the Chaldean astronomer Berosus, introduced a hollow hemisphere or hemicycle, which remained in use for many centuries and became popular in Rome, four examples of which were discovered in Italy in the 18th century. The art of dialling appears to have emanated from the East, probably China, which was an old established nation 2500 BC.

Herodotus tells us that the Greeks derived their knowledge of sundials from the Babylonians, whilst the Romans in turn adopted the gnomon from the Greeks. It was extremely popular in Rome 300-200 BC, and a sundial in a Roman garden was the hallmark of respectability. [On what authority?]

In order that the earlier use of the sundials may be appreciated, it must be realised that until the days of Galileo it was believed that the Sun went round the Earth, and not the Earth round the Sun.

The known world, too, in those earlier days, bordered the Mediterranean, and we are not told what might have happened to the sundials on the Equator and in the Southern Hemisphere, for whilst the sun is due south at noon in the Northern Hemisphere, it is due north in the Southern Hemisphere and directly overhead at the Equator [only at the Equinoxes, twice a year, about March 21 and September 21].

With no trains to catch, nor Trade Union hours to keep, time was of little importance, and the only necessity which probably arose was amongst the religious houses where rituals were performed and masses were said, according to the beliefs of the dominant race.

The Greeks have, fortunately, left an excellent example of their knowledge of the subject in the octagonal Tower of the Winds, which has eight declining dials [seven since one is a true south-facing dial].

It is not clear whether the Anglo-Saxons obtained their knowledge from the Roman settlers or, as is more probable from the Vikings, but there are numerous Saxon dials to be found in this country which are divided into four tides, each line being marked with a cross. The word "tide" in Old English meant "time", and it was not till long after the Norman Conquest that it was applied to the periodical rise and fall of the sea.

The Norsemen continued to use this system, but divided their dials into eight divisions, which were then subdivided into halves and quarters. This total of sixteen divisions made up our present day of twenty-four hours.

The sundial was used in the early churches and monasteries not only as an indicator of the passing of time, but on many of the porches are found dials, the style or gnomon (shadow-maker) of which showed when the numerous masses must be said. It is the remains of these dials on our old parish churches which are so often overlooked. In the early Norman days mass dials were more important than time dials, which is evidenced by one writer who visted fifty churches in the Cotswolds alone and found thirty-five mass clocks. Although the world "clocks" is now freely used, it is perhaps hardly the correct expression, for the word "clock" means "to strike" [clock is derived from archaic words meaning bell].

In Egyptian days the intervals of the night were marked off by a clepsydra, an ancient device, one of which was discovered in Karnac, and dates from Amenhotep III, 1450-1380 BC. This was a water-bowl, the inside of which was marked off in intervals. A measured quantity of water was allowed to drip through a hole in the bottom, thus exposing the marked intervals as the water uniformly escaped [not a correct statement]. This instrument also passed into Europe, but appears to have been supplanted by the sand glass.

There are some excellent examples of 7th century Saxon dials in this country, notably at Escombe-Durham, Newcastle, Winchester, and Wanford, all of which are in wonderful preservation. Another well preserved dial is that of Kirkdale, Yorkshire, which dates from 1064 AD. Welsh interest lies in what Mrs Gatty, in her book on Sundials, describes as "the most remarkable in the collection". It is a dial on St. Cybi's Church at Holyhead, which was founded by St. Kebius in 650 AD. The lines above the dial are attributed to a Welsh Bard named Aeurin Cwawdrydd, who lived about 510 AD, and wrote twelve stanzas on the months of the year. The following are the last two lines:

"Y hoedl er hyd ei haros
Adderfydd yn nydd ac yn nos."

Translation:

Man's life though he prolonged it may
Draws to its close by night, by day.

Charles I took a keen interest in the art of dialling and built a sundial to be set up in the Priory Gardens behind Whitehall. Queen Henrietta also erected one at Holyrood, fashionable examples which no doubt account for so many being erected in the 17th and 18th centuries.

The variety of sundials is very extensive and many ingenious designs are to be found both here and on the Continent. Their erection invariably called for a motto, for no dials (sic) seem to have been considered complete without some reference to the subtleties of life, and here again the variety is unlimited. The shortness of life and impending death seem to be the favourite themes, but humour creeps in occasionally. *Sic transit gloria mundi* (Thus passeth the glory of the world), seems to be the most favoured, but morbid ones are much in evidence.

Prepare to die; Consider your latter end; Beware of the last hour; I shall return, but never thou; What is the hour? - perchance my last; One of these hours will be the last of life. These are well patronised - but one finds occasionally more mundane references, such as:

What is the time? Come why do you ask? Is it to start or end your task?

Wait a moment never say, When hours you mean, or chance the day.

I live in the present - a past I recall - But my future depends on the strength of this wall.

Since I never lose, a fresh excuse go choose.

Believe me mortals when I say, the past is what we make today.

Times wastes our bodies and our wits, But we waste time, and so we're quits.

An interesting story is told as to the origin of the **strange motto** over a sundial at the Inner Temple, **London. A dial having been ordered, the workman was instructed to call later for the motto to be incribed. He did so saying,** "Please I have come for the motto for the sundial". The clerk, in no mood for such demands, of which he knew nothing, replied "Begone about your business", "But I was told to call at this time for the motto", replied the workman; to which the clerk again replied, "Begone about your business". The workman took this to be the motto and inscribed the dial accordingly.

The Benchers, on hearing the explanation of this strange motto, were so amused that they decided to let it remain. [An apocryphal tale, repeated on several occasions, but plausible enough].

Mrs Gatty in *The Book of Sundials* states that this appeared in the periodical **Notes and Queries,** Second Series, Volume 5, No. xi, page 279; the dial concerned was on the old brick house which stood at the east end of the Inner Temple Terrace, demolished in 1828.

As far as the mottoes presented by the author are concerned, they appear to have been manufactured for the article, perhaps emulating T. Geofrey W. Henslow who devoted a complete book to his mottoes and verses for sundials - *Ye Sundial Book Mottoes and Verses for Sundials,* published London, 1914 and 1935.

In spite of the authors of the previous articles being well educated persons, their presentations are far from polished, with many grammatical errors, and evidence of a lack of any real research into the subject. Most of the opinions expressed are subjective without any foundation of fact on which to base them, so the main interest in their work lies in the lists of dials and locations which they produced. Anyone who has searched for these dials knows how exasperating it can be to locate them, once seen the evidence is so obvious that one wonders how it was possible to overlook it. Even when armed with the knowledge of the site of the dial, it is often difficult to run it to earth since many have become so faint, especially if covered with moss or lichens, so as to blend into the general background as if camouflaged by intent. It is much better to have more than one pair of eyes when looking for examples, and it is easy to forget in the euphoria of discovery that there may be other examples, either remote, or in close proximity. Sometimes there are little groups of these dials, for which there seems to be no logical explanation. The writer visited Kirkdale on several occasions to look at the main Anglo-Saxon dial before it occured to him to look for any others which might be there. Modern logic does not enter into the search since the discovery of some dials is by serendipity alone.

One often wonders how the lines of scratch dials were cut, some writers glibly mention the use of a penknife or pocket knife, but if a modern penknife is anything to go by, it is at best a very poor tool for incising sandstone, of which the majority of scratch dials are cut into. Since the old wheels for sharpening tools were made from a hard sandstone, kept wet to act as a lubricant and cooling agent for the cutting edge being sharpened; it is evident that there are particles in the stone much harder than the steel of an implement. It is much easier to cut a groove with a small chisel and rake it out to uniformity than cut it with even the hardest of tempered steel tools. Of course we are presented with well-weathered stone today, when stone is quarried it is often much easier to work when "green" than later when the "sap" has been driven out of the stone and it becomes very much harder.

Another strange feature of scratch dials is the extreme shallowness of the central hole supposedly for the gnomon. Most writers consider that the original holes have been filled with cement, or were placed in the joint between stones, disappearing with later repointing of the joints. Sandstone is far from being a permanent material, and considerable weathering of the surface may occur under unfavourable conditions, nevertheless if the original incised lines have survived, the level of the original surface cannot have been so depleted as to affect the depth of the hole for the gnomon significantly. Often these holes have a large diameter, for example the sundial on Bewcastle Cross, possibly this may be caused by the rusting of the rod gnomon, for the product of rusting occupies a much larger volume than the original metal rod, hence the pressures resulting become great enough to burst the stone structure round the base of the rod. Stone is a poor material to resist such pressures although it may be applied incrementally over a long period of time. This was well known to the Greeks and Romans, who only used bronze ties in stonework. One must suppose, in the total absence of gnomons from scratch dials, that they were removed by human hands where they did not rust away, although wrought iron, which is the material which would be used, weathers exceedingly well. The writer obtained some wrought iron nuts and bolts from SS Great Britain which had been abandoned in the Falkland Islands for decades, and lay there with sea water flowing in and out of the hull. The nuts ran as sweetly on the bolts as when first made, yet they had never been protected by paint. Even a modern steel nail of small diameter driven into an outside wall takes a very long time to waste away. It is noteworthy too that stonework partially protected by paint weathers better than nearby unprotected surfaces.

Another theory for the large diameter of holes for rod gnomons is that the rod was inserted into a lead plug, itself inserted into the stone, this would prevent the rusting process damage which could split the stone completely, since the lead is soft enough to deform under pressure, whilst holding the rod securely in place. Furthermore the rusting of the inserted end of the rod would be prevented entirely since it is the moisture absorbed by the stone, in conjunction with the oxygen of the air, which attacks the iron rod inserted directly into the stone. The lead would prevent the access of both of these to the metal, hence it would remain unaltered. Furthermore, if a new rod had to be inserted, or the original became loose, it would be an easy matter to insert the new, and in both instances, lightly tap the lead to make the gnomon secure again. In general, the majority of the central holes in scratch dials seem too shallow to be satisfactory for the purpose of holding a rod gnomon.

Many writers on the subject take the appearance of scratch dials at face value when clearly the dial may well have been modified over the years if it is anything more than a basic example. When there are several together, it would seem that the requirements of the users must have altered in some way to make the work of cutting another, possibly side by side, worthwhile. What is the connective thread between the cutting of so many dials, which clearly suggest a common origin in spite of superficial detail changes? Possibly the answer lies in directions being given to parish priests from the Church authorities, for it would not have been wise to cut into church walls without prior approval. Even today one seldom sees graffiti on the exposed walls of churches, inside towers and stairways is another matter. The property of the Church has always been jealously guarded and one requires a dispensation before even quite minor matters are undertaken.

To sum up the present position, it may be stated that the situation of the 1930's is little altered except perhaps for a greater awareness and a more appreciative approach to matters antiquarian; the realization that what appears today to be a simple or minor matter, actually represents something which was of importance in a more primitive age. For it must be remembered, that in Britain, in spite of the Roman invaders, sundial makers remained a millenium or more behind in the progress of delineating dials compared to the examples made in Greece before the Birth of Christ. There the ancients had mastered the cutting of a dial for the exact latitude of use and delineated the hour marks so as to divide each and every daylight period into precisely twelve parts as required by the custom of the period. Although Bede mentions that hours were unequal in the seasons, how many dials have been found in England which can show this accurately? To a large extent the large angular distance of Britain from the Equator causes greater problems than for those countries nearer the Equator where sundials originated, yet the dials which survive from the Anglo-Saxon period completely ignore the changing pattern of the seasons, the need for taking into account the latitude of the site and of orienting the gnomon to achieve a measure of uniformity of time measurement. The even more primitive scratch or mass dial seems never to have been intended other than as a time marker for the services of the church on which it was cut; a mere relic of the days when men agreed to meet when the shadow of the sun reached a certain known landmark.

Now that the British Sundial Society has been formed, it may be possible to fulfil the dream of the earlier exponents of the subject by a systematic listing of the remaining dials, locations, actual position on the church, the state of the dial, brief description, unusual features, dimensions and a photograph, drawing or rubbing. Those who are interested in joining in this programme are invited to write to David Young; he being the expert in the cataloguing of scratch dials. As members will be aware, he wrote an article on this aspect in the first number of our Bulletin, and for the first time in the history of dialling it seems that we may be able to compile a National Register of Sundials. This will be of inestimable value in the years to come, upon which it will be possible to compile a more accurate account of the history of dialling in the British Isles, which contrary to what T.W. Cole stated, is not entirely recounted by the examples on church walls, this is a gross over-simplification of the facts. Anyone with similar extracts from magazines is invited to send photocopies for the Society's records and possible use in a further discussion of the subject of scratch or mass dials.

LETTER SENT BY T.W. COLE

20.III.35 — 8 Routh Road
Telephone — Wandsworth Common
Battersea 2824 — London SW18

Dear Captain Warbuton,

Thanks for your letter which was sent on to me. The Hill Book shop have sent on a copy of my booklet to Philadelphia. Possibly you might like to have a spare copy in case you think of anyone else.

Yes, the table on p.3 does strike one as wrong at first, in fact on re-reading my Mss before printing I suddenly felt a shock that I had gone wrong, until I remembered. To make the 6th hour coincide with 12 o'clock, the end of the first hour must be taken. But actually the first hour (or any hour) literally means the duration and cannot coincide with an o'clock, meaning a point of time.

I think it is generally assumed that when the 3rd hour (say) is mentioned in the Bible that it means END of the 3rd hour. Personally I think this system of time-keeping was used normally vaguely, that is, there was always an 'about' when a time was mentioned. Identifiable points of time, as we have now, hardly fitted in with the thought regime of which the sunrise to sunset system was a part.

Your question as to a book coincides with my own curiously! I don't know of any. But my friend Dr. Ward may be able to tell you of one. It is not a subject (ie. timekeeping in other lands and at other centuries) that is touched on in most books except only superficially and by 'rote'!

If I come across anything I will remember your inquiry.

Yours faithfully,
T.W. Cole

Editor's Note: If there is sufficient interest, it is proposed to form a group devoted to the study of these ancient examples of time markers separate to those based on scientific principles. Please write to the Secretary - his address is on the rear inside cover.

THE DIALS OF BONAR

GORDON E. TAYLOR

EDITOR'S NOTE: This is a summarized version of the lecture given by Mr. Taylor at the 1991 Annual BSS Conference at Pollock Halls, Edinburgh.

We know of the existence of four sundials which were made by a certain John Bonar in the early part of the 17th century. The dials are of considerable interest, yet in spite of diligent research by Andrew Somerville[1], we know very little about Bonar himself. It appears likely that he was born around 1580 and eventually became a lay reader at Inverkeithing. In 1612 he moved to Ayr, becoming the Master of the Grammar School, where he remained until 1638. Even this simple chronology has some doubt cast upon it. In the Ayr *Advertiser* in 1928, a D.M. Lyon, writing about Ayr in olden times, states that "in 1605 the schoolmaster's servant (Barbara Grer, servant to Mr. John Bonar, schoolmaster) was reproved for night walking". Uncharitable readers might take this to infer that she was plying a nocturnal trade, but I like to think that she was merely exercising a healthy interest in using Bonar's dials as moon dials.

Bonar appears to have been well-known as a poet and as a dial-maker. The four dials that are known today were all made between 1623 and 1634. In those days dialling was normally taught in schools as a part of mathematics. Spelling had not been formalised and it is interesting to note Bonar inscribed his name as Johnne Bonar on one dial, but as Johanne Bonar on a later dial. Apart from the information of a functional nature on the dials, Bonar used almost all available space on them for poetry and other text, in Latin and English, with some references to the purchases of the dials.

All the dials are of the same type - equatorial, or equinoctial as they were referred to in those days.

The upper surface carried a dial face which was delineated to show the hours right round the clock, whilst the lower side showed only the hours from 6 am to 6 pm, with both Roman and Arabic numerals. An azimuth circle was graduated in one degree intervals, with zero points due E and W, increasing to 90° at due N and S. Inside the marks we find another full circle with the twelve signs of the zodiac each occupying about 30°. These signs are inscribed in an anticlockwise direction like the dates (months and days of the year) given on the circle just inside. Possibly Bonar was better at poetry than gnomonics. The upper side of the 1634 dial shows 31 days in November and in addition allocates a noticeably shorter length for the sign of Pisces than for the other signs. As a result the equinox is shown to occur on March 8 on the upper side, whereas on the lower side it is correctly shown as March 10. These dates are in the Julian calendar of course, since the Gregorian calendar was not adopted in Great Britain until 1752.

Written against the name of each sign is the name of part of the human body. In olden days astrologers believed that this indicated the weak point of a person born under that sign. For example, the weak point of a person born under the sign of Aries, was the head!

Continuing inwards in the dial we find a 32-point compass rose, with the names of one or more ports written against each point of the compass. The innermost circle bears the numbers 1-30, increasing in an anticlockwise direction, to represent the age of the Moon in days. The information given in the last two circles was not for time-keeping but for tidal calculations. In this connection it is interesing to note that a certain John Collier, writing in 1729, a century later; states "While the Moon is on the increase she souths before midnight: whilst [when] she is decreasing she souths before noon. These things are known by every Cabbin-Boy, Collier's Nag, and Waterman's Servant, [and] therefore needs no farther explanation".

It must be pointed out that none of the dials are complete. The gnomon, which would have passed through the centre of the dial to throw a shadow on either the upper or lower side, depending on whether the sun was north or south of the equator, is missing. It should have protruded for at least 10 cm on either side. A revolving pointer, or dioptera, part of a volvelle, is missing from all the dials except the example at Bangor.

Basically a volvelle enabled the user to determine the relative positions of the Sun and Moon, knowing the age of the Moon. The pointer on the Bangor Dial reaches to the date circle and can thus be used to indicate the position of the Sun on that date in the zodiac inscribed on the next outer ring. For tidal calculations this first pointer is set to the Moon's age when New (shown as 30) and a second shorter pointer set to the actual age of the Moon on the innermost circle. The two pointers are then rotated together so that the second pointer indicates the port of interest (and also the "establishment" of that port indicated as a time on the outer circle), whereupon the first pointer indicates the time of high tide on the outer circle.

The establishment of a port is the interval of time which elapses between the time of the meridian passage of the New Moon or Full Moon and the time of the following high tide. In practice it was used as a mean value for any age of the Moon. Another way of looking at the problem of high tide predictions is by saying that high tide occurs when the Moon has the same azimuth (or 180° difference) as the named port on the dial. For example, at Leith, high tide occurs when the Moon is seen in the SSW or NNE. Table 1 lists all the ports on the four dials, the argument on the left being the compass direction.

The 1623 dial was originally at Kenmure Castle, New Galloway, Dumfries and Galloway; and was still there in the 1940's. Since 1968, or possibly earlier, it has been at Dumfries Museum. The 1630 dial was originally at Bangor Abbey and is now at the Bangor Heritage Centre, Bangor Castle, North Down, N. Ireland.

The 1632 dial was originally in Wigtownshire, and later removed to Kinneff, Grampian and is now at the Royal Museum of Scotland, Edinburgh. The 1634 dial was examined by the present author[2] in 1966 whilst it was in private ownership in Buckinghamshire. Research by Andrew Somerville showed that it was originally at Loudon Castle. Strathclyde, until the 1950's. René R.-J. Rohr[3] saw it in 1986 in an antique shop in Brussels, with a price of 3,000 Belgian francs on it. A few months later it had been sold. Where is it now?

ORIGINAL LOCATION AND DATE OF DIAL				
Compass Direction	Kinaure Castle 11 Dec. 1623	Bangor Abbey Dec. 1630	Whithorn 22 Sep. 1632	Loudon Castle 12 Feb. 1634
N	Sky	?	Galloway	Sky
NbE	Redbane	Aberdeen	Wigton	Bamfe
				Solway Sands
NNE	Leith	Wigton	Monroe	Wigton
				Kirkubre
NEbN	Dundie	Dundie	Dundie	W. coast of Lorn
NE	Culros	London	Culros	Culros
				London
NEbE	Perth	Perth	Berwick	Perth
				Robin Hood's Bay
ENE	Stirling	..mal	Cork	Stirling
				Cork
EbN	Falmon	Torbay	Falmon	Falmon
E	Doward C		Humber	Douard Castle
EbS	Bristoll	Bristoll	Bristoll	Foulnes
ESE	Texel R	Brihar	Brihac R	Texell Road
SEbE	Kaskets	Dublin	Dublin	Dublin
				Mcnell's Castle
SE	Orknay	Orkny	Orknay	Wly Orknay
SEbS	Deep	Deep	Deep	Deep
				Needles of Wight
SSE	Yarmond	Yarmond	Yarmond	Dover fen
SbE	Callice	...nds	Calice	Calice
				W islands
S	Galloway		Y	Dunkirk
SbW	Solway	Solway	Solway	Glasgow
				Aberdeen
SSW	Wigton	Leith	Horn	Gravesend
			Leith	Leeth
SWbS	Burdeaux	..lls	g Ferrie	Dundy
SW	London	..lere	London	Amsterdam
SWbW	RH Bay	Brouage	Perth	Berwick
WSW	Corke	Cork	EWC Irland	EW coast Irland
WbS	Barnsey	...mon	Torbay	Caldy
				Lizard
W	Antwerp	Waterford	Douard C	Antwarp
WbN	Harpoell	Texell	Foulnes	Bristoll
WNW	Brihack	Kyll	Texell R	Brihack
NWbW	Dublin	Jambay?	Portland	Ushant III
NW	Freland	...ilor	Foyne	Pichtland Firth
NWbN	Lux	.. w.n	Kaskets	Kaskets
NNW	Dover	Bangar	Dover	Yarmond
NbW	Air	Ayr	Ir	Ayr
				Cape Gallant

TABLE 1 - NAMES OF PORTS ON THE BONAR SUNDIALS

REFERENCES:

1. **Somerville, A.R.**, "The Sundials of John Bonar, Schoolmaster of Ayr", *Antiquarian Horology*, September 1986.

2. **Taylor, G.E.**, "A Mariner's Equinoctial Dial of 1634?", *Journal of the Institution of Navigation*, 20.3 (July 1967).

3. **Rohr, René R.-J.**, "A Sun, Moon and Tidal Dial", *Antiquarian Horology*, September 1986.

PROGRESS ON THE SUNDIAL REGISTER

The BSS sundial register that is being set up will have two main functions:

1. To provide a basis for historical research
2. To assist any restoration work

By computerising the register, it will be possible to deal with all kinds of enquiries, and also producing specialised listings of sundials as requested.

It has been estimated that there could be as many as ten thousand sundials to be recorded in the British Isles. Even with only one sheet of paper per dial, this will require considerable storage space since the pile of paper resulting will be about two metres high; plus the accompanying collection of photographs and slides. As the British Sundial Society at present has no office or staff, that material will have to be stored in members' houses, probably in the Sundial Registrar's house, and possibly in other Council Members' houses. Thus it is essential to keep the paperwork to a minimum.

The new recording forms will support all the information required for record purposes, inevitably it will mean that for many dials there will be many blank spaces. During the past year, with the help of an Advisory Panel, I have tried to ensure that some of the information listed on the recording forms can be transferred to a computer database as easily as possible, and with with minimum risk of error. It will not, unfortunately, be possible to enter all the data into a computer because of the great variety of information that is being entered on the forms, but the more important information such as location, type, condition, and limited details of dimensions, furniture, maker(s), is stored. A separate file for bibliography is also being compiled.

Since the Society does not have the funds to purchase a license to use a database on a computer, or even to buy a computer and pay office staff; I am in the process of writing a suite of computer programs that will do the the same tasks. The system I have devised will have the additional advantage that it can be modified at any time should changing circumstances require it. A certain amount of coding is used in order to have space in the computer memory. To operate this system we shall need the help of members who own computers and are prepared to input data from the completed recording forms, using one of the programs I have written. This data will be entered into temporary files for checking before being added to the actual Sundial Register.

Two programs have been completed so far:

Program SRINPUT.PRG is used to input the data into temporary files. These temporary files are later incorporated after checking into the Sundial Register database.

Program SRALTER.PRG is used to access any particular entry in the Sundial Register and make necessary alterations as required.

A third program is under development:

Program SDIALREG.PRG enables the user to interrogate the Sundial Register. A number of options are provided and the information requested is then available on:

1. The screen 2. A file 3. Printer listing
4. File plus listing

A number of options listed here are already available.

GORDON E. TAYLOR
BSS SUNDIAL REGISTRAR

GENERAL NOTES ON SUNDIALS
(HOUR ANGLE TYPE)

1. All places on earth have different local times of sunrise and sunset. Length of day or night is the same for all places situated on the same latitude.
2. At the equinoxes, all the world has a twelve hour day and twelve hour night. Everywhere the sun rises due East at 6 am and sets due West at 6 pm. The locus of the shadow point (or nodus) is a straight line across a horizontal sundial.
3. If a dial calculated for a particular location is taken to any other place on earth but set up parallel to its original position, then it will continue to show the time as before. The range of time will differ because the change of horizon will alter the times of sunrise and sunset.
4. If a dial is rotated about its style edge through $\theta°$, its reading will change by $\theta°/15$ hours. Consequently if a dial is rotated in this way through 45°, the new times indicated will be those for a position at the same latitude but 45° E or W (depending upon the direction of rotation (ie differing by three hours from the original longitude). Again horizon interference will limit the range.
5. The horizontal dial (of the hour angle type) will indicate time from sunrise to sunset. All others will have limitations because the dial is in shadow at sunrise and/or sunset, or indeed can be in shadow all day and certain times of the year (eg the equatorial type will be in shadow for six months).
6. Markings on horizontal dials run clockwise in the Northern Hemisphere and anti-clockwise in the Southern Hemisphere. The converse applies to South-facing vertical dials, these can never indicate more than 12 hours.
7. The equator has a twelve-hour day and night throughout the year, with sunrise due East and sunset due West. Twilight is very short because of the vertical (or nearly so) direction of the sun near the horizons. At declination 0°, a horizontal dial becomes polar and a vertical dial becomes equatorial.
8. At the Pole, 6 months daylight are followed by 6 months of darkness. Here a vertical dial becomes polar and a horizontal dial becomes equatorial with equal hour divisions and vertical style.
9. A horizontal dial at 38° South becomes a vertical dial south facing at 52° North on the same longitude. Indeed any type of dial whether declining, inclining, reclining or their various combinations can be reduced to a horizontal dial at another location. Parallelism must be maintained if readings are to be as at the original site, ie the style must remain in line with the earth's axis and no rotation given.
10. On a horizontal dial, the 12-24 hour line points North and South, whereas the 6-18 hour line points East

(continued on page 19)

THE DA'IRE-YI MU'ADDIL

AN INSTRUMENT FOR DAY AND NIGHT PRAYER-TIMES IN XVIII CENTURY ISLAM

BY RENÉ R.-J. ROHR (FRANCE)

For many centuries, at least up to Napoleon's Egyptian campaign, Islamic science at no time enjoyed the consideration it merited in the Western World. There may be the excuse that even today its study is a difficult achievement, facing alphabetic and language barriers that are almost insurmountable.

Born in an almost nomadic civilisation, Islamic science gained rapidly from its many contacts brought about by an exploding history of astounding turbulence. In fact, behind these historically unique events there was a stimulant of apocalyptic power driving astronomical and mathematical studies forward, as well as the territorial conquests: the Holy Book called the *Qu'rān [Koran],* to which shortly afterwards was added, the *Haddith,* or collected commentaries of the Prophet's [Mahomet] verbal teachings.

Some few passages of the Holy Texts invite believers to offer prayers on three daily occasions. Elaborate studies of the *Haddith* undertaken in the *Medresses,* the Islamic theological universities, increased this number to five, these collectively forming the obligatory *Salath.* Moreover the hours and intervals of time for the prayers became strictly defined.

During the early periods of this new religious message, precise time determination was impossible except by strict observance of the sun's daily path. This was against the doctrine of the Prophet, who had deliberately avoided the mention of sunrise, culmination or sunset in order to avoid the possible danger of his religion falling into sun-worship. He, of course, could not foresee that these easily observable events would be in universal use by believers after his death; nor that it would soon arise that an elaborate observation of the sun was regarded as indispensable to strict observation of the *Salath.* Thus it is more than probable that these religious prescriptions and proceedings, and these alone, were the fundamental cause of the unprecedented rise of astronomical and mathematical research in Islam, placing them ahead of thinkers in the Western World for centuries. One cannot help feeling that the Islamic scientists must have felt a mysterious power guiding their research causing them to regard its pursuit as an aspect of Divine service. Yet these prescriptions of the *Salath* have never been exactly the same throughout the enormously far-reaching domain of Islam, although the present version is the most widely spread in use today.

Each new Moslem calendar day begins at sunset; nevertheless, when quoted, the list of the daily prayers invariably begins with the noon prayer, the *zour.* Its period begins a few minutes after the culmination of the sun [crossing of the noon meridian], and ends when the shadow of a vertical gnomon attains the same length added to that of its noon shadow. This gives the moment of the beginning of the *asr,* the afternoon prayer, which lasts until the lower border of the sun touches the horizon. Nevertheless isolated groups of people, such as peasants or Bedouins, usually say the *zour* when the length of their own shadow equals their height, ie when the sun's altitude is about 45°. The *asr* is followed by the *maghrib* at sunset, its exact start being the total disappearance of the sun, and its end when twilight turns into dark night, ie when the sun's altitude under the horizon arrives at minus 18° [henceforth written as - 18°]; the *Qu'rān* states: *"When a black thread will no longer be distinguished from a white one."* This begins the time for the night-prayer, the *isha,* that must be said at the latest when the morning twilight begins and the *subh,* the morning prayer is to be thought of by the faithful. Its time ends with sunrise. Moslem believers living in latitudes of more than 48.5° will face problems around the summer solstice, there being no true nights then but twilight only. At latitudes above the Arctic or below the Antarctic circles, there is not even twilight at certain periods of the year!

There are also some more obligatory prayers in relation with *Ramadan,* the fast month; and others too for the mosque officials on certain feast-days and at times of sun or moon eclipses. Almost all of them are presented in the form of mathematical curves on sundials and other astronomical instruments. To Western eyes it is possible that they may just appear to be mysterious puzzles.

But the delination of these devices may be seen as tokens of astonishing mathematical abilities. Ancient sundials in places like Damascus or Qairwan provide sufficient information to enable the *Muwaqqit* to calculate the prayer-times for every day and night over the whole year [1], as well as the necessary elements for the use of the astrolabe. In our modern days, mechanical clocks have driven the ancient methods out of use, and have even pushed the science of these instruments into oblivion. Sadly, Astronomy and Mathematics, formerly very important parts of *qu'ārnic* learning in the medresses, no longer enjoy the favour they did in bygone centuries.

The present study is intended to introduce the reader to the concepts incorporated in the XVIII century instrument known by the name of *da'ire-yi mu'addil* (the eqatorial circle), a name given to various instruments having similar purposes. There are many examples in the Topkapi museum in Instanbul, some others in the collection of the Kandili Observatory some miles away on the eastern shore of the Bosphorus, but none of these can be compared with the present one for giving - although not with mathematical precision - the times of prayer, and especially those of the night.

I first saw this instrument years ago in an antiquarian shop in Paris, and when the owner became aware of my interest in it, he asked me for what purpose it was intended. At the time I did not know, so I asked his permission to photograph it, see Fig 1.

The instrument bears an ivory label engraved with the name of the Sultan *Selim* (1789-1807), a cruel and tyrannical prince. On a thick wooden base, a second label bears an inscription containing. I have been told, an error of grammatical construction. Literary experts in Istanbul were unable to give answers to my questions as to the use of the instrument, but surmised that the author of the inscription had attempted to use the name of Selim in a play of words at the price of distorting the correct grammatical form. Everyone knows that Arabic text

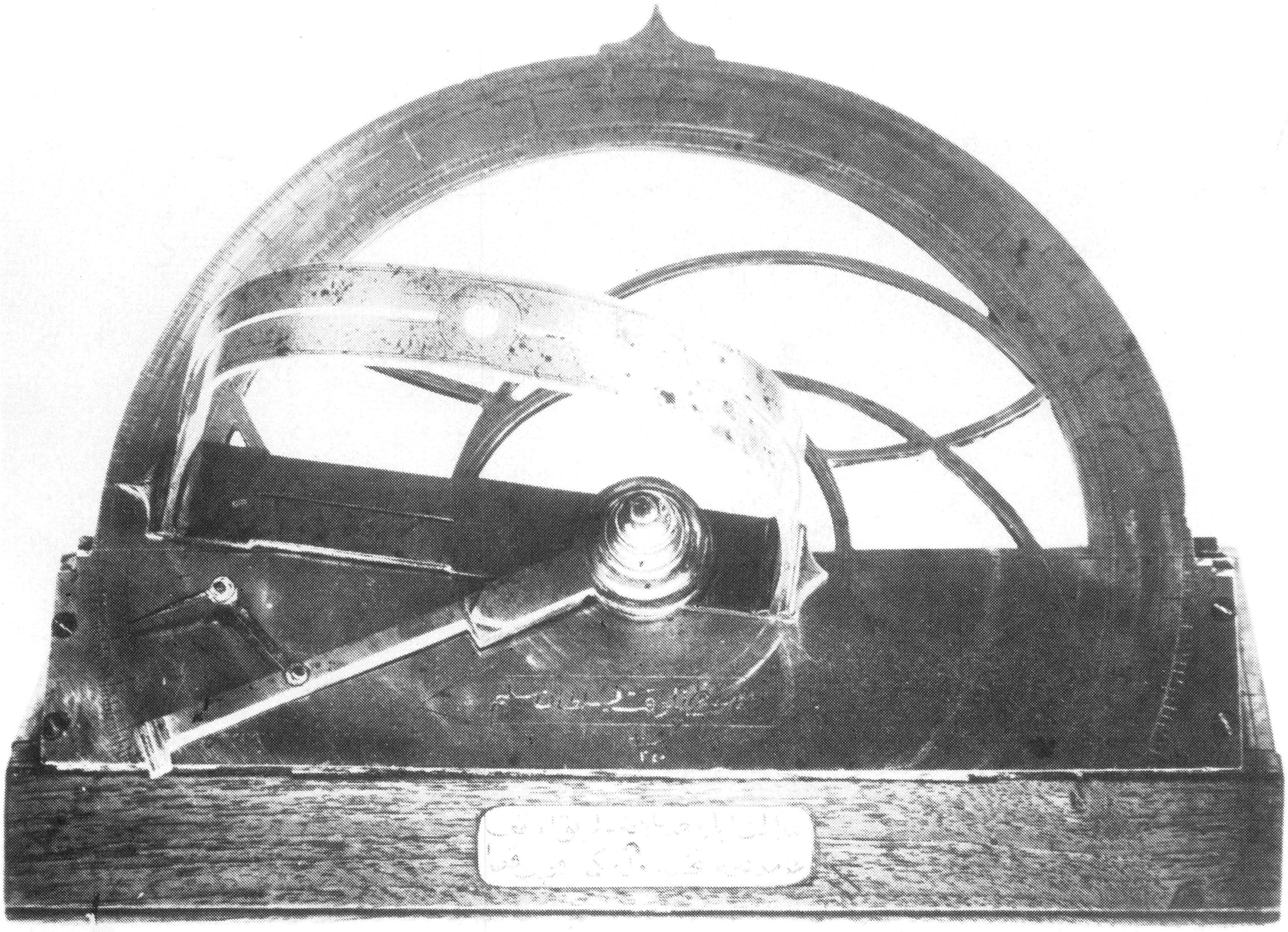


Fig 1: THE DA'IRE-YI MU'ADDIL

lacks vowels, so that readers, even if learned, may not always be able to read immediately words unfamiliar to them. My Turkish interlocutors hesitatingly offered the following translation: *Laudable progress might be built on a foundation of justice only, and only then will it guarantee uncontested sovereignty of the throne.* They thought that perhaps it was an allusion to Selim's cruel tyranny.

The width of the wooden base is some 35 cm. It bears a thick brass plate to which is fixed a semi-circular arc, with cut-out centre, inclined at an angle of 49°, ie the co-latitude of Istanbul, where it was intended to be used and was possibly made. When correctly oriented, the semi-circular plate will be parallel to the equatorial plane. From left to right, the outer part bears a double graduation in degrees and hours, with their origins on the left end of the horizontal diameter, but are extended below this line down to -23° and 1h 32m, the total angle being approximately that of the longest day of the year in Istanbul. Thus the instrument is in the form of an equatorial sundial whose style will be an alidade consisting of a slotted arched brass band turning around the centre of the semi-circle, the supporting lamella being similarly slotted in order to allow the reading of the underlying graduations. The lamella ends in short pointers, one of which indicates its position, the other being a means to ensure its correct centrality. The simultaneous passage of the sun's rays through the openings in the arch and lamella indicates the angles in terms of hours or degrees.

The rim of the semi-circle arc bears another set of divisions which corresponds to the other two scales mentioned at angles of 0°, 90°, and 180° only, the rest of the degrees scale seemingly being moved slightly upward. This scale gives the so-called astronomic or ecliptic longitude corresponding to the right ascension shown by the other two scales.

As previously mentioned, the semi-circular plate has its centre partly removed, in such a way that the remaining parts are graduated curves forcibly evocative of the canonical curves drawn on Turkish Prayer-Quadrants [2]. Further observation will reveal that parts of the drawing may be obtained by folding the plate of an

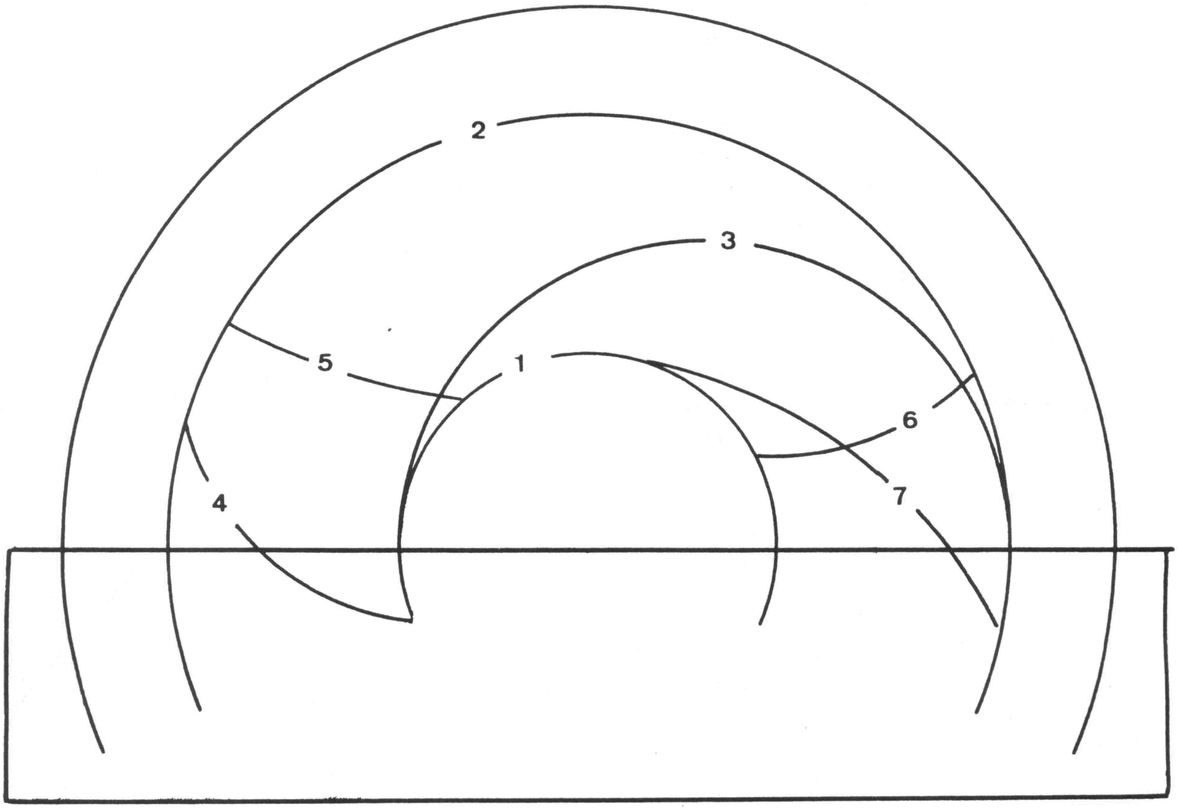


FIG 2

astrolabe along its east-west line. In Fig 2, curve 1 is the Tropic of Cancer, curve 2 is the Tropic of Capricorn, curve 3 is the Ecliptic meeting tangentially at the two tropics. The circular form of the Ecliptic denotes the stereographic projection used. Curve 4 is the part of the horizon between the two tropics to be used for sunrise and sunset, its intersection with the horizontal diameter is a point of the equator giving its radius, in spite of it not having been drawn. When the lamella is in position 90°, its intersection with curve 3, the ecliptic, will again be on the equator and there mark the Vernal point, ie the beginning of Spring. Curve 5 is the *asr* line, curve 6 the twilight limit to be used both morning and evening. It has already been remarked that this limit is not the same all parts of the Islamic world, yet the differences are not very remarkable, it is now accepted as -18° almost everywhere. As for curve 7, it marks the time of *imsak,* a daily prayer during Ramadan - the month of fasting, which the Islamic moon calendar causes to move periodically throughout the year.

The curves 3, 4, 5, 6 and 7 provide their indications by one of their points which depend upon the date. These necessary dates are taken from a supplementary pointer which can move within certain limits: to the left it meets the arch of the alidade, but on the right, for reasons which will be clear later, it cannot approach the pointer of the lamella closer than 23.5°. The length of the pointer extending between the two tropics is cut in such a way that its prolongation would traverse the rotational axis of the alidade, and this part bears a zodiacal scale, of which the centre, (ie the point of the equinox) is fitted with a pivot for a movable smaller pointer in two articulated parts, which will be referred to here as the "articulated pointer".

If the alidade is turned to follow the course of the sun on curve 3, the ecliptic, it will mark out, in moving from left to right, the course of a half-year; and on its return the remaining half-year. In addition, if it travels from 0° to 180° and returns to 0°, each degree can be considered as a day of the year for both semesters; and each 30° will thus correspond to a sign of the zodiac. So if the pointer is directed to a certain degree, the ecliptic will mark, on the cut-out portion, the declination of the sun on the corresponding day of the year. The tip of the "articulated pointer" being put on this declination, and its pointer turned until it meets the curve to be consulted, the required answer can be read. Should the pointer be hindered by the arched part of the alidade, the tip of the "articulate pointer" can be judiciously utilised.

Curve 4, being the adequate part of the horizon, will thus provide the necessary times of sunrise and sunset, and from these the length of day and night. From curve 5 the time of the *asr* will be obtained; curve 6 gives the angle in degrees or hours between sunrise or sunset and the next twilight period. Similarly curve 7 gives the time of *imask.*

Of course there is no difficulty in knowing the times of the *zour* and *maghrib* prayers which depend on known positions of the sun. There are changes with the *isha* and *subh* prayers, these two having to be recited within the limits of full darkness of the night; and to facilitate this most mosques had an astrolabe to hand. The present instrument was probably much less expensive and easier to handle, and is a characteristic example of Oriental commonsense and artisan cunning.

It has already been remarked that the angle between the movable pointer and the alidade could not go below 23.5°, a value that automatically suggests the inclination of the ecliptic. In fact this is not so, and it is also possible that the measurement of this angle may not have been perfectly accurate. It must be remembered too, that in a given place, twilight has not the same duration throughout the seasons, and so the prescribed conditions were not always strictly observed to the letter. It seems that the maker of this instrument made use of -18° as a permanent limit, whatever the season or duration of twilight. He made use of mean values only.

He took [Fig 3] the angle of co-latitude [49°] of Istanbul as the value of the angle of the course of the setting sun with the line of the horizon [BAC in Fig 3]. Let AC be the path of the sun's rays from the horizon line AB to point C, 18° down and separating twilight and night in the morning and evening. In the spherical triangle ABC, we deduce from angle $\alpha = 49°$ and BC = 18°, the value of AC to be 24.17°, an angular distance which takes the sun 96.68 minutes of time to cover. During this time, calculation shows that the moon's distance from the sun will increase by 0.82°.

Now let us suppose that at the moment of sunset the observer turns the alidade to the moon and notes the degrees marked on the semi-circle. He then turns the pointer to that degree and this movement makes the alidade rotate towards the right by 23.5°. The observer must now wait until the arrival of the moon in the slot of the alidade meridian. If during these procedures the moon's movement around the earth had not been different to the apparent movement of the sun, the sun would be at height -18°. But in its downward path, the moon has been receding on its own orbit by 0.82°, and calculation reveals the sun has descended 17.4° only, ie 0.6° or 36′ less than 18°, but in fact a difference of little importance in view of the otherwise neglected durations of the twilight period. Whatever the lack of mathematical precision, the arrival of the moon in the slot of the alidade signals the time of *isha* must be called from the minaret.

But precisely at the same moment, the prayer of *subh* must be considered. The *muwaqquit* knows the duration of the night can be obtained by the use of this instrument. From this determined duration he deducts twice the angle of 23.5° and thus obtains the duration of the *isha* prayer time, which in turn gives the time to announce the call for the *subh* prayer time. The moment the *isha* has begun, the alidade is turned to an adequate star of the eastern sky and immediately the same distance westwards by the duration just determined for the *isha*. By the time the chosen star reappears in the alidade, the time of the *subh* prayer time has arrived.

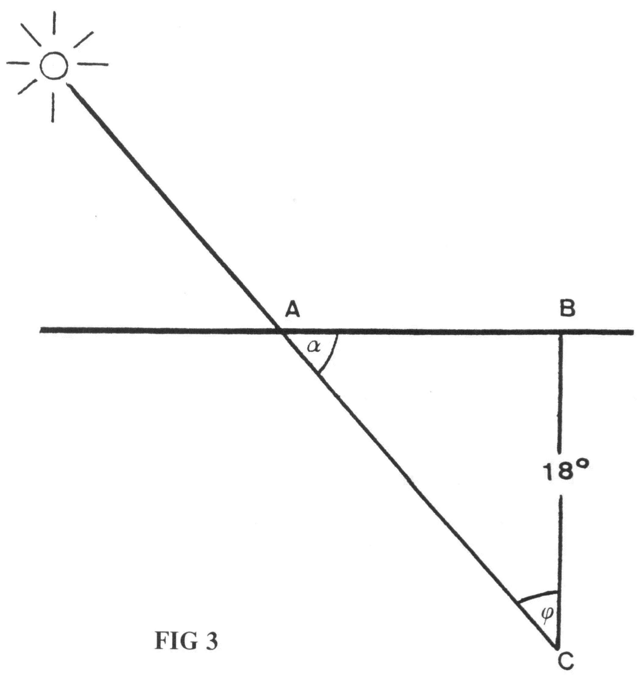


FIG 3

Moon, planets or stars can be used if the tip of the "articulated pointer" is intelligently taken into account under the different situations.

The *da'ire-yi mu'addil* is but one of the many examples of Islamic ways for the determination of given moments. More often than not, Western visitors will encounter problems when considering similar occasions in Oriental museums - but these will be their enthralling short episodes if they are diallers.

BIBLIOGRAPHY

[1] **Réne R.-J. Rohr.** "Über die Gnomonik des Islam", *Schiften der Freunde alter Uhren,* Cahier XIII, Ulm 1974.

Réne R.-J. Rohr. *Die Sonneruhr,* München 1982.

[2] **Réne R.-J. Rohr.** "Türkisch-arabische Gebetsquadranten", Schriften der Freunde alter Uhren, Cahier XV, Ulm 1976.

GENERAL NOTES ON SUNDIALS

(continued from page 15)

and West. Whilst hour divisions are not equidistant (except for the special equatorial case), 180° on the dial is always equivalent to 12 hours, hence am hour lines are in line with the equivalent pm markings.

11. Times of sunrise and sunset change daily everywhere, whereas the Equation of Time at any instant is the same quantity throughout the world.

12. Daily times of sunrise and sunset at any place do not exactly repeat each year because of long term oscillation of the ecliptic. This alters the declination angle, particularly at the solstices.

13. The am time of sunrise at summer solstice equals the pm time of the sunset at the winter solstice, and conversely.

PDB.

Editor's Note: This note was found amongst the papers of the late Noel Ta'Bois, the author PDB seems to be our member P.D. Briggs. As the information is so succinctly expressed, it seems worthwhile repeating here, even at the risk of teaching some grandparents.

SYMBOLS OF SOCIETY : THE EMBLEM OF THE BRITISH SUNDIAL SOCIETY

BY CHRISTOPHER ST. J.H. DANIEL

The formation of a new scientific body or learned society is a comparatively rare event. Consequently it is an equally rare occurrence that a symbol or emblem is required to denote the authority of such a new-found body, to embellish official documents, stationery, badges of office, and the like. The significance of the symbol is usually unquestioned by those who subsequently join the organisation, since the mind accepts that the emblem must have originated from some unimpeachable source. Nevertheless, the majority of symbols, when examined, give little idea of what the particular organisation concerned is all about. A few nautical examples will suffice to make this point.

Of course, such a symbol may be a *crest,* surmounting the helm of a coat-of-arms, designed by the heralds of the Royal College of Arms, in which case the arms themselves might be self-explanatory, although this does not follow. The coat-of-arms of the Royal Institution of Naval Architects, for example, portrays on the shield a 16th century ship at sea, silhouetted against the sun. The shield is supported by two fierce looking fish, or 'sea-monsters'. The helmet is surmounted by a crest taking the form of a single-masted medieval vessel with a square sail. The ship displayed on the escutcheon, a square-rigged three-masted bark, takes pride of place at the centre of the coat-of-arms and closely resembles the ship that similarly adorns the shield of the coat-of-arms of the Honourable Company of Master Mariners, the *Golden Hinde.* Indeed, if one did not know any better, one could be excused for assuming that this *was* the coat-of-arms of the Master Mariners company, or, at the very least, of a sea-going organisation. In fact, there is nothing to indicate that the arms represent those who design ships, rather than those "who go down to the sea in ships and do their business in great waters".

Individual symbols, nevertheless, are less easy to evaluate. The badge of the College of Nautical Studies, Southampton is a heraldic dragon, clutching a flag-bedecked staff. It is not manifestly nautical, but it is probable that its image relates primarily to the City of Southampton. The Royal Institute of Navigation has as its emblem a bird on the wing, an arctic tern, in flight over the sea, silhouetted against a background of cloudy sky and a pair of compasses or dividers, measuring, as it were, the distance that the bird has flown. The symbol is encircled with the full title of the Institute. It is an imaginative and gentle emblem. Symbolic of flight and the measurement of distance across the sea; but, without the encircling legend, it could be thought to represent an organisation concerned with marine bird-life, with some masonic affiliation! Likewise, the symbol of the National Maritime Institute portrays a breaking wave within a circle, a clever device, no doubt representing world-wide maritime interest; but an emblem which might have been more suited to the Institute of Oceanography. And then there is the symbol of the Nautical Institute, clearly the most basic form of the armillary sphere - an armillary sundial. In this form, of course, it is devoid of all its ancillary rings and essentially represents the fundamental equinoctial sundial. It is perhaps surprising that the sixty-strong council of the Nautical Institute, in 1972, should have chosen this symbol unanimously, from amongst many other devices, as its emblem. However, the armillary sphere featured in printed books as the symbol of science and learning from the very beginning. It represented both the earth and the heavens, the terrestrial and the celestial sphere. It represented the sciences of astronomy and navigation, as well as the science of gnomonics or the art of dialling. It included the study of geography and had its place in other liberal sciences. Knowledge of the armillary sphere had always been "the first Consideration among those Qualities required for forming the scholar and the gentleman".

Such a symbol is simple, clear and instantly recognisable. Furthermore, the device is symbolic of those sciences, which play an essential role in the mariner's art, and yet its appearance is as modern as its origin is ancient. Thus, the armillary symbol of the Nautical Institute, whilst not being immediately self-evident as an emblem of nautical science, is a wholly suitable symbol for this organisation. It would also have been a wholly suitable symbol for the British Sundial Society!

There are other bodies which have armillary spheres of different kinds as their emblems, amongst them the British Horological Institute; but none are as outstanding as that of the Nautical Institute. It is simplicity, combined with an instantly recognisable device, that is the essence of the symbol and it was to this end that this distinct sundial symbol was produced for the British Sundial Society. Not everyone likes it, which is not surprising because many members are not 'au fait' with every class of sundial and see it as something other than a sundial, - a belt-buckle, to give but one example! The important point to remember is that it is symbolic and symbolic in more ways than one: not only does it represent a particular type of dial; but, also, the vertical gnomon is symbolic of the ancient obelisk, from which the science of gnomonics is popularly supposed to have been derived. It is a strong symbol, yet a simple and clear emblem, based neither on the vertical nor the horizontal sundial, but on the one class of dial which is fundamental to the understanding of the whole art of dialling, the *equinoctial* sundial. As stated by Thomas Stirrup, in his work *Horometria: Or the Compleat Diallist,* published in London, in 1652: "This Diall, though, of all other, he be the simplest, yet is he mother to all the rest, for out of him, as from a root, is derived the projectment of those 24 houre lines on any other great Circle or plane whatsoever".

EDITOR'S NOTE: The selection of a suitable emblem is an extremely difficult task, as the original BSS Commitee found out. Many members have been critical of Mr. Daniel's design, some have even written about it. However, no one to date has produced any other design which is even remotely suitable. But from the designs shown here, none of the bodies have chosen an emblem which instantly identifies the institute precisely and unambiguously. The armillary sphere would have been a possible choice except it is already used by two societies.

THE COLLEGE OF
NAUTICAL STUDIES

THE ROYAL INSTITUTE
OF NAVIGATION

THE NATIONAL
MARITIME MUSEUM

THE ROYAL INSTITUTION
OF NAVAL ARCHITECTS

THE NAUTICAL
INSTITUTE

THE BRITISH
SUNDIAL SOCIETY

PROFILE - CUMBRIAN MEMBERS

Mr. Robert Sylvester, on the left of the accompanying photograph, is one of the keenest members of the British Sundial Society and has greatly helped in the compilation of the national sundial record. He has also formed the first section within the BSS and publishes an interesting newsletter about twice a year. A Yorkshireman by birth, he has lived in Cumbria since 1977 and works in the Pathology Department in Furness General Hospital. Although having a life-long interest in astronomy, he has his feet sufficiently on the ground to observe sundials when the stars are obscured by the sun. He is seen here standing by the south chancel window of St. Michael's church at Isel, near Cockermouth, with Mr. Ray Hartland, examining the three ancient scratch dials on the left-hand jamb of the window.

Mr. Ray Hartland, on the right of the photograph, lives in Cockermouth and is now retired after a career with Imperial Chemical Industries. A lay reader at Isel church, he has written a paper about the scratch dials on Isel church which was published in 1990. He has shown that the indications are better fitted to the school day hours than the times of service in the Church. The school was actually held in the church at one period.

Members may like to be reminded that the earliest surviving **British** sundial - Bewcastle Cross lies within the boundaries of Cumbria and is 25 miles north-east of Carlise. An article on this dial may be found in *Antiquarian Horology*, Volume VIII, No 5, pages 497-505, March 1974; and in *Clocks* magazine, Volume 9, Issue No 2, pages 21-25, August 1986.

**St. Michael's Church at Isel near Cockermouth, Cumbria
30th August, 1990**

TELLING THE TIME BY THE SPIRE
A LITTLE KNOWN FEATURE OF THE CLOSE
CURIOUS WILTSHIRE SUNDIALS

Editor's Note: The following extract is taken from the ***Salisbury Times*** newspaper of Friday, 28th April 1933, and it contains several items of interest, especially the multifaceted dial from Ivychurch, and the Salisbury Cathedral noon mark.

THE SUNDIAL is rapidly becoming a common-place of the small garden, returning to the fashion of an older generation which laid out its Dutch Gardens and pleached alleys. The general appearance of these sundials is familiar enough, consisting of an ornamental stone pillar, bearing a flat table upon which the metal dial plate bearing the gnomon, rests. This, in addition to the numerals of the hours, is usually engraved with some apt motto on the subject of the sun and shadows cast by it.

THE SHADOW OF THE SPIRE

There can be no doubt that the idea of recording time by the shadow cast by the sun has possessed a fascination for the human mind from quite early times, as witness the scriptural dial of Ahaz. Here in Salisbury, the Cathedral spire itself has been made into a sundial. On the low north wall, which encloses the Cathedral Green, may be seen (just opposite No. 28, The Close) an engraved line over which the shadow of the spire passes at mid-day, thus indicating the hour of noon. This is not an accidental mark, for the word Meridies is cut across the line. The dial has been in existence of many generations, and there are records of its having been recut when the lines had become worn. Indeed there is every probability that this may be the dial mentioned by Evelyn, the dialist, when he visited Salisbury in 1653, and "saw the Cathedral, the Cloysteres, the Palace, and gardens, and the great mural dial". (Seems unlikely - Editor).

It was in the seventeenth century that the art of dial making became popular, and in Scotland, under James VI, afterwards James I of England, it enjoyed distinct royal patronage. The Scotch dials of this period were very elaborate and of considerable intricacy. They were often stone blocks with the corners chamfered off to produce a solid polygon. The faces of the stone were sculptured with sunk designs, each of which carried a metal gnomon, and was engraved with lines to indicate the hours. These multangular dial stones with "cup-shaped" or sunk dials, are certainly rare in England.

A RARE ONE IN THE MUSEUM

In the Salisbury Museum will be found one of these dials which originally came from Ivychurch, near Alderbury, which is interesting, since it is made of local stone, and has no apparent connection with dials in Scotland. Moreover, it forms one of a group of similar dials in the South of England, notably in the Market Place at Wilton, and at Westwood Manor House, near Bradford-on-Avon.

The Ivychurch dial was found, built into one of the walls, during the demolition of the building. It is 5¾ inches long, and of the same breadth, and 6¾ inches high, the additional inch being for insertion in the pedestal on which it stood. The block presents five main faces, available for sun shadows, viz., the top and four sides. In addition the corners of the stone have been chamfered off, producing eight other small faces. The four vertical faces of the stone would have been turned to the cardinal points of the compass, while the top bears a dial of the usual form.

The south face has a sunk heart upon it, on which were eleven lines diverging downwards from the cusp of the heart. This was evidently a "south vertical dial" indicating the time from 6 a.m. to 6 p.m., the shadow being thrown by a metal stilus inserted in a slit, which still exists above the hollowed out heart.

TO INDICATE THE SEASONS

The eastern face is rather more complicated in its design. It bears a sunk pattern which resembles an open book, set obliquely on the face of the stone, in the centre of which is a hole which formerly contained a stilus. On the centre of the edges of the "pages" are two small metal marks. This dial is so arranged as to show the hours from sunrise to noon. But it does more. The shadow of the stilus moves at the equinoxes (March and September) along a line joining the two metal marks, above them from Autumn to Spring, and below them from Spring to Autumn. In this way it records the passage of the seasons.

The west face is even more elaborate, since it has three hollows, all set obliquely. In the centre is a hollow formed by two intersecting curves, with central hole for the stilus; above it is a rectangular hollow, and below another rectangular depression with a curved base. The centre hollow with its stilus indicated the afternoon hours as well as the period of the year by its line of movement. The exact uses of the two other hollows are not very clear.

There remain the eight triangular dials formed by the cutting off of the corners of this cube of stone. Each had a stilus which can still be seen. The shadows on each dial would indicate 3 a.m., 9 a.m., 3 p.m. and 9 p.m., if the sun were above the horizon at these hours. The first and last, of course, are unobtainable in this latitude. The best preserved of these eight small dials is that on the lower north-west angle, where a shadow would be thrown from 4 p.m. until sunset. The lower north-east dial, also well preserved, indicates the hours from sunrise until 8 a.m. No word has been said about the north face of the stone, which has a sunk crescent recumbent upon it. This, of course, would have had no use in these latitudes, since it would be obscured from 6 a.m. to 6 p.m. In a somewhat similar dial preserved in the Dover Museum, this face is blank.

MADE OF CHILMARK STONE

Although it bears a close resemblance to the Scotch dials already referred to, the Ivychurch example is distinctly local, the stone came from Chilmark, and it is calculated for use in the latitude of Salisbury. It is not without interest to enquire into the date of this dial. Similar examples in Scotland date from 1623 onwards; and are due to the mathematical activities of Napier of Merchiston (died 1617) and to the learned proclivities of James VI, who was an enthusiast on dials.

The English dials, however seem to group themselves together. As already pointed out there are three in Wilts, and there is also one from Wigborough, Somerset, now in the Taunton Museum; one at Great Fosters, Egham, and the dial from Burford, described in the "Times" (November 29th, 1932). It may be that they are due to the influence of the Bavarian mathematician, Nicholas Kratzer, who was at Corpus Christi College, Oxford, and who gave special impetus to dialling in England. In his manuscript De Horologis, still preserved at his old college, he says that much of his information was derived from a book in the Carthusian Monastery at Auerbach, near Vienna. His portrait by Holbein, in the Louvre, represents him holding in his hand a polyhedron of dials. He designed a dial for the garden of his college, at Oxford, probably between 1520 and 1530. It was taken down at some unknown date, but a sketch of it has survived. It must be remembered that this was a great period for the building of new houses, and the laying out of pleasure grounds, in which the dial was an important part. The tradition of Kratzer's dial is carried on by that at Westwood Manor, Wilts, which now stands upon a low pedestal. It is an hexagonal block of stone, literally covered with hollow dials.

THE WILTON DIAL

The dial in the Market Place at Wilton, and that from Ivychurch might well belong to the first half of the 17th century. The Wilton dial is now surmounted by a stone vase. Mr. A.C. Tait, of Bebington, Cheshire, a well-known authority on this subject, states in answer to an enquiry: "I have never known a polygonal dial to be so used, and the dial-stone at Wilton seems to have been cemented into the upper part of a mutilated cross, merely to preserve it. Sadly weather-worn as it is, and now difficult to indentify as a type, it has certainly been the most elaborate of all (in Wiltshire), showing an anvil-shaped outline encrusted with sunk dials. A dial of this shape is more likely to have stood low down, so that its intricate geometry could be admired at close quarters, than in its present elevated position". Mr. Tait, in the foregoing extract, refers to the common practice of replacing the top of a village cross when crosses were being broken owing to religious disturbances.

AT THE POULTRY CROSS

There also arises an interesting speculation as to the possibility of a dial-stone on the top of the old Poultry Cross, before its restoration on the Chichester model. An illustration of the Poultry Cross with the wall surrounding it, appears in the "Gentleman's Magazine" for May, 1818, page 393. Rising from the centre of the roof is the shaft of what might well have been the old cross, surmounted by what looks very like a dial of the same type as that from Ivychurch.

One further consideration is worthy of notice. The Priory of Ivychurch, founded by Stephen, passed at the dissolution of the Monasteries to the Dean and Chapter of Sarum, from whom it was leased by Henry, Earl of Pembroke. According to Aubrey, "The Right Honourable Mary, Countess of Pembroke, much delighted in this place. Henry, Earl of Pembroke, had a lease of it from the Church of Sarum, as also his brother, Sir Philip Sydney, who wrote here much of the Arcadia". The connection between Wilton and Ivychurch thus seems fairly established, and it is not to be wondered at, therefore, that these curious seventeenth century dials should be found in both places.

FRANK STEVENS

The preceding was considered of sufficient importance to be reprinted as a separate sheet, perhaps to be sold to visitors to Salisbury Museum in the 1930's.

THE ACCURACY OF USING POLARIS TO ALIGN A GNOMON

(CONTINUED FROM PAGE 34)

For dates in any month, apply a correction of -3.94 minutes per day. For each year after 1992, add +1.00 minute per year.

Example for 19 March 1995:

Lower transit 1992 Mar 0	3h 52m
-3.94 x 19	-1h 15m
1995-1992	3m

Therefore lower transit is at 2h 40m GMT.

To reduce time errors due the azimuth of Polaris to one minute, observe within half an hour of transit. Note that from the latitude of the British Isles, it is not possible to observe a transit in a dark sky early June to late August.

This exercise does demonstrate another interesting point, namely that when setting up a sundial, it is far more important to orientate it correctly with respect to the north-south line than it is to set it at the correct angle to the horizon. It also shows that the optical system for sighting Polaris must be very accurately aligned parallel to the style. Since, in latitude 52°00, an error in the assumed position of the pole of 0°.75 leads to a maximum time error of 6.2 minutes, we can say that in order to keep the time error to 1.0 minute, the alignment of the optical axis relative to the style has to be within 0°.10. This requires a very fine adjustment to be applied to the position of the eyepiece, or the objective, or both. If they are, for example 200 mm apart, then an adjustment of 0°.10 requires a linear adjustment to one end of 0.35 mm.

REFERENCE

1. **Mills, A.A.** "Aligning the Gnomon". British Sundial Society *Bulletin* 91.1.10.

A SELF-ORIENTING EQUIANGULAR SUNDIAL

BY FREDERICK W. SAWYER III, USA

A self-orienting sundial is one which satisfies two criteria:

1. In order to function correctly it must be properly oriented with respect to the celestial axis;
2. The dial itself provides an easy means for accomplishing this orientation without appeal to a magnetic compass, predetermined meridian lines, or any other external device.

In effect then, a self-orienting sundial serves as both a solar clock and a solar compass, with the compass always determining true celestial, rather than magentic north.

The purpose of this article is to present an elegant type of self-orienting dial, one which is a modification of a hybrid sundial described by Albert Ericson in 1972. Ericson noted that the dial he invented has actually been discovered a century earlier by the philosopher-mathematician J.H. Lambert. Subsequently I pointed out (*Sky and Telescope,* December 1975, p 355) that the dial has had both a much earlier discovery and a later independent one. The earlier discovery was by the seventeenth century English scholar Samuel Foster, and the later discovery was by Gordon Taylor, of the Royal Greenwich Observatory, the designer of the Tercentenary sundial originally installed at Hurstmonceux Castle and now at Cambridge. Further, I have since learnt that the design I have developed for a self-orienting dial was also previously described two centuries ago by L. Oberrett (see annexed bibliography).

The Foster/Lambert hybrid dial is composed of a horizontal base with a circular ring having hour-points marked at 15° intervals. The gnomon stands in the plane of the meridian above a diameter of the circle with its north end rising above the base at an angle of $45° + 0.5\ \varphi$, where φ is the latitude. The base of the gnomon moves in a slot along the north-south diameter so that its distance from the centre of the hour-circle on any given day is [$R \tan \delta \times \tan (45°-0.5\ \varphi)$], where δ is the solar declination, and R is the radius of the hour-circle. When this distance is negative, the gnomon base is south of the centre.

To understand why this dial works, consider the orthographic projection of the celestial sphere in Fig 1, where HH′, PP′ and QQ′ are respectively projections of horizontal, polar and equatorial great circles for the proposed location of the dial. The line DD′ parallel to QQ′ is the projection of the sun's path on any given day; so the angle QTD has measure δ. Let BB′, the base of the dial, be a horizontal line so positioned that angle HTB also has measure δ. Lines DD′ and BB′ are therefore projections of two equal intersecting circles. Consider a point (the sun) moving at a uniform rate on circle DD′; we wish to find a line (the gnomon GG′) so that the moving point's projection through the line onto the second circle BB′ also moves at a uniform rate. To satisfy this requirement it suffices for the line to be the perpendicular bisector of both the angle DSB between the circles and the line determined by their points of intersection. Since the two circles are always parallel respectively to the planes of the equator and the horizon, the (north) angle between them is ($90°+ \varphi$); therfore the bisector is always a line lying in the meridian plane and forming an angle of ($45°+ 0.5\varphi$) with the horizon.

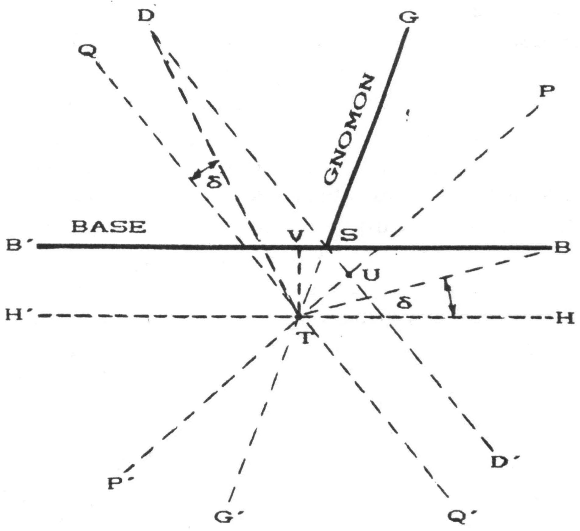


FIGURE 1

Since the actual radius chosen for the celestial sphere is completely arbitrary, on any given day we can set equal to $R/\cos \delta$ so that the dial itself maintains a constant radius VB equal to R. We then calculate the distance VS of the gnomon's base from the centre of the dial as follows:

$$VS = VT \tan (STV) = [R \tan \delta \tan (45°+ 0.5\ \varphi)].$$

Now, having justified the equiangular dial, note that a virtually identical argument applied to the projection in Fig 2 will yield a dial which uses a similar hour-circle but has a gnomon pointing south at an angle of ($45°- 0.5\ \varphi$) with the distance from the centre of the dial to the gnomon's base equal to [$R \tan \delta \tan (45°+ 0.5\ \varphi)$]. Because of the unusual south-directed gnomon, this dial proves to be even more fascinating than the original.

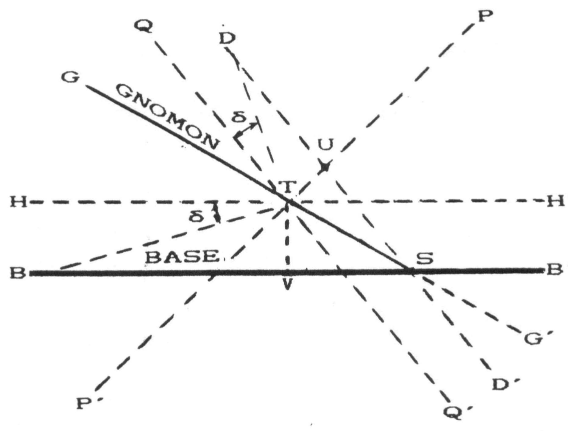


FIGURE 2

Suppose now that a north dial (from Fig 1) and a south dial (from Fig 2) are combined so that they share one common hour-ring with two sets of hour-markings. If the dial is set up at the equator ($\varphi = 0°$), then the two gnomons may be joined at their bases, since at this latitude the distance from the centre of the hour-ring to the base of either the gnomon is always simply R tan δ. The separate north and south gnomons may be viewed as a single V-shaped indicator with both limbs elevated 45° above the base plane. As a final step in the development of the self-orienting dial, note that a horizontal dial on the equator can be adjusted to work at any latitude on the same meridian by inclining its base so that it remains perpendicular to the plane of the equator.

We thus arrive at a reclining dial whose base is elevated above the horizontal at an angle φ towards the north. The hour-circle has two sets of hour-points, one marked clockwise and centred at the north point, and the other marked counter-clockwise and centred at the south point. The hours are marked at intervals of 15°. There is one V-shaped gnomon with north and south limbs inclined 45° above the base; the gnomon itself moves daily in a slot so that its distance from the centre of the hour-circle is R tan δ, where R is the radius of the hour-circle and δ is the solar declination.

Because there are two sets of hour-points, one of them may be marked on the circumference of a ring which is free to rotate. After the dial has been correctly orientated, the ring can be rotated to correct for the equation of time and the constant adjustment to Standard Time (or Greenwich Mean time); this simple correction is possible because the hour-points are equally spaced around the ring. The two scales can thus be used to read Standard time (or Greenwich Mean time) and Apparent time simultaneously.

In order to orient the dial, simply rotate the entire instrument, maintaining the proper inclination of the base, until the limbs of the gnomon register the same time before and after noon, whichever is the most appropriate, on both hour-circles. As an example, suppose the actual hour to be 2 pm local apparent time. The instrument is rotated until both scales register the same time; the only possible readings that can be obtained in this manner are 10 am, Noon and 2 pm. The two spurious readings will always be for Noon and for as many hours to one side of Noon as the correct reading is to the other side. As long as the diallist can distinguish between the morning and afternoon hours, the proper positioning of the instrument is no problem.

Proof that the dial is self-orienting is straighforward and depends on the two following facts:

1. If the same time (other than noon) is registered on both hour-scales of the dial, and the position of the gnomon in the slot is then changed, two non-identical readings will result.
2. A rotation of the dial out of position is kinematically equivalent to a rotation of the sun through an equal angle in the opposite direction. The effect on the shadows cast is identical for either method of rotation.

The motion of the gnomon does not change the angles between the shadows of the limbs and the meridian line, so changing the position of the gnomon has the effect of moving both hour-readings either clockwise or counter-clockwise along the hour-circle, the actual direction depending only on the time of day and whether the gnomon is moved north or south. Since the two hour-scales are marked off in opposite directions, this motion results in an earlier reading on one scale and a later one on the other scale.

To discover the effect of rotating the dial out of position, it is permissible by (2) to imagine the sun being rotated from its true position at the same altitude to a different azimuth. If this imaginary rotation only changes the sign of the sun's azimuth or makes it zero, then one of the two spurious readings mentioned previously results. If, on the other hand, the azimuth changes in absolute value and is non-zero, then the imaginary position of the sun corresponds to a time other than Noon and declination different to the true one. Now if the gnomon were to be positioned in its slot at the point marked for this false declination, then the same time could be read from both hour-scales, since the situation would be indistinguishable from one in which the sun actually did occupy the imaginary position and was shining on the properly oriented sundial. However the actual position of the gnomon corresponds to the true declination of the sun on the given day; and since the two declinations are not the same, we can conclude from (1) that in fact different times are registered on the dial's two hour-scales. Thus, except for the two positions in which obviously false readings are obtained, at any given time there is only one position of the dial relative to the sun which will result in agreement between the dial's two indications. When the readings are the same for the proper inclination of the dial at the latitude of use, the noon-line is correctly positioned on the meridian and the gnomon is directly aligned on the line joining the celestial poles, thus the dial can also act as solar compass.

BIBLIOGRAPHY

Drecker, Joseph *Die Theorie der Sonnenuhren, Die Geschicte der Zeitmessung und der Uhren,* Band I, Lfg E, ed. Ernst von Bassermann-Jordan, Walter de Gruyter & Co., Berlin, 1925. (Theory of Sundials, History of Time Measurement and Clocks).

Ericson, Albert, "A Hybrid Sundial", *Sky and Telescope,* 1972, 44(11):299, 305.

Foster, Samuel, *Elliptical or Azimuthal Horologiography,* eds. John Twysden & Edmund Wingate, London, 1654.

Hanke, W., "Zur Theorie der Homogen Sonnenuhr in moderner Sicht", *Die Sterne,* 1975, 51(3):159-166. (A modern view on the Theory of the Hybrid Sundial).

Janin, Louis, *Le Cadran solaire analemmatique: histoire et developpements,* Centre Technique de l'Industrie Horlogere, Note No 74.2057, Bescançon, France, 1974. (The analemmatic sundial, history and development).

Lambert, J.H. "Eine neue Art Sonnenuhren", *Berliner Astronomisches Jarbuch fur 1977,* ed J.E. Bode, 1775, pp. 200-202. (A new kind of sundial).

Oberreit, L., "Ueber eine von Lambert erfundene neue Art von Sonnenuhren", *Leipziger Magazin fur reine und angew. Mathematik,* Leipzig, 1786, pp. 165-184. (On one of Lambert's realisations of a new kind of sundial).

Taylor, Gordon E., "Equiangular Sundials", *Journal of the British Astronomical Association,* 1975, 86(1):7-17.

de Vries, Thys J., "De Hybride Zonnewijzer", *De Zonnewyzerkring voor belangstellenden in de gnomonica - Bulletin,* 1979, 3:72-81. (The Hybrid Sundial).

BOOK REVIEWS

OROLOGI SOLARI - TRATTATO COMPLETO DI GNOMONICA by Girolamo Fantoni. 552 pages. 85 b & w, plus 41 full colour illustrations, 378 diagrams in text. 26 x 28.5 cm. Published by Technimedia srl. Rome, November 1988. Price not known.

The modest title translated is "Sundials - Complete Treatise of Dialling", and for once we have a book which lives up to its promise in the title. The work is divided into four main sections, preceded by an introduction and concise summary of geography and cosmography, this short preliminary treatment setting the scene sufficiently well for a complete newcomer to have sufficient grounding to continue with the rest. Fig 8 showing the day and night areas of the world is particularly neat and not seen before.

The "first" book deals with directional sundials, that is sundials which register time from the direction of the sun irrespective of altitude. This goes into great detail in the course of twenty chapters delving deep into every aspect of the subject, the treatment is open and simple to read, it is supported by clear well prepared diagrams and the occasional illustration of an actual example of an old sundial. Of course this takes a great deal of space to cover in such a thorough manner, and having arrived at page 339 by the end of this part, it is no surprise from the dimensions quoted above, to learn the book weights $5\frac{1}{4}$ pounds (almost $2\frac{1}{2}$ kilograms). The treatment is almost entirely mathematical.

The treatment naturally moves on to altitude dials, the first being the quadrantal type and referred to here as the clinometer type because of the plumb line setting, the second is the well known "Cappuccino" altitude dial, then the "Regiomontanus", the "Little Ship of Venice", and others. This section ends on page 439 with an illustration of "The Ambassadors" by Holbein the Younger.

In the third book the azimuth type of dial is dealt with, starting with an introductory note and general principles involved, as in the first two books, then the general concept of the azimuthal projection before proceeding to the horizontal astrolabe, the analemmatic dial and the one designed by Lambert.

This leads on to nocturlabes and moon dials, treated more shortly, since of course strictly speaking they are hardly "sundials" although coming under the general heading of "dialling". The reviewer has gained a clearer idea of the use of the moon as an indicator of time from Fantoni than any other writer.

Proceeding further the usual appendices are incorporated, preceeded by an essential bibliography, it is rather short considering the breadth of the subject matter, yet some of these references are quite new to the reviewer in spite of having collated 3,500 references. Appendix A deals with astronomical tables, Appendix B with trignometrical formulae, table VIII of which deals with spherical trignometry; and Appendix C with symbols most commonly used in dialling.

Finally the section containing the coloured plates is reached, usefully preceded by an index. Among the examples, the following caught the reviewer's eye:

A stained glass dial in the great room of the municipal building of Ulm, constructed about 1560 by Hans Harderbecker, the modern armillary sphere in Zurich Park, the replica "bow-string" dial in front of the Adler Planetarium in Chicago, based upon the monumental dial by Henry Moore and formerly sited in "Times Square", London, 1967. One of the outstanding achievements of the Continent, the example of a meridian line in Santa Maria degli Angelo in Rome is shown to great effect with some of the details. An almost unknown dial to most of us is that in the garden of the Quirinale Palace in Rome, a magnificent commission of Pope Urban VIII in 1628, a most splendid piece of work. The photograph of the "Tower of the Winds" in Athens brought back memories to the reviewer of a long walk in the early morning to visit it. A simple but striking example installed by the author is pictured in the park Circolo di Martina, Rome. As befitting in a book mentioning moon dials, the example of the dial at Cambridge in Queens College is shown, with its table of correction for the phase of the moon below. Lastly Gordon Taylor's dial, formerly at Hurstmonceux, is shown. Unfortunately the colour reproduction lacks the sparkle to do the dials justice.

The author Girolami Fantoni was born in Reggio Calabria in 1920 and was an Admiral in the Italian Navy in World War II and subsequently with Nato as Commandant of the Central Mediterranean area. Dialling is one of his relaxations, and this *magnus opus* is proof of his depth of knowledge. It is rather unfortunate for most readers that the text is Italian, in fact the reviewer has had to resort to generalities because he does not trust his limited capacity of understanding the Italian language to achieve complete understanding. It might also be asked why the review is so long after the publication date, the answer is simple, the reviewer has only just received a copy. This is a book for the serious diallist, not the dilletante, and requires mathematical competence to be able to follow the discussions. With an English text, it would have become a standard and essential reference work for those who design and construct dials.

Charles K. Aked.

***CADRANS SOLAIRES,* ARTISSIME, NYONS,** pp 61, 48 line diagrams, coloured illustration on cover and centre page spread. Published circa 1982, and reprinted. French text. This is intended primarily as a publicity booklet, the price of the items are not given, possibly a separate price list was also given.

This little book has been published by Artissime of Nyons, France, according to the centre pages, (this is a small town near to Avignon) which since 1982 have been making replica portable sundials of all types, plus tiles bearing illustrations of sundials, available in a number of sizes, for example the one shown here can be supplied in five sizes from 10 x 10 cm to 40 x 40 cm. The foreword thanks various authors, in particular Dr Raphaël Blanchard for his study of the sundials of Briançais which appeared in the *Bulletin de la Société d'Etudes des*

Hautes-Alpes in 1895, which made reference to a number of sundials that have now disappeared for ever.

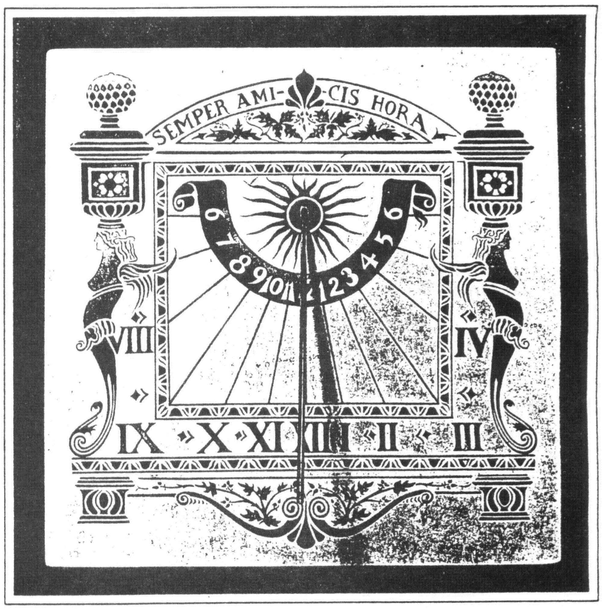
Basically this little work is a 61 page booklet containing two pages of colour illustrations of the firm's products, the first half of the book being devoted to old(ish) sundials and illustrated with 30 engraved illustrations. Page 33 then goes on to the different kinds of sundial, the first illustration being from the work of Quadrant dial, the Ring sundial, Scaphe (which seems a little out of step), the Shepherd's dial (again from Finé), the Equinoctial ring, the Diptych dial, polyhedric dials, and lastly and interestingly, an engine for marking out mural dials, called the ***sciatére***, based upon the equatorial dial.

Page 43 is entitled "Construction of a Sundial", and the following pages give the usual outline of the principles, with practical details of constructing the main types of sundial, plus mottoes, and a small glossary of gnomonic terms. A very short bibliography of modern works completes the little booklet.

Although concisely brief, it is a booklet which would be invaluable to anyone entering the world of dialling for the first time, at least to French readers and those with a passing acquaintance with French mural dials.

The address of this firm is ARTISSIME, 32 bis route de Montélimar, 26110 NYONS, FRANCE. Attempts to contact the firm have met with no reply to date. The tiles would be a splendid decorative feature in the bathroom or kitchen. Perhaps some English tilemaker could be persuaded to produce a range of English sundial tiles.

CADRANS SOLAIRES



ARTISSIME

THE GIFT OF SHADOWS by W.A. Hutchinson, 80 pages, profusely illustrated. Published by Skeeby Publishing Berkshire, 1990. 10 x 7½ inches. Glossy thin card covers. ISBN 0 9516027 0 5. Price not known. Foreword by Professor Keith Jones.

One might open with the comment that this is an unusual book. It is proposed to mention only Chapter 16 of the book, commencing on page 53, for the simple reason that this is devoted to sundials, vertical and horizontal; on the basis that a shadow is the indicating means of showing time. There are but seven illustrations of sundials, and in spite of the book's theme, not a decent shadow amongst those illustrated in the chapter. Even the large sundial at the Toledo Gate, Seville; which the reviewer cannot visualise without sunshine falling on it, is unfavoured by shadow. The one exception is that of the dial on Wensley Church, North Yorkshire (on page vi), where the photographer has caught the dial with the light falling obliquely across its face to reveal the subtle texture of the indicating surface, together with the almost hidden detail of the gnomon transformed into a graceful shadow pattern across the stone face.

Just as the gardener can only see the unpicked weeds, the garden pests, the overgrown hedge and so on, whilst the untutored visitor merely exclaims "What a beautiful garden" and sits down gratefully on the garden seat to enjoy the view the owner cannot see for himself; so too the diallist searches for the details hidden to the uninitated person. But then the Sun never sees the shadows it so profusely creates for us to marvel at when the light falls propitiously at the precise moment that we can appreciate it to the full, it has never seen the time indicated by a shadow on a sundial which we all take quite for granted.

Looking at the book as a whole, the reviewer is reminded of the engineering blueprints of old because all the illustrations are reproduced in a blue tint, as is the text. This, to the reviewer's mind, does not do justice to the material since it creates a rather cold impression, for we usually associate warmth and light with sundials.

CAMBRIDGE SUNDIALS, by Alexis Brookes and Margaret Stanier, 56 pp, 24pp of coloured plates and one map, thin card cover with coloured plate, A5 format. Published by Pendragon Press, Cambridge, 1991. Price £3.50.

This is a pleasant little book which, for the first time, lists the sundials to be found in Cambridge and it has the great advantage of illustrating each in colour, accompanied by a text of varying length according to the amount of information known about the dial. This does lead to some vacant white spaces on thumbing through the book, no doubt the inveterate diallist will add his or her comments.

The opening may confuse readers because page 3 shows a map, on the facing page is a heading CONTENTS which serves both as the key to the map and the actual contents of the book. Since the book is not paginated, it makes precise location of an example in the book somewhat awkward.

Cambridge, as a university city, is blessed with a large number of sundials. The mathematician of the seventeenth century often amused himself with the design and delination of sundials, and in so doing left his mark upon his college. The custom continues to this day and so new dials come into existence such as that in the Fellows' Garden at Peterhouse College, a very attractive and colourful example. Old dials have been restored so that the sundials at Cambridge are as resplendent as at any time in the past. For those who cannot get to Cambridge, and for those who do not have the time to make arrangements to view the private examples; this little book is the perfect expositor for sundials in Cambridge. It also lists and illustrates the sundials on open access within five miles of Cambridge. A considerable knowledge of Cambridge is necessary to unearth all the examples shown.

One dial not shown, which is due to be erected in Cambridge, is Gordon Taylor's reclining equatorial sundial formerly at Greenwich Observatory at Hurstmonceux. By the time the second edition of this book is produced, it will be possible to include this example on its new site. Perhaps too the extra cost of paginating the book may be found. It is bound to have a ready sale to tourists in Cambridge, if nowhere else, and it is a most welcome and pleasant addition to anyone's dialling library. It does not have a technical approach and therefore can be read by anyone, even if they are only mildly interested in the subject.

Because of its format and binding, the book will not take kindly to a tour of the dials themselves, so a copy for use and another for the library would seem to be indicated. It is just too large to slip into a pocket easily and the corners of the cover soon begin to curl. But the size of the illustrations makes up for this disadvantage, although the quality of the photographs varies widely from excellent to fuzzy, one dial being a mere blurred addition to a much more clearly focussed garden. Perhaps someone using an automatic focussing camera without being aware of the limitations of such systems. Nevertheless, congratulations to the authors.

THE EARTH IN SPACE National Maritime Museum Educational Series Information Leaflet No 3. Price 25p.

This is a 6-page leaflet intended for school children aged 5-11 requiring information relating to "The Earth in Space" (Attainment Target 16). It succinctly condenses the information about the Sun/Earth relationship during the cycle of the seasons, with a brief mention of sundials hardly calculated to elucidate their functioning. There is another brief section on the last page which deals with the making of simple sundials which is hardly better in its approach. What is disconcerting is that often these literary essays intended for children are less than obvious to those with a smattering of knowledge of the subject. A child needs a far different approach in the imparting of information compared to an adult, and the outline must be simple and unadorned, straightforward and authorative; with clear illustrations.

CUMBRIAN SUNDIALS by Robert Sylvester, 5 A4 pages, August 1991.

This is a little publication listing the research in locating Cumbrian sundials undertaken by Mr. Sylvester, one of the most energetic of those engaged in the National Survey of the British Sundial Society. It comprises a comprehensive listing of sundials in Cumbria, plus scratch dials, with sufficient data to find them and give basic details. It is an excellent little guide to most of the Cumbrian sundials, and will be extended as Mr. Sylvester's research programme continues. This present list has about 120 examples known, with another twenty awaiting verification, plus a sad little list of about twenty-five Cumbrian sundials that are no more.

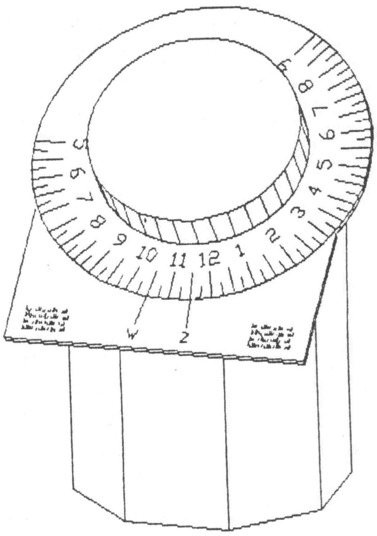
Specific queries relating to Cumbrian sundials can be directed to:

Robert Sylvester,
Barncroft, Grizebeck,
KIRKBY-IN-FURNESS,
Cumbria, LA17 7XJ.
Tel: 0229 89716

He would appreciate details of any sundials not listed by him.

A SUNDIAL FOR THE BLIND

Gerard Sonius, member of 'De Zonnewijzerkring', has developed a sundial for the blind. The dial is located at the blind-institution 'Bartiméus', Zeist, The Netherlands. The dial was put in use 24th April 1991. The principle of the dial is an equatorial rotating dial with the figures in relief. An electronic device is fitted to the dial which gives a sound when it points to the sun. On the stationary part two marks are placed, for summertime and wintertime, where the blind can determine the time in 5 minute intervals. An explanation is given in Braille characters, as well as in printed characters, upon the plate below the dial.



LETTERS TO THE EDITOR

GIBBS AND PILKINGTON TYPE SUNDIALS

In the July issue of our journal I noticed the article on the Gibbs and Pilkington type sundials. Some time ago I saw a photograph of one of these dials in the book *Sundials...* by Frank W. Cousins. It was described as a 'heliochronometer' and I decided I would rather like to have one of these. My only hope of owning one was to make one, and I now enclose photographs of the finished dial. I had no working drawings and so the internal mechanism is entirely of my own design.

Photographs 1 shows a general view and the supporting quadrant for latitude adjustment. Photograph 2 shows the Equation of Time dial, the little upright peg to the left both serves as the indicator for the Equation of Time and as an adjusting peg for turning the main dial. The cursor on the outer rim is adjustable for longitude, as can be seen, but it also carries two masks, separated by one hour for producing the GMT and BST indications, thus saving having to move the cursor when the hour is changed twice a year. The main dial is six inches in diameter.

Photograph 3 shows the Equation of Time pointer which moves across the target. I felt this was a much neater arrangement than having the whole target move. When turning or setting the Equation of Time dial, the pointer is moved a precise amount via an internal cam. The shape of the cam was designed using the Equation of Time tables published in the aforementioned book.

My first cam was designed to move the pointer the distance that the minutes represented as part of the circumference on which the target sits. When testing the sundial with an artificial sun (car headlamp bulb), I found the Equation of Time was in error by 100 per cent under-movement. I had forgotten that the holes through which the sun rays pass move in the opposite direction of the target, thereby reducing the 'effective' movement of the pointer by one-half.

I re-designed the Equation of Time cam to give the double motion of the pointer required and the sundial now keeps accurate time.

For domestic purposes and to please my wife, I made, and French polished, a mahogany base on which the dial is mounted. I am a pensioner and have good workshop facilities, eg lathe etc, but my mathematics are a bit wobbly.

PS. I will be making another example sometime soon with improvements, ie. with redesigned base to allow the fitting of a compass; and cosmetic improvements around the dial area. Perhaps my efforts may be of interest to other BSS members.

THE HOUSEWIFE'S TRICK

I enclose as promised, a copy of a letter which I wrote to the Editor of the Journal of the British Astronomical Association, and published in BAA Journal of April 1975. I thought it fitting to draw attention to the serious errors and wrong ideas that may be encouraged by attempting to adjust a sundial by giving it a small twist in Azimuth using what A P Herbert humorously calls "The Housewife's Trick" in his book *Sundials Old and New.*

The mathematics involved in adjusting the dial reading by a twist involves the use of spherical trigonometry, but

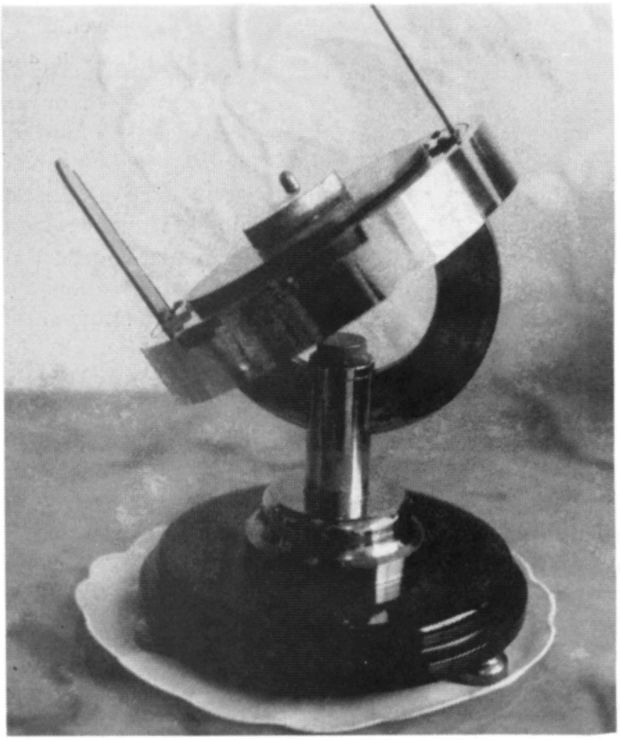


Figure 1

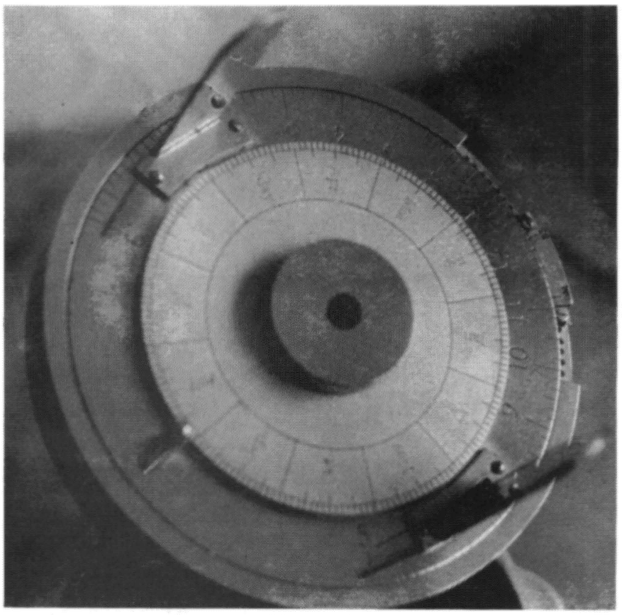


Figure 2

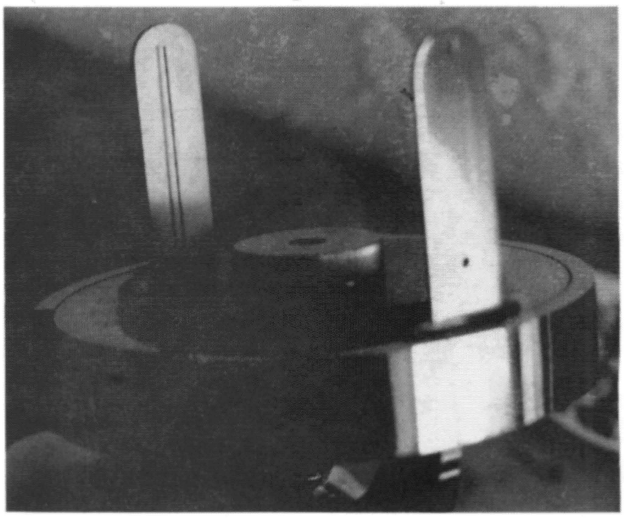


Figure 3

the nomogram shown here can be used to show what happens should we unwisely attempt to adjust, for example, the dial to read BST instead of Sun Time by an anticlockwise twist of 15°, the equivalent of about one Hour angle. This nomogram has been specially drawn for sundialists, as it shows graphically how the Sun's main parameters are related, using two sets of curves, one set for altitudes and the other for azimuths. These curves are plotted on graph paper having rectangular coordinates, X for Hour Angles, and Y for Declinations. Positions are, these days, readily tabulated using a computer or a programmable calculator.

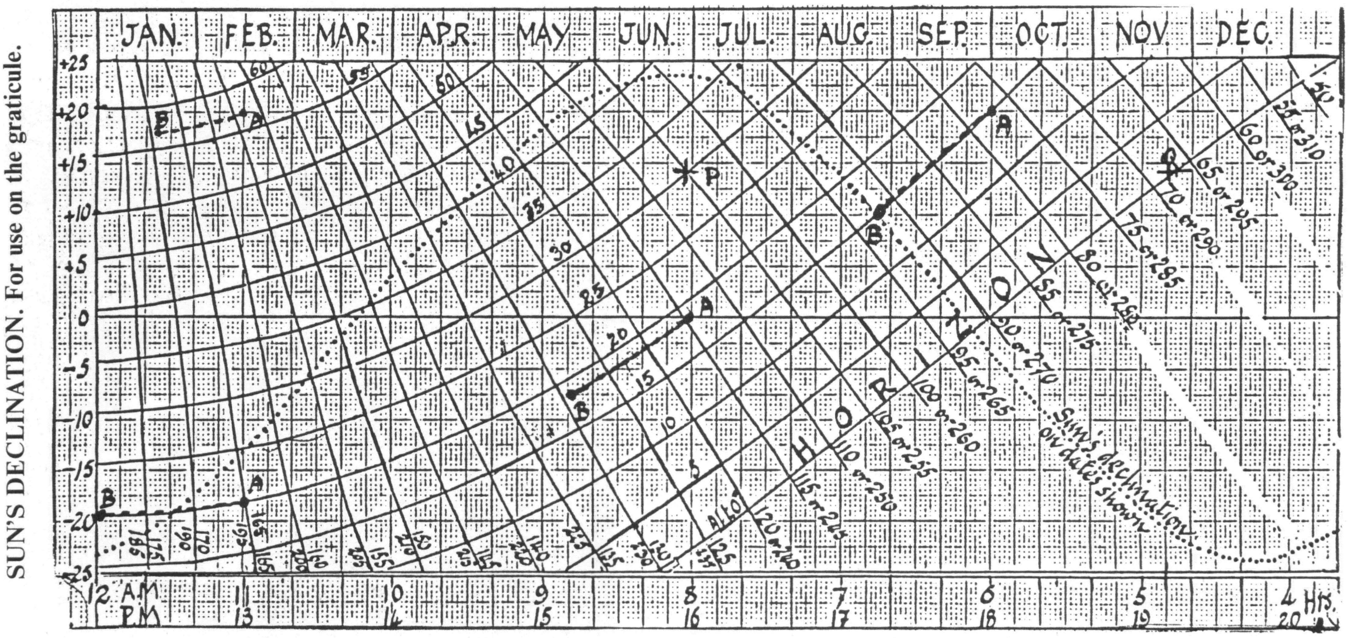
This nomogram gives the Sun time as soon as we know its altitude OR its azimuth, together with the Sun's declination or date. Conversely, if we know the Sun time, ie the Hour Angle, we can find the Sun's azimuth, and so the nomogram can be used as a sundial, and a sun compass, which makes it an instructive device for use in schools.

The set of curves can also be used to demonstrate what happens if we play the 'housewife's trick'. As an example consider the Sun to be at 8 am at declination 0°. An anticlockwise twist of 15° is equivalent to moving the Sun 15° in azimuth, but keeping the altitude constant. It will be seen that we change the azimuth from 114° to 129°, so that the simulated Sun moves from A to B, and then its Hour Angle changes from 8.00 am to 8.50 am, a change of 50 minutes. Similarly for the Sun at declination 20° and the Hour Angle of 11.00 am, a 15° twist will bring the simulated Sun to B, and change its Hour Angle from 11.00 am to 11.35, which is a change of only 35 mintues. In mid-winter, with the Sun at declination of -20°, a 15° twist will change the Hour Angle **by exactly 60 minutes**. In this way the errors and inconsistencies of the Housewife's Trick can be quantitatively exposed.

H.R. MILLS

A SUN COMPASS AND SUN CLOCK

Latitude 51°N



LOCAL SUN TIME

1. Read the sun's declination for the date from the dotted curve.
2. Enter this declination on the Y axis.
3. Read the sun's altitude and azimuth from the graticule.
4. Read the Local Sun Time along the X axis.

Note: GMT = Local SUN Time - E + Long West or -Long East. See Equation of Time graph. Atmospheric refraction causes the sun to rise about 5 minutes earlier and to set 5 minutes later than the times for the theoretical sun.

EXAMPLE:
On May 1st the sun's declination is 14°, from the dotted graph. Observed alt. of sun 30°. From the graphs the Sun Time is 0805 and its Az. 106° or Sun Time 15.55 and Az. 254° point P. The 14° declination line intersects the horizon curve Q showing sunrise at 04.50, Az. 68°, and sunset at 19.10 hrs. Az. 292°.

CURIOSITIES OF DIALLING
1. THE SHADOW SQUARE AND INSTRUMENT HORARUM
BY PETER I. DRINKWATER

Let us abandon for a while all abstract trigonometry, all computers and computing jargon, and get back to something much more basic: the labourer in the fields wishing to determine the time for his siesta, or the pilgrim requiring to know the canonical hours of Tierce, Sext and Nones, for the saying of his prayers along the road, without compass, sundial or clock to aid him, or even a bell sounding remotely in the distance. His own shadow, suitably paced out, is his only guide; or the marked out staff of a Pilgrim, casting and measuring. In Islam, the latter came to suffice: the shortest observed shadow being allowed to increase by a quarter of the length of the cast staff before midday prayers were observed, and to increase by a whole staff's length (or by two whole staff's lengths in more northerly latitudes!) before midday prayers were observed (corresponding to the Christian Nones). This is still the rule in Islam today.

Christian Europe was more particular. Palladius's *De re rustica* (4th Century AD) contains a fully developed Shadow Scale with figures for each of the twelve Temporal Hours ("Are there not twelve hours in a day?" John 11:9) for each of the twelve months in paired doublets. Allowing for some obvious scribal slips (the original, and its mediæval English translation, uses Roman numerals) it arranges thus:

	J	F	M	A	M	J	
1	29	27	25	24	23	22	**11**
2	19	17	15	14	13	12	**10**
3	15	13	11	10	09	08	**9**
4	12	10	08	07	06	05	**8**
5	10	08	06	05	04	03	**7**
6	09	07	05	04	03	02	**6**
	D	**N**	**O**	**S**	**A**	**J**	

This represents an attempt to render logical the *observed* behaviour of a shadow without any understanding as to *why* or *how* it so behaves. The originator assumes a notional six foot height and a single foot pace, the technique being to align the tip of one's shadow with some object and then to pace out, heel to toe, the distance to that object. The midday Shadow at some Mediterranean latitude is guessed at from observation and the lengthening of that shadow by the hour is determined by the sequence +1+2+3+4+10. This has a rough, utilitous contact with reality in Mediterrranean latitude and is easily remembered. Waugh, in his *Sundials: Their Theory and Construction,* gives a much more abstract scale (for which the Venerable Bede is held ultimately responsible) in which the *mid-summer* midday shadow is asserted to be one foot, and an increase of two feet is assumed; by month as well as by hour; with again the wild leap of ten feet to the first and eleventh hours. Thus for December/January the scale (declining from midday) is 11, 13, 15, 17, 19, 29. To a mediæval Religious only the figures for midday and mid-morning/mid-afternoon would be of interest; and it is these figures which one so often finds quoted at the head of each Month in mediæval Kalendars: from one of the above two, or another similarly abstractly constructed shadow scale. I am aware of only one *clear* attempt (of Anglo-Saxon date) to determine these figures by actual observation, using the ecclesiastical 'Scratch Dial' or 'Canonical Hours Dial' as a marker: this uses half feet and such expressions as 'far-near' to express smaller fractions! A means of *correctly determining* these shadow lengths, by Latitude, Season and Hour, existed always in the Analemma of Vitruvius (perhaps to be the subject of some future article) but although the seminal copy of this was written out from a now lost older copy in Anglo-Saxon England, the space left for the exemplification of the diagram was never filled in, and the secret therefore lost until more modern times. It is the ground of all dialling.

There existed however, on the Astrolabe, and on Quadrants, two devices which allowed for the much more accurate determination of these lengths than mere numerical progressions, by means more accessible than the precise but complicated horological geometry of a lost classical antiquity. These were (/are) the 'Instrumentum Horarum' and the 'Shadow Square'. A typical arrangement of these two components, as they might appear on a Quadrant, is indicated in the first diagram. A quadrant arc AC on centre B is divided equally into 6 parts, and circular arcs are swept from these two points to the centre B from individual centres found along BC, extended beyond A for the 1/11 Hour. This is the 'Instrument Horarum'.

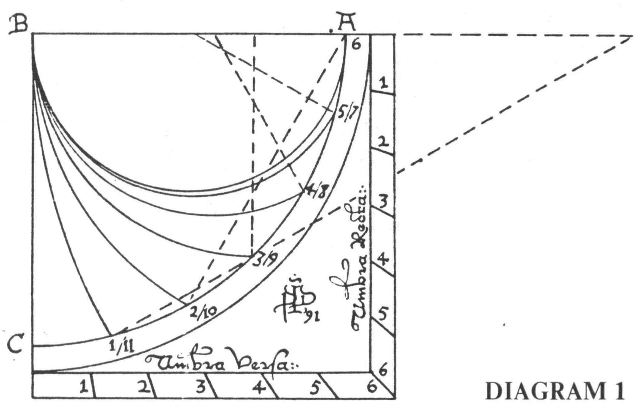


DIAGRAM 1

The 'Shadow Square' is a Square, one of whose corners is point B: the two sides most distant from B are both equally divided; in the instance into 6 parts. 6 is a usual number, 12 is also found, or 10. These are the bare bones as found on a quadrant, a scale of degrees and a moveable Zodiac scale may also be found (the Zodiac scale can be fixed if a use in a single latitude is envisaged), but these are not essential. On an Astrolabe the 'Instrumentum' is turned through 90° (to accommodate the moveable pointer) and may be doubled to form a lunette with the Midday line as a central circle. The Shadow square, also doubled, would then occupy the lower half of a complete circle. The Shadow square, also doubled, would then occupy the lower half of a complete circle inclosing both devices. On a Quadrant, as illustrated, there would be a pair of sights along BA and a plumbline hanging from B, with a pobble bead free to slide along its length, as well as the weight at its end (well beyond the end of the square). To set the instrument for a Day at a particular Latitude one aligns the sights to the Sun at Midday (or rather the *preceding* Midday) or thereabouts, allowing the plumbline to swing freely. The pobble bead is then slid along the plumbline to lie directly on the point where the plumbline crosses the Midday semi-circle. The sights may then be aligned with the sun at any time on or around that 'day' and the Hour will be adequately indicated by the pobble bead. To determine one's *Shadow length* at the time, note where the plumbline crosses the Shadow Square: if that point is on the 'Umbra Recta', then that *is* the length; if it is on the 'Umbra Versa' then divide the value given into the 'Whole Square' (36), and one has the figure required. That much without *any* knowledge of Latitude, and with only a determination of midday (such as any scratch dial would give adequately) required to set the instrument. A traveller might well sit down before setting out on a journey of a few days and calculate a simple seasonal scale by this means (merely moving the line with its set bead manually, without sighting each hour), and committing it to memory.

With a more elaborate Quadrant, incorporating a scale of degrees around its arc and having either a moveable Zodiac Scale of solar declination (see my previous articles, or my book for examples of these values (such as is given accurately in many mediæval Manuscripts), it is possible to work out an adequately accurate table for an whole year at one sitting, given one's latitude. The following, calculated for Shipston (just over Latitude 52°N), achieves whole numbers with a minimum of 'give and take', and was worked out in a few minutes with such a Quadrant:

	J	F	M	A	M	J	
1	144	72	48	44	29	27	**11**
2	48	44	29	20	14	13	**10**
3	36	29	18	13	09	08	**9**
4	25	24	14	10	07	05	**8**
5	24	21	13	08	06	04	**7**
6	23	20	12	07	05	03	**6**
	D	N	O	S	A	J	

Such a Quadrant was also used to provide the 'Umbra Versa' Scale of Shadow lengths required for calibrating the popular Cylinder Dial. All of the many tables (for various latitudes) in the several Manuscripts I have studied (either in original or in transcription) are quite clearly calculated by no other means.

The 'Instrumentum Horarum', in spite of its simplicity, is a precisely accurate construction; but *only* when the Sun's visible track is a *semi-circle* (as in all places at the Equinoxes, and as at all times at the Equator) is its *reading* precise; at other times it approximates by treating the Sun's visible track *as if it were* a semi-circle, when it is actually either *more*, or *less*, than that. This effect, as well as the slight roughening of the values due to the manual calculation is clearly discernible in the tables. Values are most 'out' at Midsummer in Latitudes well away from the Equator. The second diagram illustrates the nature of these divergencies. At Shipston ABC on centre D is the orthographic projection of the visible hemisphere. IDA is the Latitude, DE is the visible Celestial Æquator. It is midsummer and the sun's visible track is FG, projected and divided equally into six parts marked in doublets for the precisely correct 12 temporal hours as KIG: it is much more than a semi-circle (the curve on the projection is a half of the whole) and is projected on to the shadow scale shewn by the dashed lines. DG is the notional semi-circle assumed by the 'Instrumentum Horarum', projected and divided equally into six equal parts and marked as doublets of the temporal hours by the quadrant GCEH

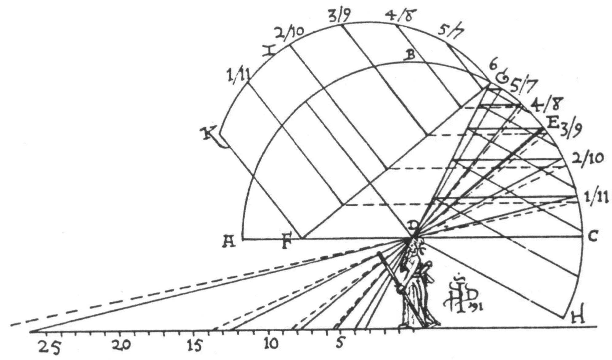


DIAGRAM 2

(again this is half of the whole). Projection to the shadow scale is continued by the solid lines. It will be seen to yield values which are only slightly shorter than the true; well within the margin of error inherent in such a crude method as that of the paced out shadow scale to a notional height of gnomon. The discrepancy declines sharply towards the precise correctness theoretically present at the Equinoxes.

The elaborate Quadrant described a few paragraphs back was called 'old' in the 13th century! The then 'new' quadrant, replacing the sliding Zodiac scale with a fixed stereographic projection of the Zodiac (all four quarters into one!) and incorporating (among other things) a Sine function, may well be the subject of a further article. But this is enough for now!

Interest in the 'Instrumentum Horarum' became largely academic following the introduction of equal 'clock hours' into popular use (with the clocks which told them!). The *Kalendarium* of Nicholas of Lynn, published in 1386 and utilized by Chaucer, goes overboard for these modern hours, mentioning the 'Instrumentum Horarum' only as a curiosity. He gives exhausive sets of tables for the shadow lengths of these modern hours at his chosen latitude, calculated by trigonmetry so precise that his figures would satisfy the most rigorous of Computer buffs. So we are back to the beginning again! It really is time for me to stop.

"SUNDIALS CAN BE SIMPLE AND LEGIBLE"

BY MAURICE J. KENN

Having observed, with difficulty, numerous sundials of varying degrees of complexity, I was provoked some years ago, into making from commonplace materials a sundial which was not only simple in concept but which was also readily legible, from the front, from either side, from above, from behind, and from a distance in each case.

Thus, even if placed indoors, near a window with a southern aspect, the sundial could be read easily from almost anywhere in the room.

The principal feature of this sundial, shown in Figures 1 and 2, was the translucent semi-cylindrical dial with also a translucent top-end plate (all part of a convenient plastic jar) surrounding a conventional "Pole-Star-seeking" gnomon (part of suitably-mounted, discarded knitting needle).

Hourly time intervals are clearly marked and are evenly spaced (at 15° intervals) and are independent of latitude. The sundial normally indicates solar time but can, if required, be made to indicate local-mean-time (even Summer-time) by appropriately twisting the dial in accordance with the 'Equation of time' (and Calendar).

Although somewhat crudely made, this sundial gave me, and my visitors, great pleasure for many years, when located on the window sill of my south-facing office at Imperial College, London. However, upon taking early retirement, I was duly presented, by my well-meaning colleagues and friends, with the more elegant and more beautifully constructed (but not quite so sophisticated) version of the sundial, as shown in Figures 3 and 4.

My original simple sundial was conceived because of the shear frustration encountered when endeavouring to discern the indistinct shadows on so many conventional dials and because certain of the latter dials also appeared unduly complex in concept.

REFERENCES

KENN, Maurice J. 'A Novel Sundial'. *The School Science Review,* Vol. 57, No 200, pp 542, March 1976.

HERBERT, A.P. 'Sundials Old and New'. 1967.

H.M.S.O. *The Nautical Almanac,* 1974.

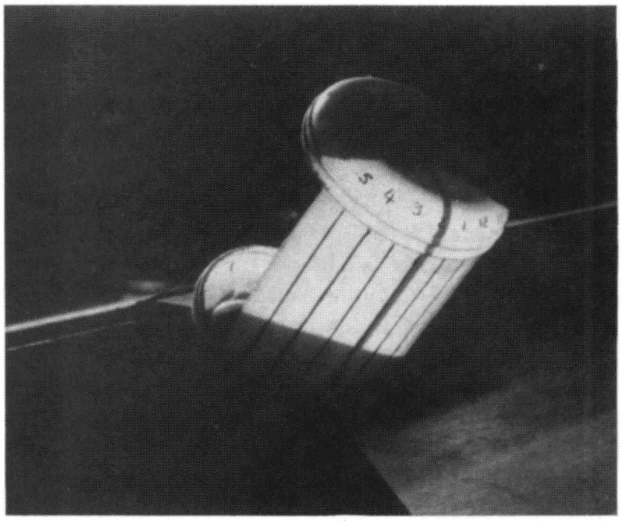


Fig 1. Novel Translucent Sundial (Viewed from Behind)

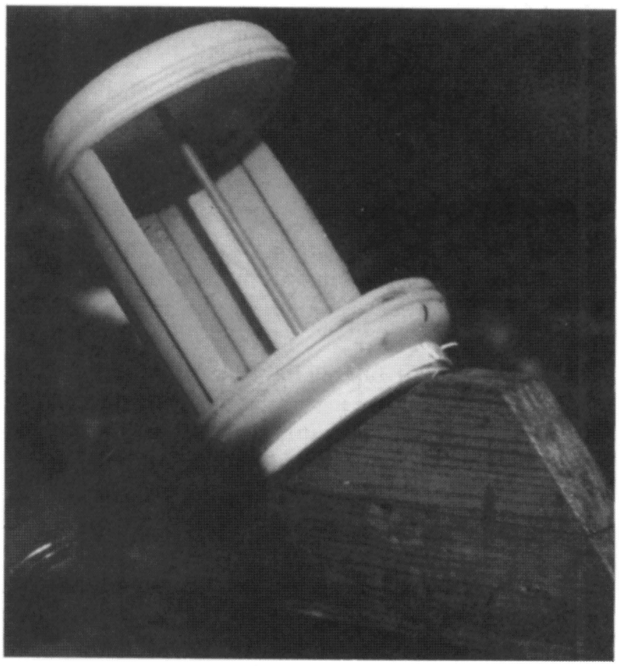


Fig 2. Novel Translucent Sundial (Viewed from Front)

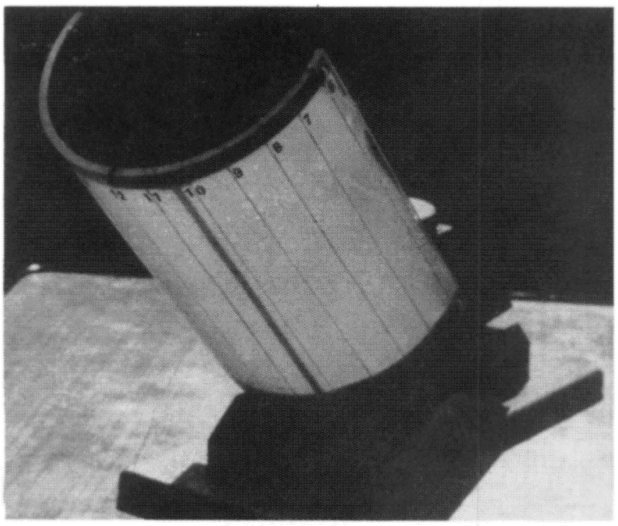


Fig 3. Novel Translucent Sundial (Refined Version)

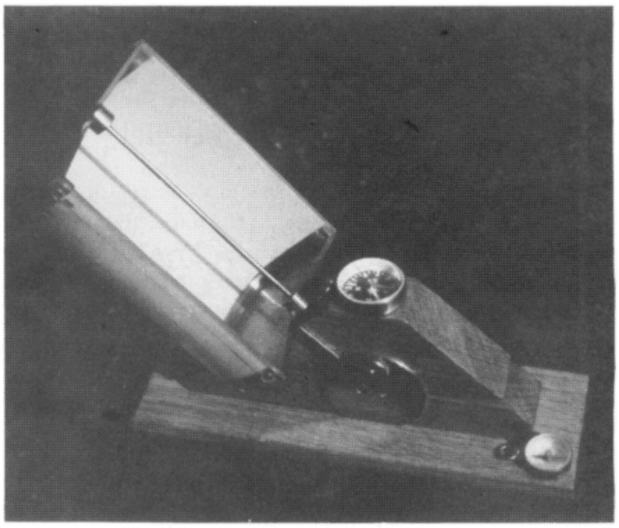


Fig 4. Novel Translucent Sundial (Refined Version)

THE ACCURACY OF USING POLARIS TO ALIGN A GNOMON

GORDON E. TAYLOR

In a previous paper[1], it has been suggested that an optical fitted on a gnomon could be used to observe the star Polaris at night and thus align the gnomon to a certain degree of accuracy. What then is this accuracy?

Polaris, the Pole Star, is not quite at the north celestial pole, and its distance from this pole, which we will call p, is slowly varying with time. For our purposes it is amply accurate to use a value of $p = 0°.75$ over the next few decades. Thus, a first sight, one might think that as $0°.75 = 3$ minutes of time, this could be the maximum error. Unfortunately this is not the case, as we shall see.

Figure 1, not to scale, shows the celestial pole P, and the zenith Z. The angular distance ZP is equal to the observer's colatitude. The apparent path of Polaris around the pole is shown as a circle. The maximum azimuth of Polaris occurs when it is at the position X, such that the angle ZXP is a right-angle. If we call the observer's latitude φ, and the azimuth angle of Polaris z, we find from simple speherical trigonometry that:

$$z = \arcsin(\sin p / \cos \varphi) = \arcsin(0.0131 / \cos \varphi)$$

If this equation is solved for latitude 52°.00, we find that the maximum azimuth of Polaris is 1°.22, which is, of course the maximum error of alignment of the gnomon in the horizontal plane. What effect will this have on the time obtained from the sundial?

For a horizontal dial the angle x, that a time line makes with the noon line, is found from:

$$\tan x = \sin 52°.00 \tan h$$

where h is the hour angle of the Sun. An inspection of any horizontal dial shows that the rate of change of x with respect to h is at a minimum when $h = 0$ so the above equation can be rearranged, and substituting 1°.22 for x, then

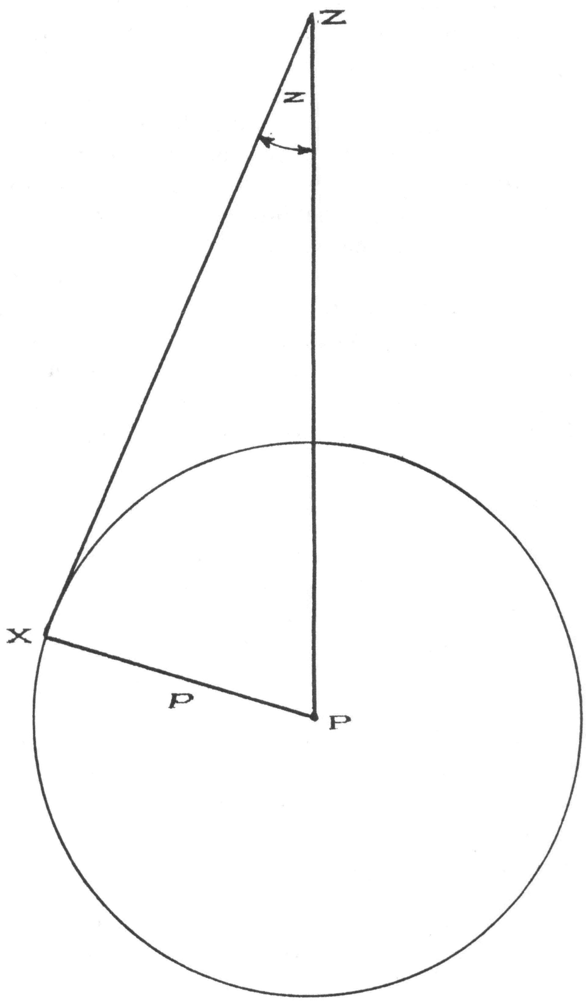
$$\tan h = (\tan 1°.22 / \sin 52°.00)$$

Solving this equation gives the maximum time error, which occurs about noon, of 6.20 minutes.

If, when we made the observation of Polaris, it had been directly above or below the pole, there would have been no error in azimuth but there would have been an error in altitude of 0°.75. This error would be directly translated into an error of latitude. Thus we can calculate time lines for two latitudes, say 52°.00 and 52°.75, and deduce the maximum time error from the differences resulting from the two calculations. This turns out to be 1.2 minutes only.

Summarizing, we may say that if you are not worried about errors of up to 6 minutes in the indicated time, then you can use the Pole Star at any time for the alignment of a horizontal sundial. Otherwise you can still use the Pole Star if you can tolerate the one minute error, by observing it near the upper or lower transit.

The approximate times of upper and lower transits or Polaris on the Greenwich meridian for any date in the next ten years may be determined by using Table 1 below. Certain simplifying assumptions have been made in performing the calculations, but the times obtained should be accurate to ± 4 minutes.



YEAR	UPPER TRANSIT	LOWER TRANSIT
1992	h m	h m
Jan 0	19 45	7 47
Feb 0	17 43	5 45
Mar 0	15 50	3 52
Apr 0	13 48	1 50
May 0	11 50	23 48
Jun 0	9 48	21 46
Jul 0	7 50	19 48
Aug 0	5 48	17 46
Sep 0	3 47	15 45
Oct 0	1 49	13 47
Nov 0	23 43	11 45
Dec 0	21 45	9 47

TABLE 1: APPROXIMATE TIMES (GMT) OF TRANSITS OF POLARIS ACROSS THE GREENWICH MERIDIAN

(continued on page 23)

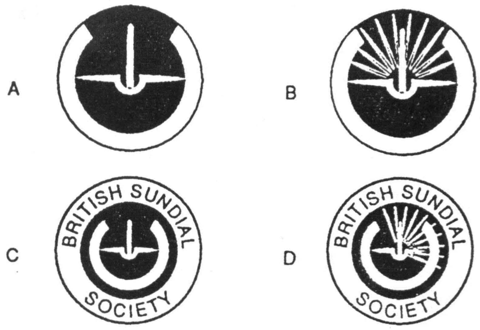
THE SECRETARY'S NOTEBOOK

Sitting down to write this page, I can hardly believe that it is only ten years ago when I first became interested in Sundials, and only five years since I met anyone else interested in the subject. That was Andrew Somerville, whom I had contacted following reading an article of his in *The Scots Magazine.* Although I learnt a lot through avidly reading every book I could obtain, and travelling around the country looking for dials (a very pleasant and rewarding occupation), it was the personal contact with others of like interest that brought a fresh light to things -and exposed misconceptions!

I write this to emphasise the need for members to contact one another from time to time, and I repeat my plea for the enterprising amongst you to help us organize a local meeting in your area. Alternatively you could request an up-to-date list of members in your locality from our Membership Sectretary and arrange a pleasant evening in your own home.

BADGES

At the last Annual General Meeting it was suggested that the British Sundial Society might produce a lapel badge. Subsequently the member who proposed the idea has sent some designs and an estimate of prices from a well-known manufacturer. A selection of them is illustrated here, and I would be interested to hear members' comments. An order will certainly be placed if we are reasonably sure that they would have a ready sale at about £3.00 each. They are attractive and of good quality metal and enamel.



DESIGN A
The portion shown white would be raised flush polished gilt against a background shown black which would be stippled gilt.

DESIGN B
As design A except that in the stippled gilt background there would be fine lines depicting the rays of the sun.

DESIGN C
Here the centre portion is reduced and is surrounded by a rim enamelled in any colour with the wording in gilt letters.

DESIGN D
As design C but with sun's rays.

THE BSS BULLETIN

Currently we still have for sale all the back numbers of the BSS *Bulletin,* these can be obtained at £3.00 post free inland each from the Membership Secretary (overseas members please add extra to cover the postage). The first three *Bulletins* 89.1, 89.2, and 90.1 were produced as photocopies with paper covers. In June 1990 a change was made to a better quality printed edition, thus issues 90.2, 90.3, 91.1 and 91.2 are printed in the same way as the copy you are reading now. If you require any of these to make up your full set, I would advise you to order in the near future as we hold limited stocks only, particularly of the early original Bulletins. A list of sundial makers is available from the same source or direct from me, for which there is no charge, but please send a stamped addressed envelope. I still have copies of English and Scottish Sundial listings from our recording group, as mentioned in the last *Bulletin,* at £2.00 each.

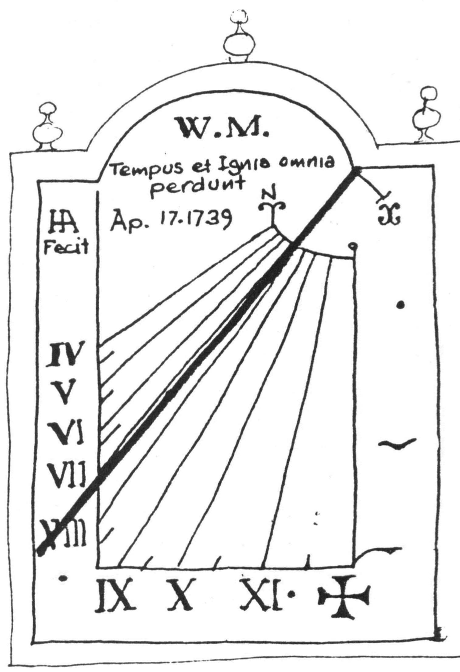
A PUZZLE

Among the many interesting letters from members I recently received one from Barrie Wilde who presented me with a bit of a puzzle. He had recorded an east declining vertical dial in Stoney Stratford but was at a loss to understand the symbols on the righthand side of the dial. Unfortunately they were a mystery to me too, and even our Chairman and Editor seemed baffled when I showed them the picture although they did come up with a rather long shot that at some time (or times) or another, when it was repainted, the painter simply copied what he thought was there. A drawing of the dial is reproduced here and I would be interested (as would Barrie) to hear of a likely explanation.

VOLUNTEERS WANTED

Last but not least, we are looking for members prepared to stand for election to the BSS Council at our next Annual General Meeting. Several of the current Council members have given me an indication that they would welcome a chance to relinquish the 'reins of office' (to have more time with their families as the politicans would say), so the Council will be looking for new blood, young or old, experienced or just enthusiastic. The BSS Council meets about three times a year and we would hope that each Council member would take on some post to help the Society (one likely position likely to be vacated is that of Treasurer). If anyone would like to see how we go about things, I am sure that there would be no difficulty in arranging for them to attend a meeting as an 'observer' - we are most definitely not a secret society!

DAVID YOUNG
HONORARY SECRETARY



SUNDIAL CALCULATIONS - PROGRAM LISTING

Because of difficulties in setting Mr. Parr's listing at the printer and his original being too faint to reproduce, it could not be included in the last *Bulletin* to complete the article. The editor has re-typed the listing and Mr. Parr has tested this to check it runs correctly. See *Bulletin* 91.2 for the introduction to this program, and *Bulletin* 90.2 for details of obtaining this program from Mr. Parr by sending a formatted 5¼ inch disk. It will certainly save a great deal of time and searching for errors, speaking from experience.

```
 10 REM * ABBREVIATED SUNDIAL PROGRAM * H C PARR
 20 @%=&20208:CLS
 30 PRINT" S U N D I A L   H O U R   L I N E S"
 40 PRINT" ===================================="
 50 INPUT"LATITUDE NORTH in deg.         ?"phi:PHI=RAD(phi)
 60 INPUT"RECLINING ANGLE in deg.        ?"beta:BETA=RAD(beta)
 70 INPUT"DECLINATION (W of S) in deg.   ?"alpha:ALPHA=RAD(alpha)
 80 INPUT"Output on Printer (Y/N)        ?"Z$:Z$=LEFT$(Z$,1)
 90 IF COS(ALPHA)=0 THEN X=PI/2 ELSE X=ATN(TAN(BETA)/COS(ALPHA))
100 IF X=0 THEN Y=PI/2-ABS(ALPHA):GOTO140
110 IF SIN(BETA)/SIN(X)>1 THEN X=BETA
120 IF SIN(BETA)/SIN(X)<-1 THEN X=-BETA
130 Y=ASN(SIN(BETA)/SIN(X))
140 IF -PI<=ALPHA AND ALPHA<-PI/2 THEN Y=-Y
150 IF -PI/2<=ALPHA AND ALPHA<=0 THEN Y=PI-Y
160 IF PI/2<=ALPHA AND ALPHA<=PI THEN Y=PI+Y
170 Z=ASN(SIN(ALPHA)*SIN(X))
180 IF ALPHA>PI/2 OR ALPHA<-PI/2 THEN Z=-Z
190 GAMMA=ASN(SIN(Y)*COS(PHI+X))
200 IF alpha>90 OR alpha<-90 THEN GAMMA=-GAMMA
210 IF ABS(GAMMA)<0.01 VDU7:INPUT''"ERROR: POLAR DIAL. Press RETURN"Z$:END
220 IF TAN(PHI+X)=0 THEN EPSILON=0 ELSE EPSILON=COS(Y)/TAN(PHI+X)
230 EPSILON=ATN(EPSILON)+Z
240 CLS:IF Z$="Y" OR Z$="y" VDU2
250 PRINT" S U N D I A L   H O U R   L I N E S"
260 PRINT" ===================================="
270 PRINT"Latitude            = ";phi;" deg. N"
280 PRINT"Reclining angle     = ";beta;" deg. "
290 PRINT"Declination         = ";alpha;"deg.  W of S"
300 PRINT"      HOUR             ANGLE"
310 PRINT"      ----             -----"
320 FOR HOUR=-11 TO 11
330 H=RAD(HOUR*15)
340 IF H=0 AND COS(PHI+X)*Y>=0 THEN T=0:GOTO 400
350 IF H=0 AND COS(PHI+X)*Y<0 THEN T=PI:GOTO 400
360 DENOM=SIN(PHI+X)*COS(Y)+SIN(Y)/TAN(H)
370 IF DENOM=0 THEN T=PI/2 ELSE T=ATN(COS(PHI+X)/DENOM)
380 IF H>0 AND T<0 THEN T=T+PI
390 IF H<0 AND T>0 THEN T=T-PI
400 theta=DEG(T+Z)
410 IF theta>180 THEN theta=theta-360
420 IF theta<-180 THEN theta=theta+360
430 ETA=ACS(COS(T)*SIN(PHI+X)+SIN(T)*COS(PHI+X)*COS(Y))
440 ZETA=ATN(-TAN(PHI)/COS(H)):IF ZETA<0 THEN ZETA=ZETA+PI
450 IF FNtest=1 PRINT TAB(4);HOUR;TAB(16),theta
460 NEXT HOUR
470 PRINT' "Angle of STYLE      =";ABS(DEG(GAMMA));" deg."
480 PRINT"Inclination of SUBSTYLE = ";ABS(DEG(EPSILON));" deg."
490 VDU3: END
500 DEF FNtest
510 IF GAMMA>0 GOTO 530
520 IF ETA<RAD(66.5) OR ZETA<RAD(66.5) THEN =0 ELSE =1
530 IF ETA>ZETA =0
540 IF ZETA<RAD(66.5) =0
550 IF ETA>RAD(113.5) =0
560 =1
```

End of listing.

A NEW LATITUDE - INDEPENDENT SUNDIAL

BY J.A.F. DE RIJK (Netherlands)

ABSTRACT

Most sundials can be constructed only for a fixed latitude. A study of all the ways in which time can be derived from the sun's position in the sky showed that there is only one possibility to derive time without knowing the latitude where the sundial is used. The first practical solution was found by Freeman in 1978. Another solution, which is simple and more accurate, is described in this article.

This article is reproduced by kind permission of the author, and the Royal Astronomical Society of Canada, in whose journal the article first appeared in Volume 83, No 3, 1989, pages 137-144. The article by Professor Freeman which is referred to here, was reprinted in BSS *Bulletin* 91.1, February 1991, pp 18-28.

To avoid re-setting of the article, the article is reproduced directly from the original, hence the unusual format to fit into the *Bulletin*.

1. *The possibility of latitude-independent sundials*. Most people, informed a little about gnomonics, know of the existence of sundials which need not be oriented North-South. E.g. many types of quadrants belong to this class. But not everyone believes that there is a class of sundials which are latitude-independent – not in the sense that you can use them for as many latitudes as you like by some mechanical or graphical correction, but in the literal sense: they work also if you are fully unaware of the latitude of the place where you use them. They also bear no latitude information. How this is possible is best understood if we review the mathematical possibilities of constructing sundials.

There are two classes of sundials which give the time (local apparent solar time) in a *direct* way:

a. The polar-style sundials (which came into use about 1400 A.D.) appearing usually in their flat form on church walls and similar places and in the 3-dimensional form as armillary spheres in parks and public squares;
b. The much older shadow-point sundials (invented *ca*. 300 B.C.) which are a projection of the celestial sphere on some flat or curved surface.

These classes are of course latitude-dependent sundials.

There are also *indirect* sundials, where the time is found by measuring, for example, the altitude of the sun, which is graphically transformed to an indication of the time. Then the sundial has a "built-in" nomogram. The whole group of indirect sundial classes can be found if we consider the mathematical relations between the variables that determine the place of the sun in the sky.

These are:

- ϕ – the latitude of the place of observation,
- δ – the declination of the sun on the date of observation,
- τ – the time (local apparent solar time) of observation,
- h – the altitude of the sun,
- Az – the azimuth of the sun.

The relation between these variables is expressed in two equations:

$$\sin h = \sin\phi \sin\delta + \cos\phi \cos\delta \cos\tau$$
$$\sin\delta = \sin\phi \sin h + \cos\phi \cos h \cos Az$$

If we eliminate ϕ we obtain a simple relation between τ, δ, h and Az:

$$\sin\tau \cos\delta = \sin Az \cos h$$

and it is clear that we can calculate the time (τ) if δ, h and Az are known. So, if we can construct a device that can be set on the date (which fixes δ), and that is able to measure h and Az, then it could also indicate τ (the time) if we built in a suitable nomogram to avoid any calculation.

2. *The solution of Freeman*. The first latitude-independent sundial was proposed by Freeman (1978). He designed a gnomon that was part of the curve

$$x^{2/3} + y^{2/3} = h^{2/3}.$$

Further, the time was not indicated with much accuracy. Freeman remarks that the error around 6 o'clock was more than 30 minutes. In 1982 I found a simpler solution (figure 8), which has an accuracy that varies from two minutes near noon to about six minutes around 6 o'clock.

3. *A solution indicated by the formula* $\sin\tau \cos\delta = \sin Az \cos h$. First I realized that it is not necessary to know the azimuth and the altitude of the sun but only the product $\sin Az \cos h$. The problem was: how could an instrument indicate this product?

In figure 1 PQRP′ is the azimuth plane of the sun and SN the south-north direction. The line AP gives the direction of the sun. If we take AP = 1, we can read from the figure:

$$P'A' = \cos h$$
$$\text{and } A'A'' = \sin Az \cos h.$$

The product $\sin Az \cos h$ is thus available in an easy-to-measure line A′A″. In figure

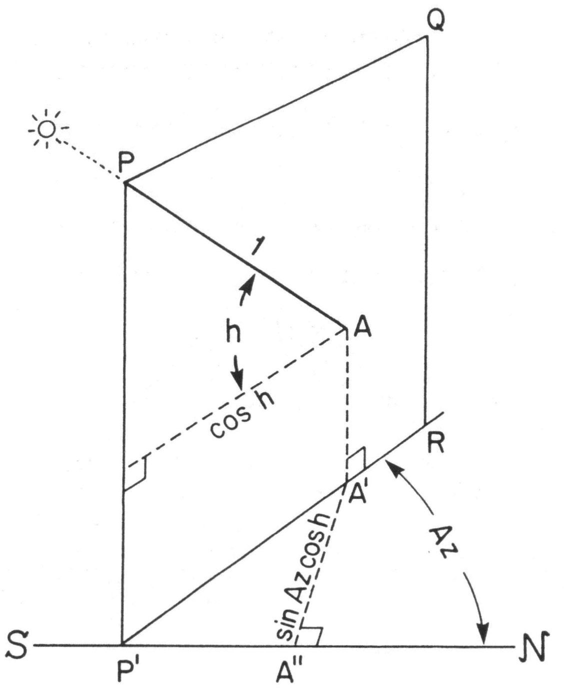


FIG. 1—We can find sin *Az* cos *h* as a perpendicular on the south-north line in the horizontal plane.

2, V is a plane that can turn around the axis PP′. H is a bar that can turn around an axis through P, perpendicular to V. H bears a sight. B is a vertical bar that can slide horizontally. Now we proceed as follows. Turn V so that it is in the azimuth plane of the sun (in that case the shadow of V becomes a line). Turn H in a way that it points in the direction of the sun. Now slide B till it touches the end A of bar H. The perpendicular A′A″ on the north-south line equals sin *Az* cos *h*, if PA = 1.

There are several possibilities to handle the second part of the equation sin τ cos δ. I shall explain only the one which produces the clearest hour lines, and which has a minimum of construction difficulties. In figure 3, cos δ is set on the *y*-axis and sin τ cos δ on the *x*-axis. For a constant τ, cos δ = *a* sin τ cos δ is a straight line through 0. In figure 4 the hour lines for $\tau = 15°$ (1 o'clock and 11 o'clock), $\tau = 30°$ (2 o'clock and 10 o'clock) and so on are constructed. In reality the declination of the sun lies always between 0° and 23½° and for our purpose only the hour lines between AB and DC are of interest. To give a better reading we can enlarge the vertical scale without losing the relation between τ and δ. In figure 5 the vertical

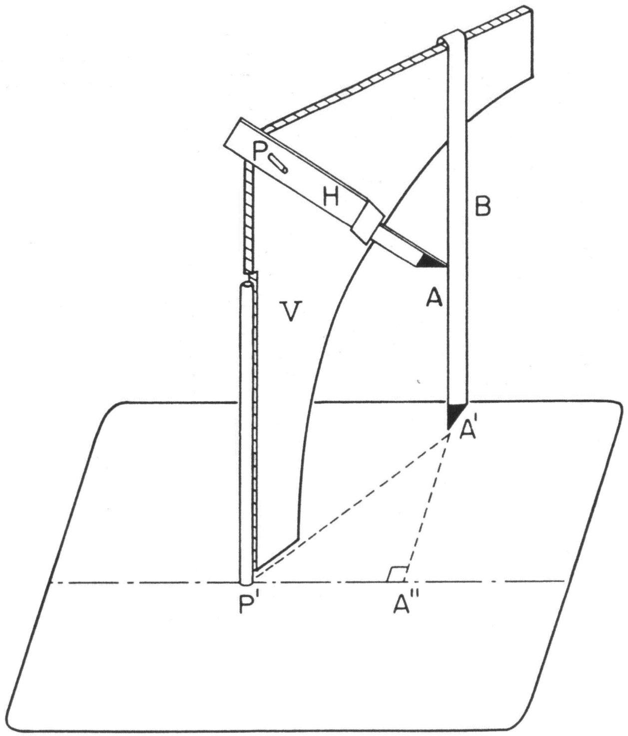


FIG. 2—A practical solution for finding the perpendicular of the length sin *Az* cos *h*.

scale is enlarged 10 times. Now we have a suitable grid which gives for every τ and δ the product sin τ cos δ.

4. *Putting together the sin τ cos δ and sin Az cos* h. A possible arrangement which does the job (giving τ, if δ, *h* and *Az* are known) is sketched in figure 6. The device of figure 2 is mounted on the north-south line of a ground-plate. The hour-lines are drawn on a plate which can slide in the north-south direction. There are no date-lines on that plate. It is easier to make a date-scale on the edge of the plate and use a transparent cursor with one date-line.

To find τ we proceed as follows:

a) Place the instrument horizontally in the north-south direction.
b) Turn the azimuth plate so that its shadow becomes as small as possible.

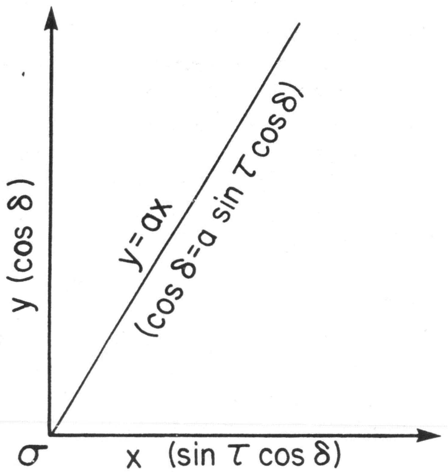


FIG. 3—If we choose cos δ on the y-axis and sin τ cos δ on the x-axis cos δ = a sin τ cos δ will be a straight line through 0 for a constant τ.

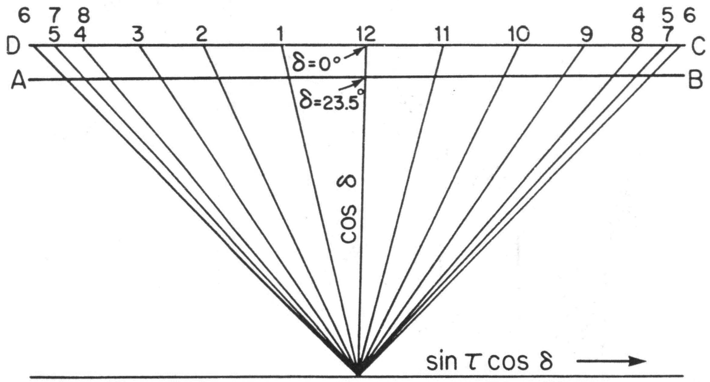


FIG. 4—The straight lines for the hours between 4 o'clock in the morning till 8 o'clock in the evening for every δ.

c) Turn the altitude bar until the shadow of the axis falls over the centre of the little screen.

d) Push the perpendicular bar until it touches the end of the altitude bar.

e) Set the date-line of the cursor to the date of observation.

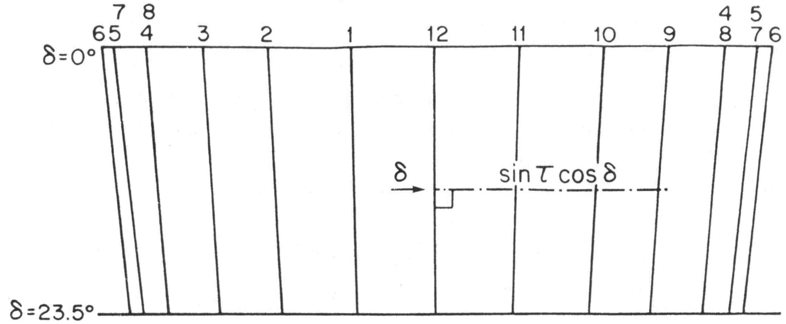


FIG. 5—The same scale as in figure 4, but now only between δ = 0° and δ = 23° .5 vertically enlarged 10 times.

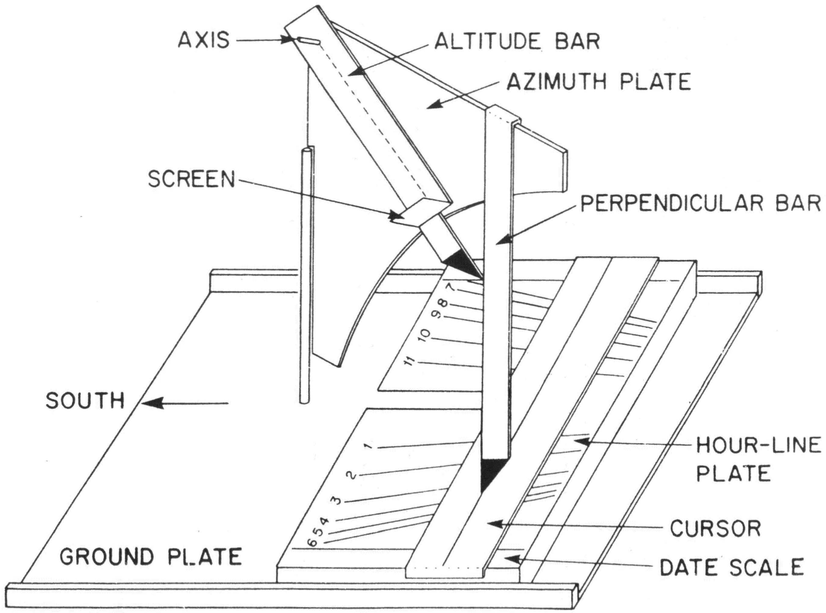


FIG. 6—Sketch of a latitude-independent sundial based on the principles treated in this article.

FIG. 7—The first working model of the latitude-independent sundial.

f) Move the hour-line plate, so that the date-line is under the point of the perpendicular bar. That point now indicates τ for in this point $\sin \tau \cos \delta = \sin Az \cos h$.

5. *The instrument.* The first model of this latitude-independent sundial was very simple (figure 7) and closely resembled the drawing of figure 6. In 1986 there was an opportunity to make a more sophisticated one as a parting gift to Prof. R. van Lieshout (figure 8). Several improvements have been made.

The altitude bar is replaced by an open tube with a lens in front. That bar is pointed to the sun, so that a tiny image of the sun is projected on the middle of the screen. The bar is coupled by a scissors mechanism with a perpendicular bar that indicates the time on the hour-line plate. Further, only half of the hour-line plate (of figure 6 and 7) is used, so that the instrument can be smaller or, with the same dimensions, can be more accurate. This reduction of the hour-line plate is possible because the hour-lines are symmetric around the 12 o'clock line. The only thing to be done is to turn the instrument through 180° at noon, and for that there is built in a semi-automatic device. A compass and a levelling device complete this improved instrument.

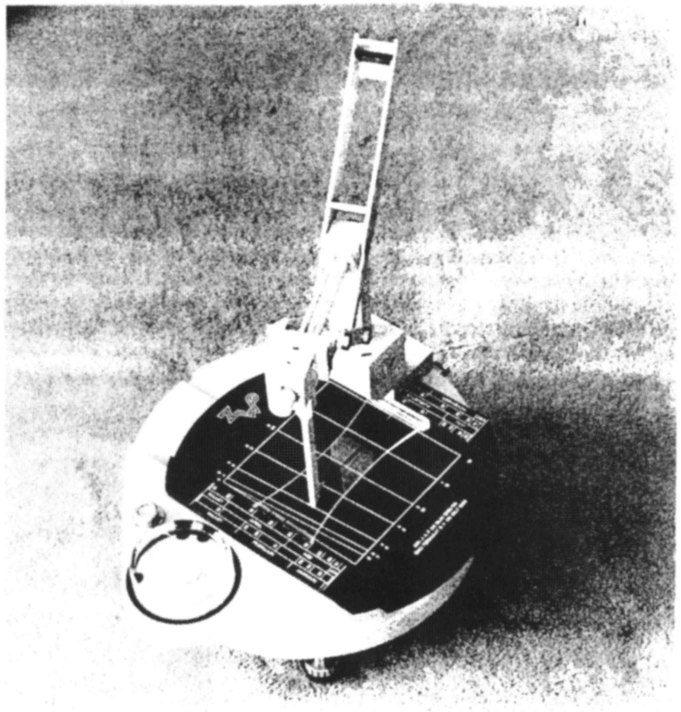


FIG. 8—A more sophisticated execution of the latitude-independent sundial.

REFERENCE

Freeman, J.G. 1978, *J. Roy. Astron. Soc. Can.*, **72**, 69.

MWS

USEFUL ADDRESSES

Mr. Charles K. Aked 54 Swan Road WEST DRAYTON Middlesex UB7 7JZ	[Editor]	Tel: 0895 445332
Mr. M.J. Cowham The Mount TOFT Cambridge CB3 7RL	[Minute Secretary]	Tel: 0223 262684 [Day] 263532
Mr. C. St. J. H. Daniel 57 Gossage Road PLUMSTEAD London SE18 1NQ	[Chairman]	Tel: 081 3178779
Mrs. Anne Somerville Mendota Middlewood Road HIGHER POYNTON Cheshire SK12 1TX	[Scottish Dials]	Tel: 0625 872943
Mr. G.E. Taylor Five Firs Cinderford Lane Cowbeech HAILSHAM East Sussex BN27 4HL	[Dial Recording]	Tel: 0323 833255
Mr. R.G. Thorne 15 Chesterfield Road Laira PLYMOUTH Devon PL3 6BD	[Treasurer]	Tel: 0752 227582
Mrs. Janet Thorne 15 Chesterfield Road Laira PLYMOUTH Devon PL3 6BD	[Membership]	Tel: 0752 227582
Mrs. Jane Walker 31 Langdown Road Little Sandhurst CAMBERLEY Surrey GU17 8QG	[Education]	Tel: 0344 772569
Mr. D.A. Young Brook Cottage 112 Whitehall Road CHINGFORD London E4 6DW	[Secretary]	Tel: 081 529 4880
Mr. Peter K. Scott 38 Exford Drive Breightmet BOLTON Lancs BL2 6TB	[Computer Programs]	Tel: 0204 35766

[Advisors]

Mr. Peter I. Drinkwater 56 Church Street Shipston-on-Stour Warwickshire CV36 4AS	Mr. E. J. Tyler 41 Great Gardens Road Hornchurch Essex RM11 2BB.