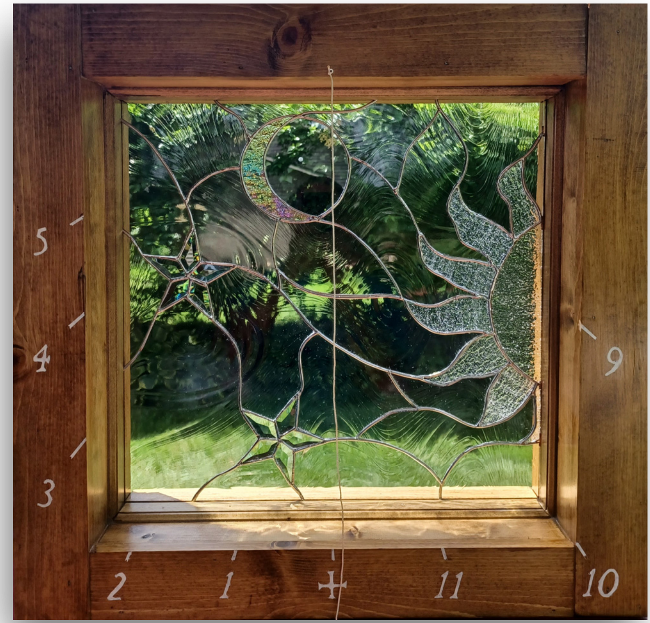
THE COMPENDIUM

JOURNAL OF THE NORTH AMERICAN SUNDIAL SOCIETY



VOLUME 29 ISSUE 4 - DECEMBER 2022

THE COMPENDIUM 29(4) – DECEMBER 2022

CONTENTS

Front cover: A photo by Mark Montgomery showing the unusual Window Dial discussed in his article, p.11 this issue.

THE COMPENDIUM – JOURNAL OF THE NORTH AMERICAN SUNDIAL SOCIETY
ISSN: 1074-3197 (PRINT), 1074-8059 (DIGITAL)

SUNDIALS.ORG

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ERRATA

Re: THE COMPENDIUM 29(3), Sept. 2022.

At p.5, line 9, *sin(θ)* should be replaced by *tan(θ)*. The subsequent calculation of t and HA, at lines 17 to 24, should be altered accordingly. The values obtained change from $t = -22.36°$ and HA = 10:31 a.m., to $t = -23.06°$ and HA = 10:28 a.m.

At p.57, Fig. 4, the gold-colored line representing a shadow on the compass rose should be one point (11½°) counter-clockwise from the placement shown, *i.e.*, the intended direction is Northwest by West.

SUNDIALS FOR STARTERS: DEEP FAKES AND MULTIPLE SUNDIALS

Robert L. Kellogg (Potomac, MD)

Last month I made a presentation to STEM students at a chapter of Sigma Chi for the Institute of Electrical Electronics Engineers. There is considerable concern about 'deep fakes' using machine learning to create printed text, voice, and now synthetic images upon demand. The malware and phishing implications for the future bring us to the situation of 'trust but verify'.

But strangely, for those of us interested in sundials, 'deep fakes' have existed for centuries. Artisans increase their revenue by ascribing a dial to a more prestigious dial maker. But wholesale fakes?

Back in 1998, Steve Woodbury entered a brass patina sundial from The Oatlands Plantation in Leesburg, Virginia, into the NASS Sundial Registry as #255 and wrote about it in *The Compendium* 6(2), June 1998. Oatlands was owned by William Corcoran Eustis. Wikipedia notes that his grandfather was a Chief Justice of the Louisiana Supreme Court and his mother was "the only surviving child of banker and philanthropist William Wilson Corcoran, co-founder of the Riggs Bank." In the garden of their estate, now part of the National Trust for Historic Preservation, is a sundial sitting on top of a Tennessee marble pedestal, with a sculpted mythological tortoise at the base supporting all (Fig. 1).

Fig. 1. Oatlands Plantation Sundial #255.

The dial itself is 9.25″ (23.5 cm) in diameter. The patinaed surface is slightly rust stained and the gnomon is simple, but nicely proportioned (Fig. 2).

Fig. 2. Oatlands Patina Dial and Gnomon.

The dial appears appropriately designed for latitude 39° and the hour lines, contained within a chapter ring, are delineated for every 15 minutes. The word 'FECIT' is followed by a maker's mark that looks like a crown (and in retrospect reminds me of the Toronto Maple Leafs Hockey Team insignia). The simple 8-point compass rose uses English nomenclature (Fig. 3).

So far, so good, but now we come to the engraved date (not seen in Fig. 3): "1717". The style of the compass rose and chapter ring are certainly not from the 18th century. For example, an 18th century sundial at the College of William and Mary [Registry #116, *The Compendium 1*(3), Aug. 1994] shows true English craftsmanship of the era (Fig. 4). So, what is the real history of the Oatlands sundial? The only other piece of information available is that it may have been purchased by Edith Eustis during the first part of the 20th century.

Fig. 3. Detail of Sundial Face.

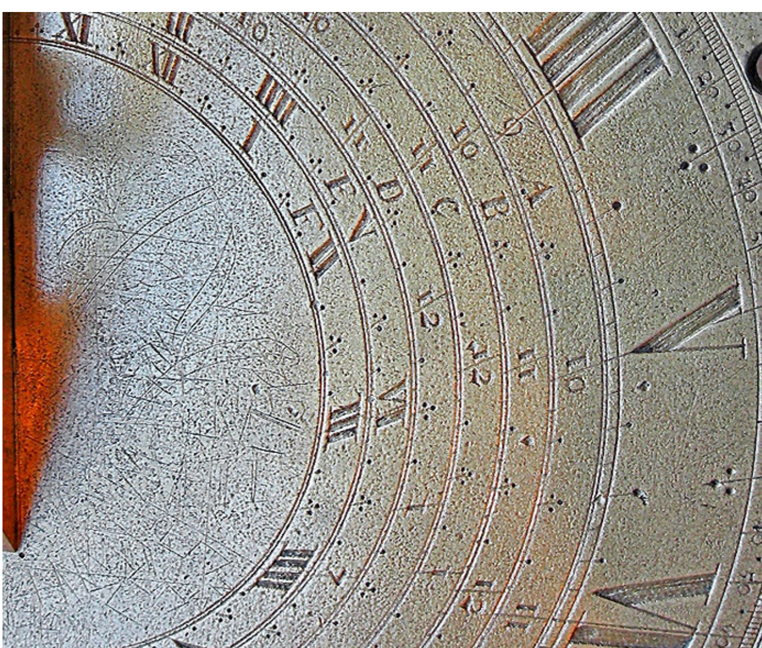


Fig. 4. College of William & Mary Sundial.

Then this Fall, a serendipitous query came from Joseph Murray, asking about a sundial that came from his father-in-law's home in Flint, Michigan, and noting that it looked identical to dial #255, the Oatlands dial on the NASS website. "Any information you can provide would be greatly appreciated." With photos of his dial in hand (Fig. 5), we pieced together the puzzle of the two identical dials.

Fig. 5. Sundial investigated by Joseph Murray. The design is identical to the Oatlands dial.

Indeed, they were identical. Fig. 6 compares sections of the two dials. Murray's dial, with its gnomon torn off, had been kept indoors. It retains its brass finish while the Oatlands dial has been submitted to a century of weathering. Look closely at the East compass line. There is an identical ‘squiggle’ in each. And at the 5 p.m. mark, the Roman V in each has the same peculiar shape. These are so identical that they are carbon copies. This implies that the two dials came from the same mold or were stamped with a common die.

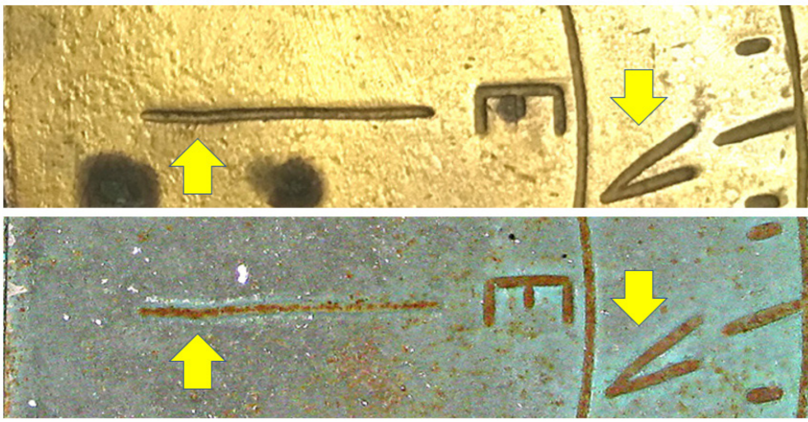


Fig. 6. Comparison of details.

Joe measured his dial as exactly $1/8^{th}$ of an inch (0.3175 cm) thick and measured the weight on a postage scale, tipping in at 2lb 1oz (936 g). Doing the math of 936 g divided by $\pi \times (23.5 / 2)^2 \times 0.3175$, 138 cm^3, gives 6.8 g/cm^3. A table of common metals gives the densities of tin at 5.76 g/cm^3, zinc at 7.13 g/cm^3, solid brass at 8.55 g/cm^3, and lead at 11.34 g/cm^3. We can exclude solid brass and lead. Tin is not usually alloyed with zinc unless combined with copper to make brass, leaving tin as the most likely metal of the dial. And the bright brass or patina on the dials? Look at where the gnomon was torn out. The brass is only skin deep, having been electroplated on.

During the late 1800s and the first years of the 1900s, stamped tin ceiling tiles were all the rage. Steel dies and a press created intricate patterns such as Fig. 7, a modern 2′ × 2′ tin tile from American Tin Ceilings. We can imagine that some entrepreneurs got the idea of stamping out sundials and selling them at inflated prices as 18^{th} century antiques.

Fig. 7. A 2 × 2 ft tile from the American Tin Ceiling Co.

There is one place on the dial that has a distinct difference – the word FECIT. Fig. 8 compares the two marks and the letter stamp dies were slightly different as well as the letter alignment. We can imagine several workers with their set of dies, hammering out the word FECIT, to suggest a handcrafted (and therefore unique) sundial. Then the base metal was electroplated and a gnomon attached.

Fig. 8. FECIT Detail Comparison.

How is it that these mass-produced dials just happened to have a dial face and the gnomon aligned with the Oatlands latitude of 39° 2.467′?

Part dumb luck, but part in the more generic design of 40°, useful for a great part of the United States.

Fig. 9. Modern lead sundial for sale by N.E. Gardens.

Soft metal casting or stamping is more common than we think, and merchandise is still sold at a premium. For example, the New England Garden Company of Sudbury, MA [https://tinyurl.com/2sxcun4h] has a whole catalog of lead sundials (e.g., Fig. 9) ranging from $145 to $645. They even sell a 'Friary Lead Wall Sundial' for $680. The website states that:

> *We pride ourselves in our extensive selection, created for us by exceptional small foundries, dry cast stone makers, and artisans across England and beyond…. Our design team creates distinctive water features and vignettes in the showroom, utilizing a unique mixture of antiques, reproduction pieces and interesting salvage finds.*

Perhaps it was such a showroom that Mrs. Edith Eustis visited 120 years ago and succumbed to the alure of a small brass sundial that she could place on an elaborate pedestal supported by a tortoise.

Bob Kellogg rkellogg@comcast.net

A 17TH CENTURY WINDOW DIAL

Mark Montgomery (Chesterton, IN)

Being a stained glass artist, I am always on the lookout for new ways to make stained glass sundials. I was pleasantly surprised while reading Thomas Strode's 1688 book *A New and Easie Method to the Art of Dyalling*. In one section of the book, Strode describes a 'nocturnal' built into an existing window. This is the story of my efforts to reconstruct Thomas Strode's Nocturnal [1].

The title for chapter XII is: '*How to make a Nocturnal Dyal, to see what's aclock at Night by the Stars, or at Day by the Sun, when it shines bright, or enough to be discerned, but not clear to give a shadow'*. What dialist wouldn't be intrigued?

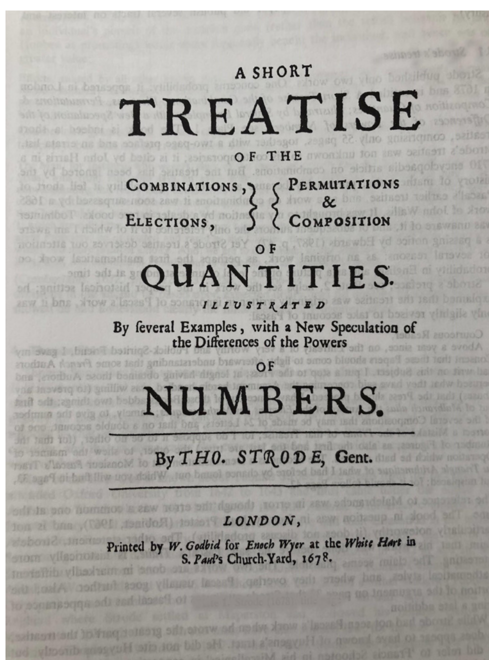
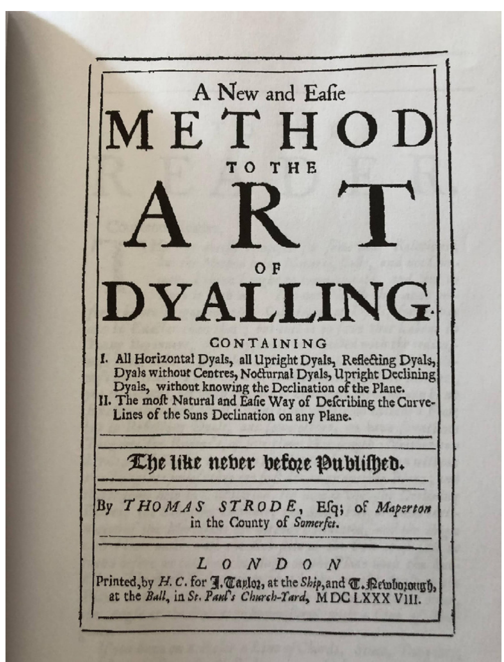

A SHORT
TREATISE
OF THE
COMBINATIONS, } { PERMUTATIONS
ELECTIONS, } { & COMPOSITION
OF
QUANTITIES.
ILLUSTRATED
By ſeveral Examples, with a New Speculation of the Differences of the Powers
OF
NUMBERS.
By THO. STRODE, Gent.
LONDON,
Printed by W. Godbid for Enoch Wyer at the White Hart in S. Paul's Church-Yard, 1678.

Fig. 1. Title page of Strode's work on probability.

Who was Thomas Strode? The Strode family name is famous throughout English history. Strodes have been knighted and served in parliament. The Strode Act of 1512 set precedent in English law that echoes in the halls of the US Congress today. Yet the lineage, and life, of our Thomas Strode is mostly unknown. Son of Thomas Strode of Shepton Mallet, he entered Oxford University in 1642 at the age of 16. He left three years later, during the English civil war, and traveled with his tutor, Abraham Woodhead, in France. He then settled at Maperton in Somerset, where he taught mathematics. The exact dates of his birth and death are unknown, but assumed to be 1626-1697 [2].

Thomas Strode produced two academic works during his lifetime. His first book, published in 1678, was *A Short Treatise of the Combinations, Elections, Permutations & Composition of Quantities*, Fig. 1. Strode's treatise was the first English publication on probability theory. It is little known today because it was overshadowed by Pascal's work on the same subject. Luckily, we will not delve into his probability theory in this article.


A New and Easie
METHOD
TO THE
ART
OF
DYALLING.
CONTAINING
I. All Horizontal Dyals, all Upright Dyals, Reflecting Dyals, Dyals without Centres, Nocturnal Dyals, Upright Declining Dyals, without knowing the Declination of the Plane.
II. The most Natural and Easie Way of Describing the Curve-Lines of the Suns Declination on any Plane.

The like never before Published.

By THOMAS STRODE, Esq; of Maperton in the County of Somerset.

LONDON
Printed, by H. C. for J. Taylor, at the Ship, and T. Newborough, at the Ball, in St. Paul's Church-Yard, MDCLXXXVIII.

Fig. 2. Title page of Strode's work on sundials.

Strode's second work is of more interest to us: *A New and Easie Method to the Art of Dyalling,* written in 1688, Fig. 2. The book contains descriptions on the design of many dial types including declining, reclining, reflecting and nocturnal. He describes several ways to develop declination lines for the dials. Strode also explains why he wrote this work: “This was chiefly composed for some near Relations; but the Method being Natural, Easie, and not Common, I think I ought to communicate, and not to Bury it with me.” So, in completing this work, Strode hoped to leave a legacy to the dialing community and encourage others in their dialing endeavors.

Strode’s nocturnal

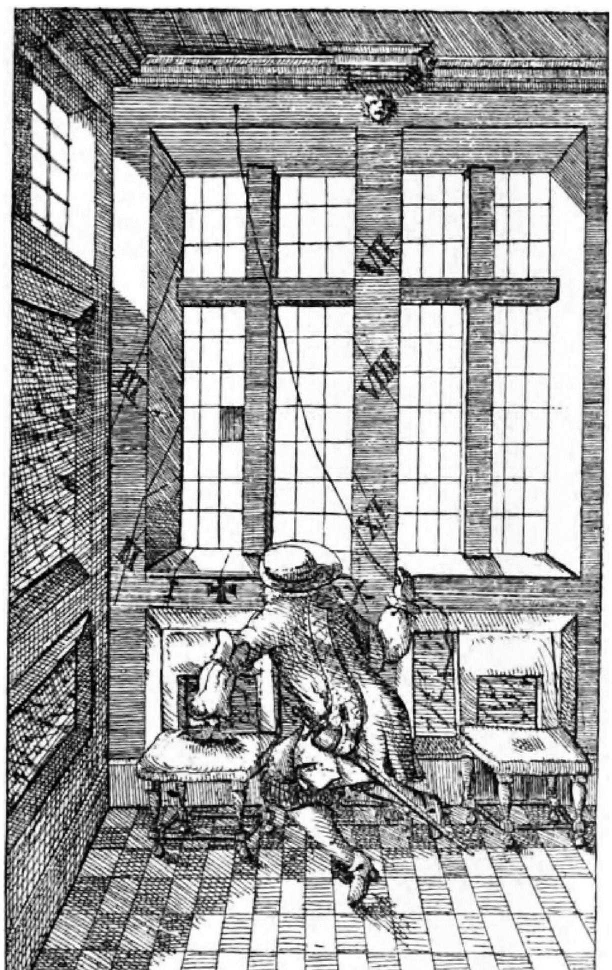


Fig. 3. Nocturnal drawing from Leybourne [3].

As depicted above, the nocturnal is an intriguing dial. This is how Strode describes it:

> *Though this sort of Dyal be not common, yet it is very useful; For in any Room where there is a Casement, and a Prospect, you may make it, though it does not respect the South.*
>
> *In the Casement of a Window, a Ring must be fixed or a Scotch[1] filed, or the Angle of the Casement, or some other Mark in the Casement or Bar of the Window, and a String somewhere in the Ceiling, or in the Wall above the Window in the Room, to be fixed by Art, in a South Plane, or somewhere below, in a North Plane: In the inner Side of the Window, by Motion of the String, the Plane of the Dyal is described, as if it were Boards fastened to the Window, and the Hours were placed on the Wall on the inside of the Window.*

The exact meaning of Strode's 'casement' is unclear. Here, he may be describing the lattice work holding individual window panes in place. In other places he may be describing the interior wall immediately surrounding the window, including the thickness of the wall opening. Strode's nocturnal consists of three parts:

First, a point gnomon, or nodus, that is located as a scratch on the window or notch in the muntins (grille work) immediately around the window. This will cast a shadow on the dial's face. The thickness of the wall, from window to inside surface, sets the gnomon's distance. In the 1600s, a building's wall could be 10″ to 20″ thick.

Second, hour markings on the inside wall immediately around the window. The plane of the inside surface becomes the dial's face.

And finally, a string fastened at the root (center) of the dial somewhere on the plane of the inside wall (or if necessary, a board

[1] 'Scotch' is an archaic word for a wedge. Here it seems to mean a notch cut into the casement.

attached to the inside wall that crosses the window). The string is in the same plane as the dial face and acts as the hour lines by moving the string across the dial face catching the shadow of the nodus. Holding the string taut, the time is read from the hour marks on the inside wall.

Being a vertical dial, it is not limited to direct south but can also decline either to the east or west, as long as the sun shines on the window some portion of the day. Fig. 4 shows my interpretation of Strode's description.

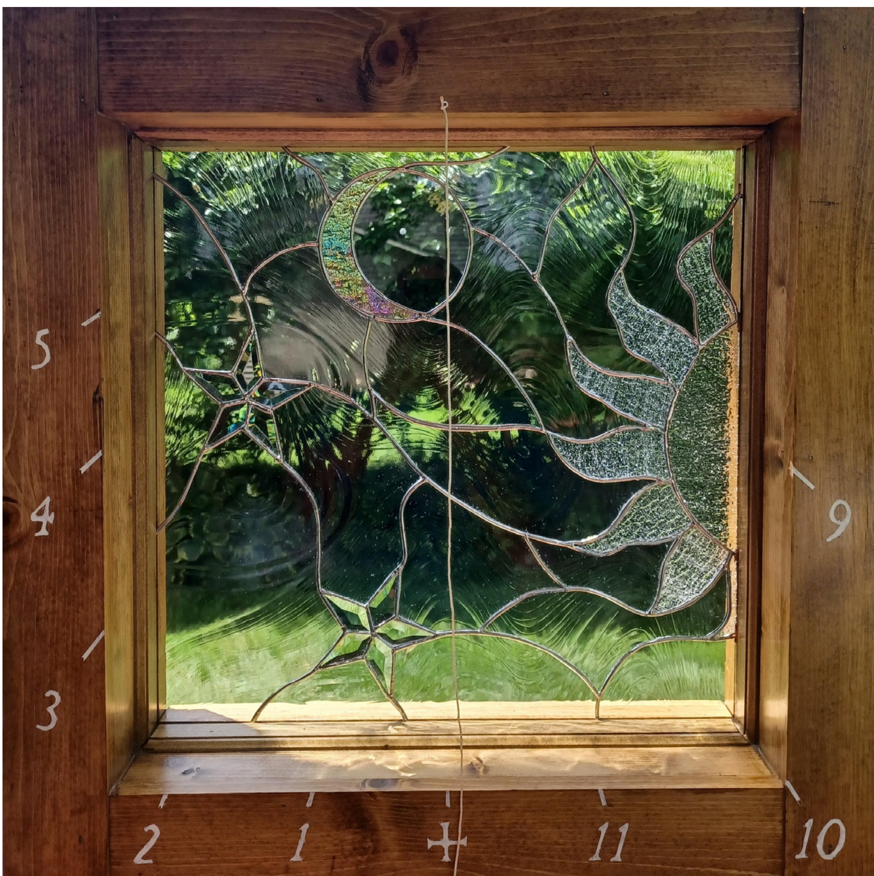


Fig. 4. The author's implementation of Strode's Nocturnal. A small dot in the clear portion of the moon is the nodus. Photo: Mark Montgomery.

Being a true mathematician, Strode understood that only trigonometric calculations can produce accurate sundials. Yet, he also understood that many people preferred to avoid mathematics and use graphical methods for dial designs. He wrote:

> *I do not Publish this as to prefer it before Trigonometrical Calculation of Dyals, for no way can be Exacter than that but this is to save the Labour in Young Beginners, lest they should be dejected with the tediousness of the other.*

Thus, his design method combines the geometrical layout of dials with tables of trigonometric values.

As an example of combining trigonometry with graphical methods, Strode defines all the trigonometric functions as a line on a triangle. Fig. 5 demonstrates the value for each trigonometric function of angle α by the length of the various lines. For example, in the black-yellow-green right triangle, the secant is hypotenuse divided by adjacent. If the adjacent (black) length is set to 1, the length of the green line equals the secant for angle $90 - \alpha$. Since $90 - \alpha$ is the complementary angle of α, the green line is the cosecant of α.

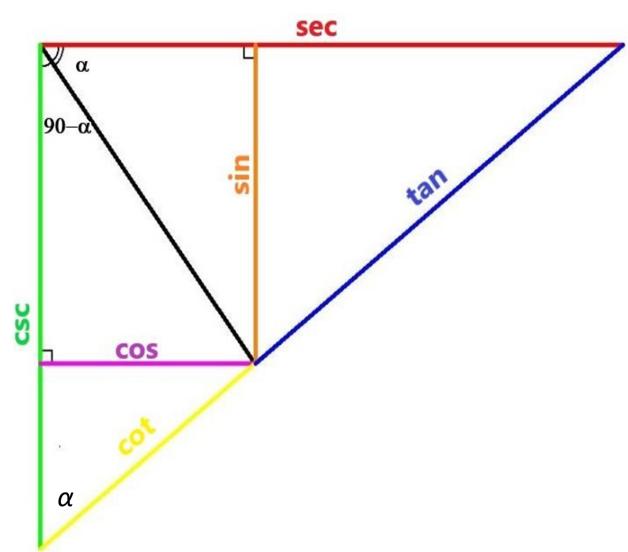


Fig. 5. Trigonometric values measured on a triangle.

RADIUS 10000.

0	Sines	Cord.	Tang.	Secant.	90	Co-si.	Com. C	Co-tang.	Cosecant
1	174	174	174	10001	89	9998	14018	572900	572987
2	349	349	349	10006	88	9994	13893	286362	286537
3	523	523	524	10014	87	9986	13767	190811	191073
4	697	698	699	10024	86	9975	13640	143007	143356
5	871	872	875	10038	85	9962	13512	114300	114737
6	1045	1046	1051	10055	84	9945	13382	95144	95668
7	1219	1221	1228	10075	83	9925	13252	81443	82055
8	1392	1394	1405	10098	82	9903	13120	71154	71853
9	1564	1569	1584	10124	81	9877	12889	63137	63924
10	1736	1743	1763	10154	80	9848	12989	56713	57588
11	1908	1917	1944	10187	79	9816	12721	51445	52408

Fig. 6. Part of the Table of Trigonometric Functions from 'A New and Easie Method to the Art of Dyalling.' [1]

In Fig. 6, we see a table of trigonometric functions. Next to the familiar sine function is the length of a chord, which was often used to lay out angles – the protractor was probably still a relatively uncommon instrument. The next columns are the tangent and secant. Next come the complementary angle, cosine, complementary chord, cotangent and cosecant. We don't use secants today. In fact, modern textbooks define secants and cosecants in terms of sines and cosines: sec = 1 / cos, csc = 1 / sin. Unlike today, the secant and cosecant had an important part of Strode's dial design procedure.

Strode's construction method

To see how secant and cosecant were used, Strode's method for laying out a simple horizontal dial follows:

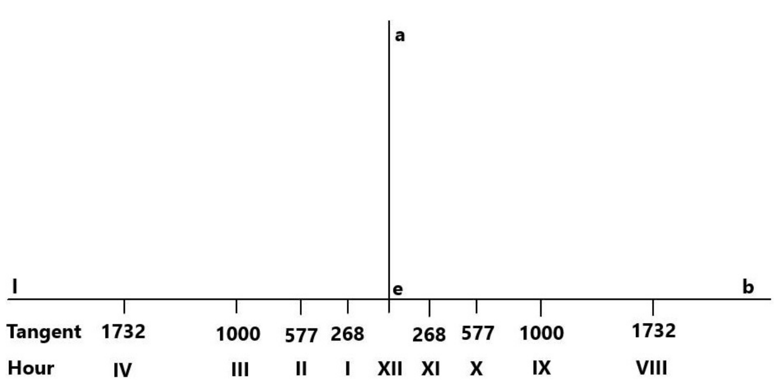


Fig. 7. First step in horizontal dial layout.

First draw a horizontal line *lb* as shown in Fig. 7. This is called the Line of Tangents.

At a convenient point, *e*, draw a line perpendicular to *lb*. This is the meridian line for the dial.

Using 15° per hour, look up the tangents for the hour angles needed and measure this distance on the line of tangents (e.g., the distance from XII to XI is the tangent of 15° or 268).

Strode claims:

> *From this Tangent Line, so marked, may be made any Horizontal, or Direct south or North, whether Upright, Inclining, or Reclining for any Latitude, by the true placing of the Center of the Dial.*

Thus, Strode can draw a wide variety of dials using this same line of tangents! The trick is to find the correct center, or foot, for the dial where all the hour lines converge.

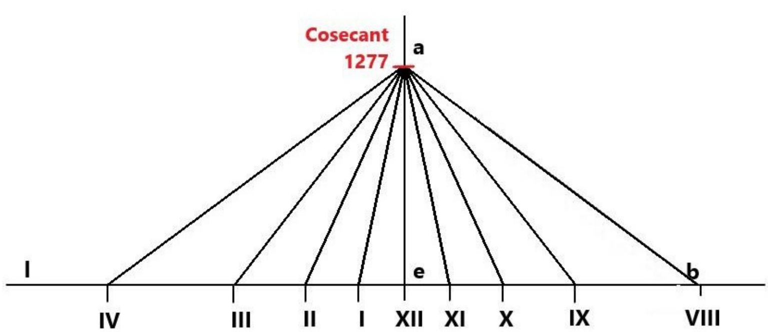


Fig. 8. Finding dial center and laying out hour lines on horizontal dial.

For a horizontal dial, the center of the dial is found by looking up the cosecant of the latitude. Lay this value on the meridian from *e* to find *a*, the dial center. To make the hour lines, join the center, *a*, to the hour marks on the tangent line, as shown in Fig. 8.

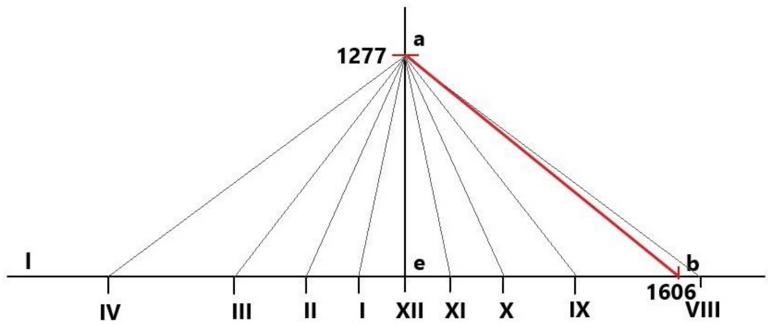


Fig. 9. Layout of style of horizontal dial using secant on line of tangents.

As shown in Fig. 9, to design the style, find the secant of the latitude and lay its value on the tangent line (point *b*). Connect *a* and *b* to show the style (red line). Angle ∠*eab* is the style height. So why does this work?

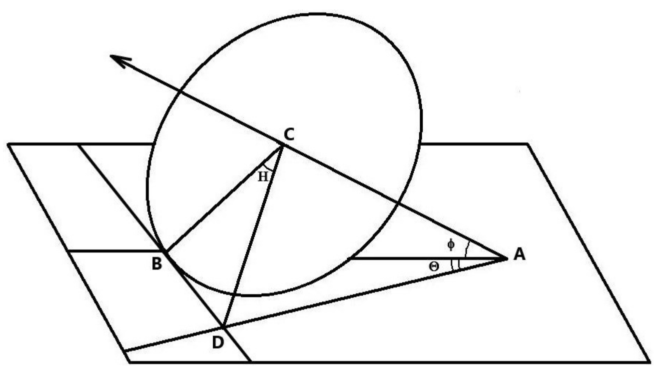


Fig. 10. Horizontal Dial showing three planes.

Fig. 10 is a familiar sketch to explain a horizontal dial. The circle and triangle *BCD* are in the equatorial plane, and angle *H* at *C* shows the hour angle. The triangle *ABC* is in the plane of the meridian with *AC* the style of the dial and angle ϕ equal to the latitude. The triangle *ABD* in the parallelogram is in the plane of the horizon with angle θ equal to the dial's hour line angle formed by the style's shadow line and the meridian. Note that line *BC* is in both the meridian and equatorial planes. For convenience we will set the length of $BC = 1$.

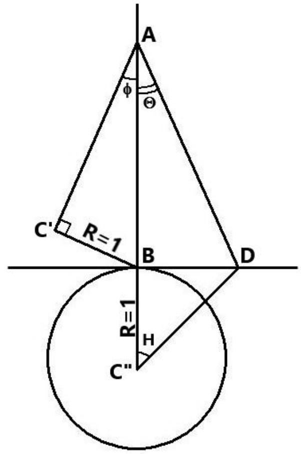


Fig. 11. Rotation of meridian and equatorial planes into the horizontal plane.

The next drawing, Fig. 11, shows the meridian plane, with its style, rotated about line *AB* and the equatorial plane rotated about line *BD*. Note, since point *C* is in two planes, it has been renamed points *C′* and *C″*. Thus, all three triangles, *ABC′*, *ABD*, and *BC″D* are in the same plane. Considering the tangent line, *BD*, and hour angle *H*:

$$\tan H = \text{opposite} / \text{adjacent}$$
$$= BD / BC''$$

However, $BC'' = 1$ so $= BD$

Also, remember that the cosecant equals the hypotenuse / opposite or for the latitude, angle ϕ:

$$\csc \phi = AB / BC'$$

However, $BC' = 1$ so $= AB$

Since $C'B = 1$, the length from the line of tangents to the dial center equals the hypotenuse, *AB*.

Strode used a similar method to design many different types of dials, including inclining and declining dials. He realized trigonometric calculation required for dials would challenge many beginning dialists. To simplify these calculations, he developed a table listing the values for both London, latitude 51°15′ (Fig. 12), and Cambridge, latitude 51° 30′.

The values needed include the substyle distance (the angle between the meridian and the substyle), style height (the angle between the substyle and the style), and inclination of the meridians (the angle added to the Line of Tangents). With these tables, Strode eliminated both tedious calculations and laborious drawings.

Latitude 51 Deg. 15 Min.

decl.	Subs.dist.	Stil.heig.	Incl. Mer.	dec	Subs.dist.	Stil.heig.	Incl.Mer.
1	0 . 48	38 . 45	1 . 17	46	30 . 06	25 . 46	53 . 01
2	1 . 36	38 . 44	2 . 34	47	30 . 25	25 . 16	53 . 59
3	2 . 24	38 . 41	3 . 51	48	30 . 49	24 . 46	54 . 56
4	3 . 13	38 . 38	5 . 08	49	31 . 13	24 . 15	55 . 52
5	4 . 1	38 . 34	6 . 24	50	31 . 35	23 . 53	56 . 48
6	4 . 50	38 . 30	7 . 41	51	31 . 57	23 . 12	57 . 44
7	5 . 36	38 . 25	8 . 57	52	32 19	22 . 40	58 . 38
8	6 . 23	38 . 19	10 . 13	53	32 . 42	22 . 08	59 . 33
9	7 . 10	38 . 11	11 . 28	54	33 . 00	21 . 35	60 . 28
10	7 . 56	38 . 3	12 . 44	55	33 . 19	21 . 02	61 . 22

Fig. 12. Table listing Substyle Distance, Substyle Height, and Inclination of the Meridians for each wall declination at London's latitude. From [1].

Strode then explained how to interpolate between these two tables to calculate the values for any location in England.

However, living just south of 42° N parallel, I was not sure the extrapolation over such a great distance would be satisfactory. Thus, I designed the dial using Strode's tables, again by graphical construction, and finally using trigonometric calculations with the following formulae (where *D* is the wall's declination):

α = substyle distance,	$\tan \alpha = \sin D \cot \phi$
β = style height,	$\sin \beta = \cos D \cos \phi$
η = Inclination of the meridians	$\tan \eta = \tan D / \sin \phi$

Note that for the nocturnal, the style length, or the distance from the window pane to the wall inside the window (casement depth), is fixed for any particular window and cannot be a variable. In my case, I used 3″ and my window declines 16° west of south.

To make this nocturnal on a window is a little more complicated than a typical vertical dial. In Fig. 13, taken from Strode's book, notice that the hours are numbered clockwise, while a normal vertical dial has the hours numbered counter-clockwise (in the northern hemisphere). This dial is viewed from the 'back' of the dial face. Thus, the numbering and the layout are reversed.

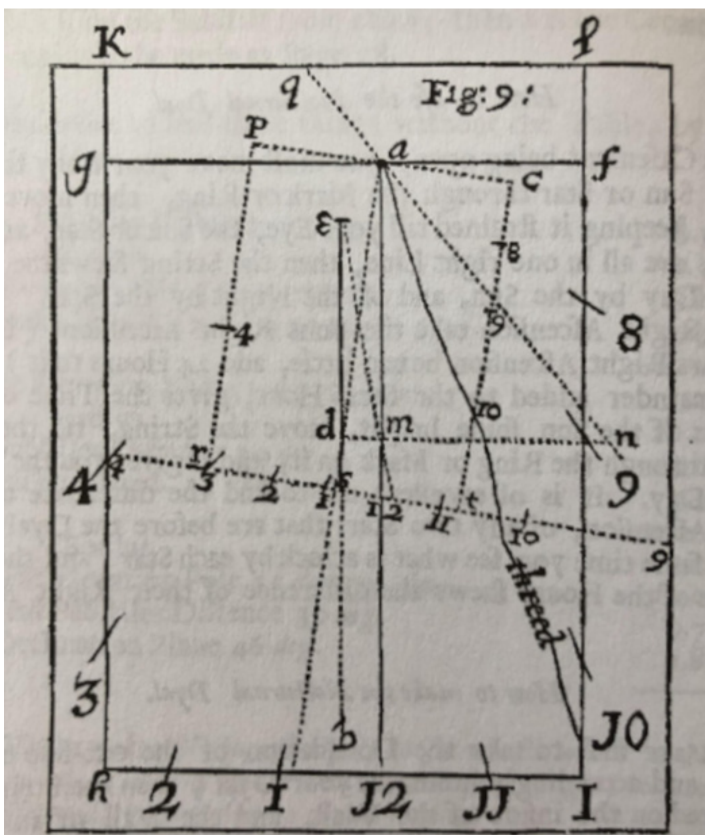
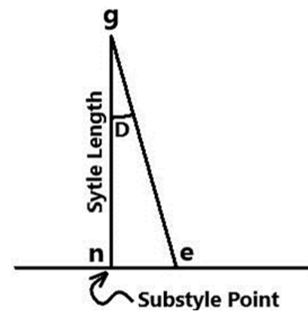


Fig. 13. Strode's layout of a Nocturnal.

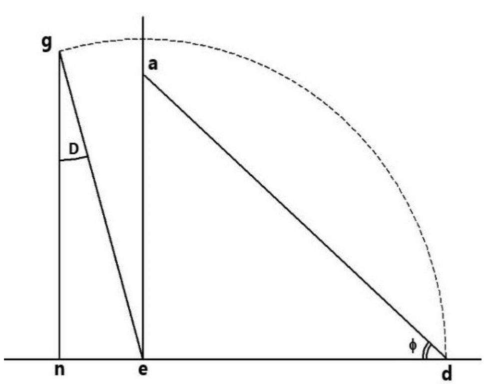
These are the instructions for designing the nocturnal using Strode's tables:

We start laying out Strode's nocturnal by picking the substyle point (nodus), *n*, on a horizontal line *ne*. This is the location of the scratch on the window.



1. Draw a line, *ng*, perpendicular to *ne* at *n*. The length should be equal to the style length. The window casement depth is 3″ for my design.

2. Add *ge* with ∠*dge* = wall declination, *D*, (16° for my design). Draw *e* on the right of *n* for westward declining windows and to the left for eastward declining windows. Note: This is the reverse of a typical declining dial in the Northern Hemisphere.



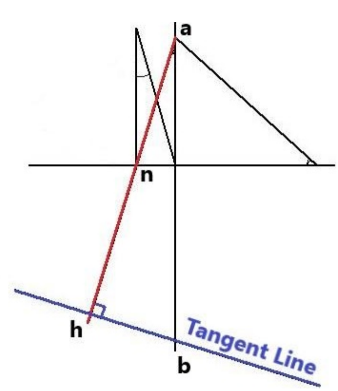
3. Draw *ae* perpendicular to *ned* at *e*. This is the dial's meridian line.

4. Find point *d* on *ned* so that e*d* = *eg*.

5. Draw *ad* such that ∠*ade* = ϕ = latitude.

6. Draw *an* (shown in red), the substyle. Note, ∠*nae* = α = substyle distance.

   Strode could have skipped Steps 4 and 5 by drawing ∠*gna* = substyle distance given by his tables.

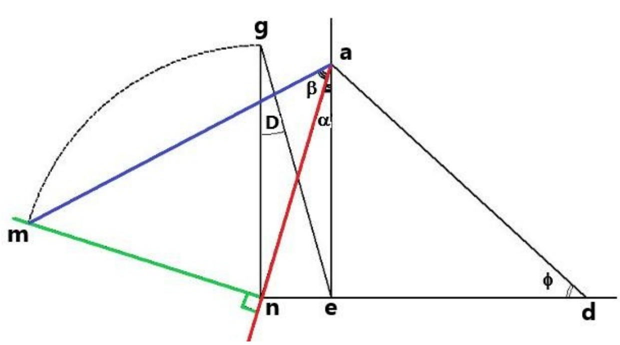


7. To complete the design graphically, skip Step 7, starting again with Step 8.

   Look up style height, β, from the tables and find its cosecant. Find point *h* on line *an* so that $ah = \csc \beta$.

   We are now ready to draw tangent values on the tangent line – or are we? If we lay out tangents for each hour at 15° per hour, starting from point *h* on the substyle, most likely we will not hit the meridian, *ab*, on the hour. The angled substyle requires an adjustment of the hour angles so that noon will fall on the meridian. This offset is called the Inclination of the Meridians. The Inclination of the Meridians is added or subtracted to the hour angle tangent before being plotted.

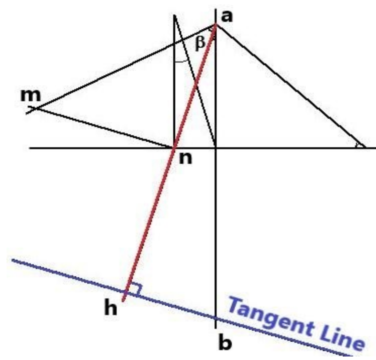
   Adding the tangents completes the construction by Strode's method.



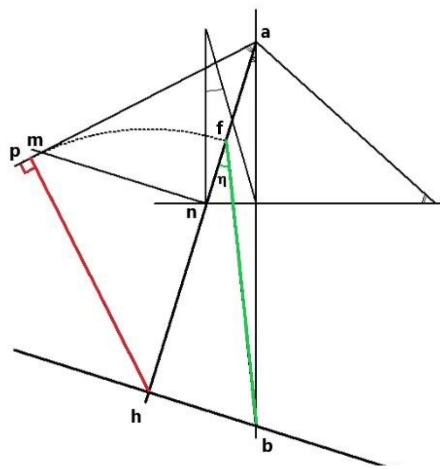
8. Draw *nm* (green) perpendicular to *an* such that *nm* = *ng*.

9. Draw *am*. Note, $\angle nam = \beta$ = style height.

10. Extend *an* to *h*. Segment *ah* (red) = cosecant of stye height, β.
11. Draw *bh* perpendicular to *ah*. *bh* is the line of tangents.



12. Draw *ph* (red) perpendicular to *am*.
13. Find *f* such that *hf* = *ph*.
14. Draw *fb* (green). Note, η = inclination of the meridian.
15. Lay out the hour marks using the hour angle tangents. The inclination of the meridian must be added to or subtracted from each hour angle; find the tangent for the adjusted hour angle.



With this, we have designed the nocturnal by graphical means.

Comparison of the three methods			
	Calculated	From Tables	Graphical
Substyle Distance	17.2°	17.0°	17.5°
Substyle Height	45.9°	45.3°	47.0°
Incl. of Meridians	23.4°	22.5°	24.7°

To be fair to Strode's tables, I extrapolated his values far beyond their intended use. And, as Strode pointed out, calculated values provide a more accurate design. My final design used calculated values.

To construct the Nocturnal required the following steps:

- Transfer the design to a large board, the size of the window, for use as a template.
- Determine the location of the nodus on the window.
- Carefully measure to determine the location of dial center on the inside window sill. If the foot is below the window sill, add a piece of wood across the window at the proper height and fasten the string to the wood and in the plane of the inside wall.
- Transfer design to window and window sill.

The final step of transferring the design to a window is an alignment problem. I nailed the pattern board to the dial's center on the window sill and used a plumb bob to keep the meridian line vertical while marking the hour lines.

How to use as a dial

Per Strode's instructions:

> *The Casement being open, you must move your Body till you see the Sun or Star through the Mark or Ring, then move your String, keeping it strained till your Eye, the Sun or Star, and the String, are all in one right Line, then the String shews the Hour of the Day by the Sun…*

During a sunny day, move the string across the window in the plane of the inside wall. When the shadow of the nodus falls on the string, extending the string to the window sill will indicate the time.

I find the shadow of the nodus on the palm of my hand and sweep the string across the window sill until the shadow of the string crosses the nodus shadow. On cloudy days, when the location of the sun can be determined but no shadows are visible, align the string and the nodus with your eye; extend the string to the window sill and read the time.

To prevent eye damage, never look directly at the sun.

To use as a nocturnal

Strode's instructions for finding time at night are: "shews the Hour… of the Night by the Star. From whose Right Ascension take the Suns Right Ascension."

As an example, on the night of August 13th, 2022, at my home in Chesterton, Indiana, I sighted the star Altair, in the constellation Aquila, by positioning myself so that my eye, the string, the nodus, and the star were all in a line. The star's time reading, H_{star}, was 10:00 a.m., or −2h. To convert Altair's time to Local Solar Time, LST, we need to add the difference between Altair's Right Ascension, RA_{star}, and the sun's Right Ascension, RA_{sun}.

$$LST = H_{star} + (RA_{star} - RA_{sun})$$

From an astronomical almanac, Altair's Right Ascension is 19h 52m. Next, we look up Right Ascension of the sun on August 13th, which is 9h 35m. The difference is +10h 17m. Thus:

$$LST = -2h + (19h\ 52m - 9h\ 35m) = +8h\ 17m$$

Since the result is positive, LST is 8:17 p.m. (a negative LST would be in the morning.)

One way to picture the calculation is to imagine a fake sun in the position of Altair. The fake sun would cast a shadow at 10:00 a.m., or −2h. However, the real sun is 10h 17m ahead of the fake sun. Thus, the real sun's LST = −2:00 + 10:17 = +8:17.

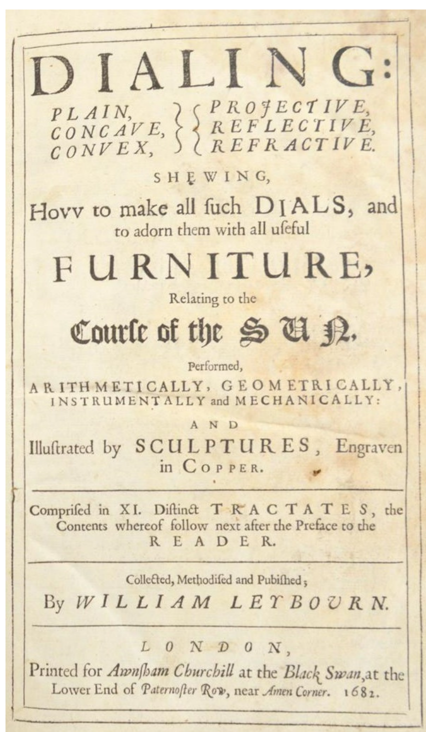
To convert this to Civil Time, I used:

	8:17	p.m. LST
+	1:00	Daylight Savings
−	0:12	Longitude correction
+	0:05	Equation of Time
=	9:10	p.m. CDT

Leybourn's 1700 publication

William Leybourn published an epistle on sundials in 1700 titled '*Dialing: plain, concave, convex, projective, reflective, refractive: shewing how to make all such dials and to adorn them with all useful furniture relating to the course of the sun'* [3] (See Fig. 14.)

Leybourn wrote his seminal text on a vast array of dial types. One section is titled: *Shewing Several ways whereby to find the Star's Hour readily, and consequently the true Hour of the Night by the stars.* A whole section on nocturnes includes the drawing shown as Fig. 3.



DIALING:

PLAIN, CONCAVE, CONVEX, PROJECTIVE, REFLECTIVE, REFRACTIVE.

SHEWING,

Hovv to make all ſuch DIALS, and to adorn them with all uſeful

FURNITURE,

Relating to the

Courſe of the SUN.

Performed,

ARITHMETICALLY, GEOMETRICALLY, INSTRUMENTALLY and MECHANICALLY:

AND

Illuſtrated by SCULPTURES, Engraven in COPPER.

Compriſed in XI. Diſtinct TRACTATES, the Contents whereof follow next after the Preface to the READER.

Collected, Methodiſed and Pubiſhed;

By WILLIAM LEYBOURN.

LONDON,

Printed for Awnſham Churchill at the Black Swan, at the Lower End of Paternoſter Row, near Amen Corner. 1682.

Fig. 14. Title page of Leybourn's work on sundials. [3]

Since Leybourn's work was published after Strode's, it seemed to confirm Strode's ideas were spreading. However, on reading the preface, I found that Leybourn carefully gave credit to the source of the information, saying it "is Wholly Mr. Samuel Foster's…"

Foster died in 1652 well before Strode's 1688 book. Once again, Samuel Foster proves to be the source of all things sundial. To be fair, Strode did not claim to invent this type of nocturnal – but he didn't give Foster credit either.

So here we are today, over three centuries after Strode's time, discussing his book and his method to lay out dials. I enjoyed recreating this dial, which is not well known in today's dialing world. Strode provided two things to the dialing world:

First, the use of cosecants and secants to lay out dials.

Second, and perhaps more important, he encouraged beginning dialists by developing a method, using tables, to improve the accuracy and simplicity of sundial design, thus inspiring more people to build sundials.

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Making a Bottle Sundial

Don Petrie (Stouffville, ON)

Fig. 1

Many years ago, at one of our sundial conferences, Helmut Sonderegger showed a type of sundial on a wine bottle (Fig. 1). Recently, Fred Sawyer demonstrated its use to NASS' *Elements of Dialing* online class (Fig. 2).

When I first saw this bottle sundial, I thought was a neat idea and that I could make one. After many false starts and side-tracks, I finally came up with a method for making them that works for me. It requires no special expertise or equipment. I have made quite a few of these bottle dials as unique gifts for friends and relatives for various celebrations (birthdays, anniversaries, etc.), and they have been well received. People seemed to be intrigued by them and interested in how relatively accurate they are.

This bottle sundial belongs to the class of altitude dials known as Cylinder Dials. The time of day is indicated by the Sun's height above the horizon, in contrast to azimuth dials where the time is indicated by the Sun's direction. Cylinder dials are also known as pillar dials or, more commonly, Shepherds' Dials. Being cheap, easily made, and portable, they were probably the most common time-

Fig. 2

keepers in everyday use. Chaucer and Shakespeare had characters refer to their "chilindres" for the time of day. The oldest known pillar dial, found in the Italian town of Este, near Padua, is made of ivory and dated to the 1st century CE.

The Dial Plan

A plan for the Hour Lines and Date Scale can be obtained using your favourite dialing software.

I use *Sonne*, the free dialing software developed by H. Sonderegger that includes an option for designing Cylinder Dials (available at: http//www.helson.at/sun.htm).

The interface defaults to German; to change to English, click on 'Hilfe' (Help), select 'Sprache' (language), and choose 'English'.

Choose 'Files' and in the window that appears, click on 'Generate Dial (Wizard)', then click 'Next'.

Insert the Latitude, Longitude, and Time Zone (the latitude of the central time zone meridian) for the location where the dial will be used. Click 'Next'.

Select the option for 'Cylindrical Sundial (Shepherd)'. A few more options appear on the right. Choose 'Shepherds' Dial'. On the same screen, choose the Gnomon Height (for this type of dial, it is actually the length) – try 40 mm to 50 mm.

You will also need to insert the width of the scale of Months. The value is obtained by measuring the circumference of the bottle to which the completed dial plan will be affixed – for a wine bottle it is probably between 220 mm and 225 mm. Click 'Next'.

Now the program-calculated maximum shadow length is shown. The shadow length is the distance from the Date Scale line at the top of the dial plan down to the lowest noon hour point, which occurs around June 21st, the summer solstice. A Gnomon Length of 40 to 50 mm is probably satisfactory (It may be altered depending on the length of the body of the bottle used. This can be assessed and changed easily after you see the final dial plan that is generated).

On that same screen where you see the shadow length, choose the options for Hour Lines ‘of local meridian’ and Scale for Months on the ‘long horizontal axis.’ Check the ‘Local Apparent Time’ box.

For the other options, I choose to show the hours from 6 a.m. (6 uhr) to 8 p.m. (20 uhr) at Time Intervals of 30 min. I uncheck the ‘Construction with Equation of Time’ box as it makes the dial plan a bit confusing. However, it is an interesting view, so try experimenting with this checked and unchecked to see the difference.

Clicking on ‘Next’ will now show the calculated plan of the sundial.

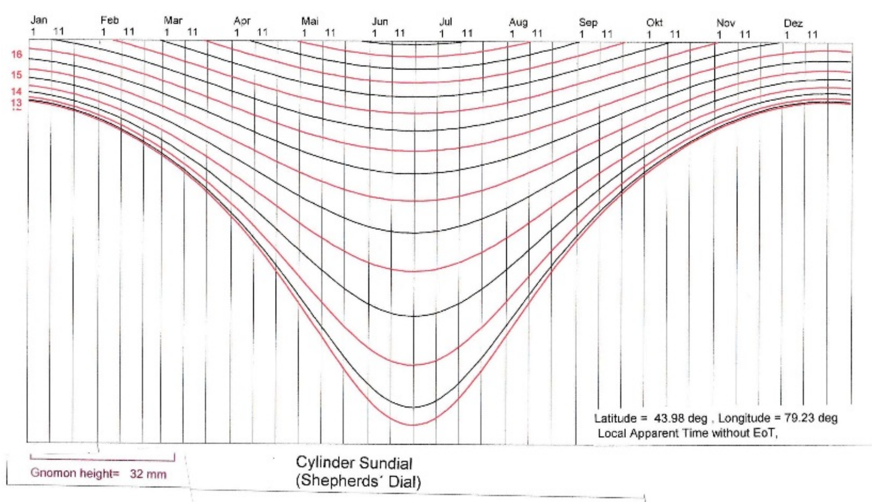

Fig. 3

Now you can click on ‘Display’ and play around with the thickness and colors of the lines on the Dial Plan. If you need to change the width or height you need to go back to the beginning of the wizard and repeat with new inputs (*Sonne* shows you what you used the previous time).

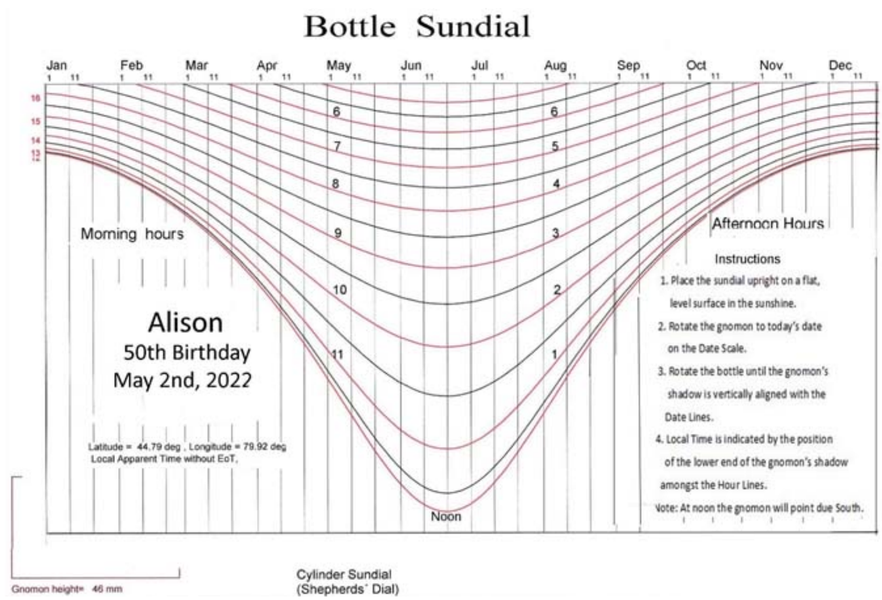

Fig. 4

The Dial Plan is now ready to print. It can be used as is (Fig. 3.), or you can add dial furniture to it depending on your creative and artistic abilities. To generate Fig. 4, I went a bit further and imported the dial plan into *Photoshop Elements,* a photo editing program. I added a title to the plan, changed the names of the months to English and enlarged them slightly, added the numerals to the Hour Lines, and erased areas of the Hour Lines below the Date Scale to make space for the dedication (or the dial's location, a motto, crest, or any other desired furniture). In the dials I make, I usually include instructions for using the sundial (Fig. 5).

Instructions:

1. Place the sundial upright on a flat,
   level surface in the sunshine.
2. Rotate the gnomon to today's date
   on the Date Scale.
3. Rotate the bottle until the gnomon's
   shadow is vertically aligned with the
   Date Lines.
4. Local Time is indicated by the position
   of the lower end of the gnomon's shadow
   amongst the Hour Lines.

Note: At noon the gnomon will point due South.

Fig. 5

The Gnomon

Firstly, allow the bottle to soak overnight in a pot of water and then scrape off the labels.

A rotatable gnomon is to be attached to the bottle dial above the Date Scale line on the dial plan. I form the spiral gnomon and its style from #10-gauge copper wire. This wire is relatively easy to work with by hand yet stiff enough to hold its shape well.

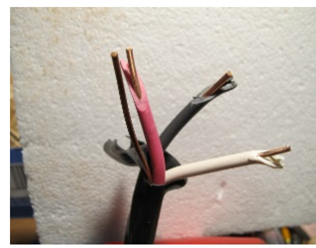

Fig. 6

For the dial illustrated here, I happened to have a 4-strand piece (NMD #30-10) of electrical wire from a previous unrelated job. I stripped off the outer coat and then the insulation from the inner wires and this gave me enough for four dials. (Fig. 6). The #10 single-strand copper wire is readily available at hardware and electrical supply stores. A piece about 3 ft. long is good for a 750 ml wine bottle dial. Strip off all the insulation being careful not to kink the wire.

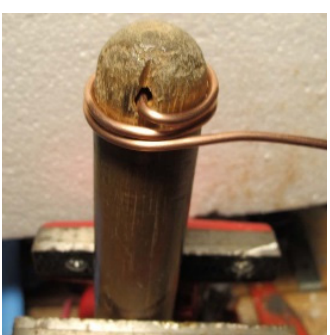

Fig. 7

It is difficult to wind the wire around a glass bottle so find an old broom stick or piece of dowel the same thickness as the neck of the bottle and drill a small hole near its end to anchor the wire and then wind the gnomon wire around it 6 to 8 times (Fig. 7). Leave 8″ to 10″ unwound at the end to shape the gnomon over the shoulder and down the side of the bottle. Snip off the end that held the wire for winding and slide the coil off of the wood form. (Fig. 8.)

Fig. 8

Fig. 9

Remove the cap from the bottle. (I like a capped bottle rather than a corked one as the dial looks more finished when the cap is replaced later.) Now, slide the coiled gnomon down the outside of the neck of the bottle and bend it tightly over the shoulder so that it fits snugly against the bottle with the end hanging vertically down the side. (Fig. 9.)

Now place the Dial Plan against the side of the bottle and slide it up under the gnomon wire to an appropriate height. Wrap it around the bottle so that the ends of the plan Date Scale lines are at the same level and temporarily tape them together. (Fig. 10.)

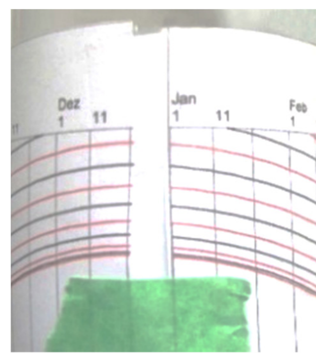

Fig. 10

Do not tape the Plan to the bottle itself – you need to be able to slide it up or down on the bottle to adjust its position. Move the Plan under the gnomon wire to its appropriate position on the bottle and mark the wire at the position level with the Date Line. (Fig. 11.)

Fig. 11

Slide the gnomon off the bottle and form the style by bending the wire away from the bottle horizontally to 90^{O} and vertically aligned with the center line of the bottle. On the completed dial, the style will lie along the local meridian line and point due south at noon. The bend should make as tight a corner as possible. I used a vise to hold it and tapped it a few times with a hammer to sharpen the corner. (Fig. 12.)

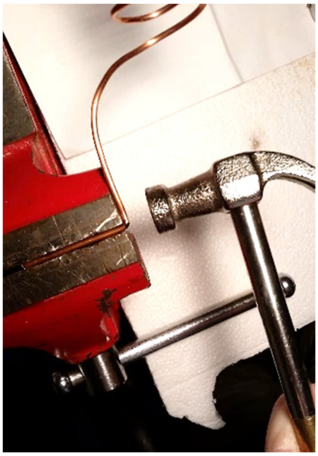

Fig. 12

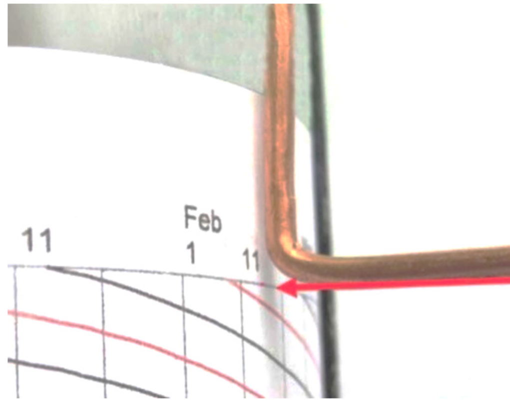

Fig. 13

Putting it together

Slide the gnomon back onto the neck of the bottle and down tightly against its shoulder and readjust the Dial Plan vertically, if necessary, so that the bottom of the style is even with the Date Line (Fig. 13).

Place some pieces of tape around the bottle at the upper edge of the Dial Plan to guide the permanent fixation of the Dial Plan on the bottle (Fig. 14). Remove the gnomon and Dial Plan from the bottle. Trim the excess paper from the Dial Plan being sure to note the Gnomon Length for use later. Apply a thin film of spray glue to the back of the Dial Plan following the adhesive's directions. Use a spray glue that dries clear, does not cause wrinkling of the Dial Plan paper, and does not set too quickly so that the Dial Plan can be re-positioned if necessary (the Gorilla and LePage brands of glues are recommended). Affix the Dial Plan to the bottle using the guide tapes which can then be removed.

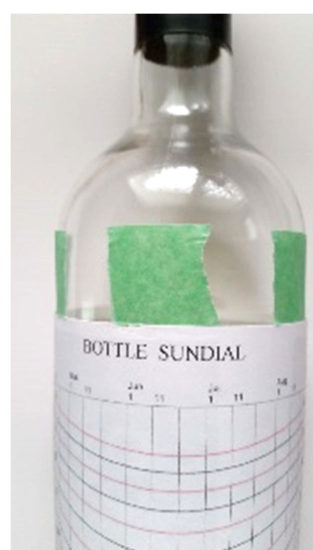

Fig. 14

The last step is to cut the gnomon wire to the correct length of the style. Replace the gnomon on the bottle well down against the shoulder to ensure that the Date Line and corner of the wire are in line. Measure the length of the style (the Gnomon Height given by *Sonne*) along the horizontal wire (Fig. 15).

Fig. 15

Before cutting the gnomon wire, it is probably a good idea to check this Gnomon Height (length) measurement on your new dial itself to ensure there has been no change in the proportions of the Dial Plan due to shrinkage or stretching. The equations for the relationships between the parameters of the Dial (Fig. 16) are:

$L = H \tan(Lat - 23.44)$ or, if preferred, $H = L \tan(90 - Lat + 23.44)$.

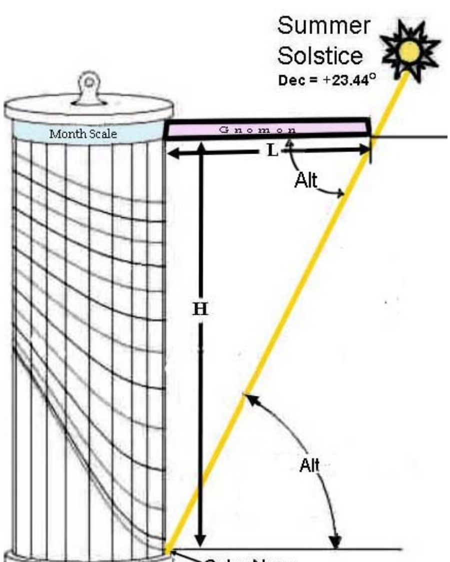

Fig. 16. Image: Carl Sabanski

L is the calculated Gnomon Length in millimeters, the horizontal distance from the tip of style to the bottle. If the Gnomon Length calculated from the Dial Plan does not agree with that given by the software, use the measurement calculated from the Dial Plan.

H is the Dial Height in millimeters of the verticle noon hour line from the Date Line to the solar noon point on the summer solstice. It is the maximum length of the vertical shadow (*umbra versa*) produced by the style.

Lat is the latitude of the intended location of the sundial. *Dec* is the Sun's declination (+23.44° at the Summer Solstice). *Alt* is the Sun's altitude ($90^{O} - Lat + Dec$) at noon.

When either the Dial Height or Gnomon Length is a known quantity, the other can be the calculated using the above equations.

The bottle sundial is now ready for use according to the instructions provided (Fig. 4).

Fig. 17

Bottle sundials can be made for bottles of different sizes if they have an appropriate shape (Fig. 17).

Making a bottle sundial is an interesting and fun project for dialists. Your friends will find it intriguing and even educational as they compare it to their digital watches. Enjoy! (Fig. 18).

Fig. 18

Acknowledgements

Thanks to Olivia Petrie and Jac Heichert for their help, and to Fred Sawyer for permission to use Fig. 2.

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All photographs by the author.

Addendum

Note that the Hour Lines on the cylindrical sundial plan are bilaterally symmetrical on either side of the solar noon line, so the Cylinder Dial plan can be divided vertically at the summer solstice date line into two mirror-image halves. Each half alone will be a functioning sundial when the hour lines are labelled properly with each indicating two different times of the day. The morning hours numbers increase in descending order from the Date Line and then reverse at the solar noon point so the afternoon hours are numbered ascending from noon towards the Date Scale.

Likewise, the month names on the Date Scale are symmetrical on either side of the summer solstice according to the Sun's changing declination. The Date Scale is labelled forwards from December 21st and then backwards from June 21st as on a Locust Leg Dial, or vice versa as on the 17th c. Pillar Dial depending on which arrangement is chosen for the Hour Lines.

This layout could be useful for a Cylinder Dial on a bottle with a narrow diameter.

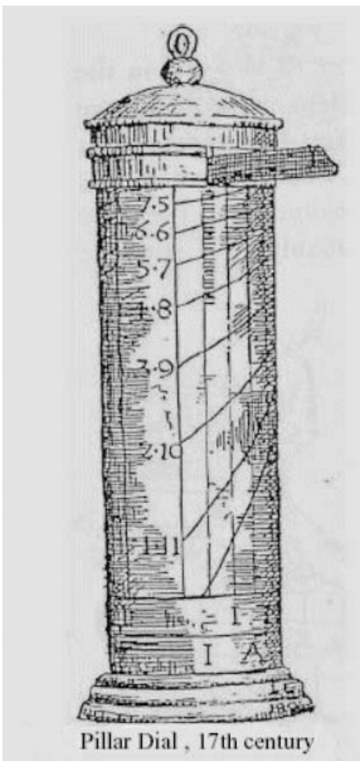

Fig. 19. 17th c. Pillar Dial. Image: Mayall & Mayall.

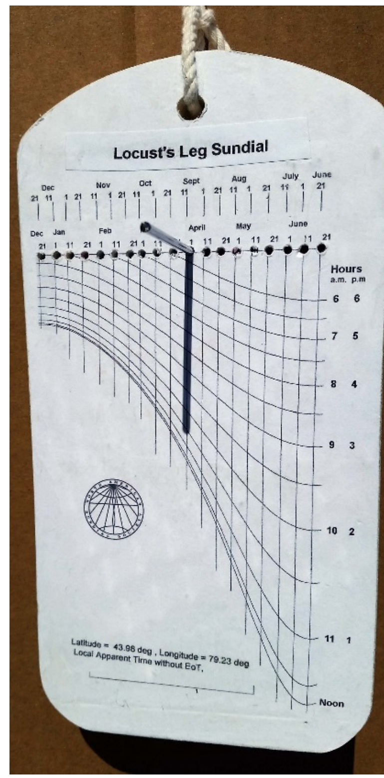

Fig. 20. A Locust's Leg Dial.

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Portable Cylinder Sundials
Part I – History

Alfonso Pastor-Moreno (Valencia, Spain)
and Robert L. Kellogg (Potomac, MD)

The oldest reference to portable dials, along with other dial types, appears in Vitruvius' book *On Architecture* IX, Chapter VIII, written in the first century BCE. In this work, Vitruvius notes, at the end of a list of dial types (Scaphe and Hemispherical, Cone, Arachne, Plinthium or Lacunar, and Pelikinon), a dial called Πρὸς πᾶν κλίμα by Theodosius and Andrias. That is, a dial for any clime (latitude), which today we call a Universal Equatorial Dial. A portable ring dial found at Philippi, and dated to 4th century CE, matches the function of working in many climes. Roman disk dials certainly qualify as another type of portable dial made for a number of latitudes.

And then in the last sentence of Chapter VIII Vitruvius mentions "Many have also left instructions for constructing portable pendulous dials". A Latin version of that sentence is a bit more specific, stating: "item ex his generibus viatoria pensilia uti fierent plures scripta reliquerunt. ex quorum libris si qui velit subiectiones invenire poterit, dummodo sciat analemmatos descriptiones." Or in other words, there are many written records from books for making 'viatoria pensilia' (hanging dials for travelers) provided the maker knows the description of the analemma.

There is no doubt that portable dials were common in the first century BCE; so common that to Vitruvius they barely need mention for there were many who could describe their construction.

In 1984 an eminent Italian archaeologist, Simonetta Bonomi, made a discovery [1]. She was studying a cylindrical object from the collection of Museo Nazionale Atestino in Padua, which, along with other objects, had been unearthed a century earlier on January 2, 1884, from the burial site of a Roman medical practitioner near Este in the

Italian province of Padua. In the museum catalog published in 1901, the object was classified as an “astuccio cylindrico” (cylindrical case) [2]. But Bonomi recognized it as a Roman Altitude Cylinder Dial.

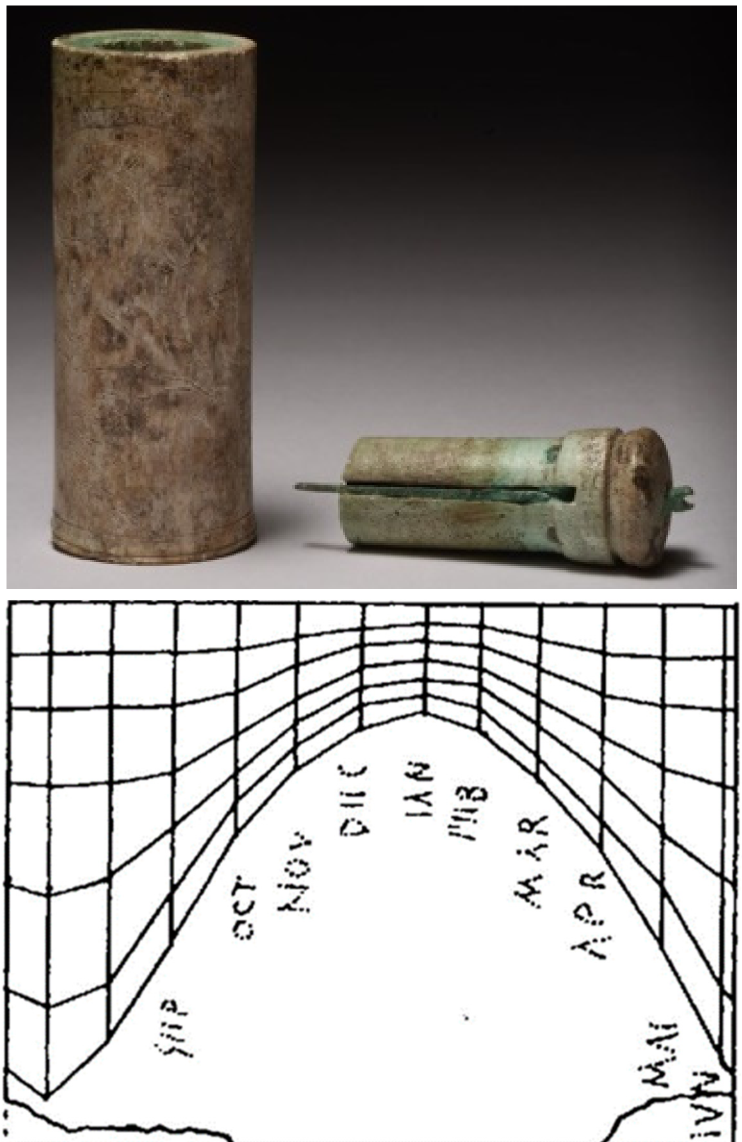

Fig. 1. The Cylinder Dial of Este with the graph of dates and hour lines etched into the surface. The dial is dated between 8 BCE and 79 CE. Photo from Museo Nazionale Atestino, Catalog Nr. IG MNA 15397. Drawing from Mario Arnaldi and Karlheinz Schaldach [3].

The Cylinder Dial from Este works as follows: (1) remove the stopper from the top of the cylinder and extend the gnomon blade to be perpendicular to the stopper, (2) put the stopper back into the top of the cylinder, and rotate it until the gnomon blade is over the date on the cylinder, (3) rotate the whole dial on a string until the gnomon faces directly into the sun and the gnomon shadow becomes a thin vertical line, (4) read the temporary (seasonal) hours from the lines running across the cylinder face.

Temporary hours lines cross the dial, dividing the day into twelve equal parts regardless of the season. The lines are drawn for the morning-afternoon hour pairs of 1^{st} & 11^{th} hour, 2^{nd} & 10^{th}, 3^{rd} & 9^{th}, 4^{th} & 8^{th}, 5^{th} & 7^{th}, and finally the 6^{th} hour at midday.

As it turns out, the Este dial contained a pleasant surprise. The stopper contains two gnomons: one of effective length 27 mm, and a shorter one of 21 - 22 mm. Mario Arnaldi and Karlheinz Schaldach [3] analyzed the use of the gnomons to determine whether they were to be used for different latitudes or whether they were to be used at different seasons of the year. They determined that the shorter gnomon was used during summer (May to September) and the longer gnomon during the rest of the year.

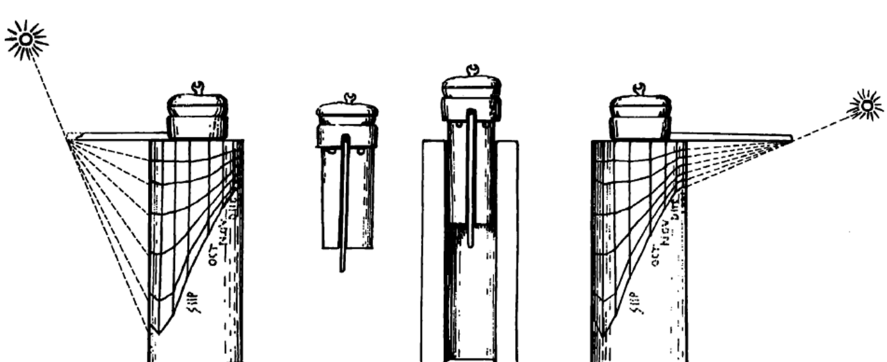

Fig. 2. Sketch of the Este Cylinder Dial showing use of the shorter gnomon (left) for summer and longer gnomon (right) for winter using the etched hour lines. Drawing by Mario Arnaldi [3].

There is something strange about the marking of the dates on this dial. Dials of this era should have the vertical lines represent about the 25st of each month (assuming the spring equinox arrived on about March 25th in those days) and the divisions are equally spaced months representing the twelve parts of the zodiac. So, December 25th should have the shortest shadow line at noon and June 25th the longest. This in turn uses the dating system where Dec 25th is represented as the 7th day before the Kalends of January. Hence IAN (January) marks the month of shortest hours. Similarly, IU (July) should mark the month of longest midday shadow.

But the names of both months of July and August are left unlabeled. The omission of July and August may have been deliberate, perhaps not wanting to recognize Julius Caesar (killed on the Ides of March, 44 BCE) as the new name of Quintilis (fifth month), or the appropriation of Sextilis (sixth month) by Caesar Augustus in 8 BCE.

A Cylinder Dial's hour lines are latitude dependent, and the Este dial was designed for a latitude of approximately 45°, consistent with the site where it was found. At latitudes of 30° and below the sun's altitude increases on the meridian causing the noon shadow to become impracticably long. Likewise at high latitudes above 55°, the sun's altitude above the horizon remains low and the shadow cast by even a long gnomon is hard to read, again making the Cylinder Dial impractical.

Once Bonomi recognized the existence of an ancient Cylinder Dial, other discoveries were made from sites across the former Roman Empire. Shortly after, another Cylinder Dial was found in the city of Amiens in Northern France [4, 5]. In 1969 Derek De Solla Price listed approximately 19 portable dials from antiquity [6]. Denis Savoie recently updated the list, now counting 26 ancient Greek and Roman portable dials discovered from antiquity [7]. As well as Este, locations where they have been found include Rome and Aquileia (Italy), Philippi and Samos (Greece), Trier and other places in Germany.

Only three Cylinder Dials are known from antiquity: the one from Este, now held by the Museo Nazionale Atestino (Italy), the one from Amiens, at the Musée de Picardie (France), and one from Domjulien, at the Musée d'Art Ancien et Contemporain d'Epinal (France).

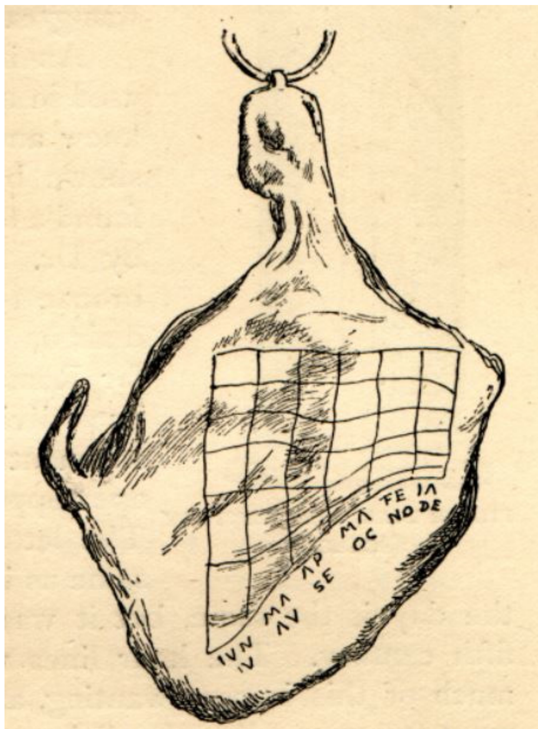

Fig. 3. The Ham of Portici drawn by Miss Eleanor Lloyd in Mrs. Alfred Gatty's 'The Book of Sun-Dials', 1900, p.185.

Vitruvius used the words "viatoria pensilia" (hanging dials for travelers) to mean all types of portable altitude dials. Perhaps the widest known ancient hanging dial is the so-called Ham of Portici, dating from the first century CE. This small silvered bronze dial was uncovered on 11 June, 1755 in the ruins of Herculaneum, buried in volcanic ash from the eruption of Mount Vesuvius in 79 CE.

Workers from the first excavation of Herculaneum, commissioned by the Prince of Bourbon, found the dial in the Villa Portici, also known as the Villa dei Papyri, a private house where a library of partially burned papyrus scrolls was discovered.

The form of the dial, which resembles a ham, has been extensively studied [8]. It is an altitude dial with similarities to the Cylinder Dial.

Temporary (seasonal) hours go across the dial face and vertical lines represent the boundary between the twelve months of the zodiacal year. In this dial the twelve months have been doubled up and the month pairs labeled between the month lines: IUN-IU (June-July), MA-AU (May-August), AP-SE (April-September), MA-OC (March-October), FE-NO (February-November) and JA-DE (January-December). Notice that both July and August are used and the longest shadows occur at the end of June while the shortest occur at the end of December.

As mentioned, the Este dial has a movable gnomon that is placed on the date, then the whole dial is rotated until the gnomon faces directly into the sun. The Ham of Portici has a fixed gnomon, seen in the drawing as the 'hook' at left. When properly working, the gnomon is actually much longer and the tip set a specific distance above the dial face at the upper left corner of the hour-date lines. To read the time, the dial is suspended from a string at top of the dial and turned until the shadow falls on the vertical date line (or distance between) corresponding to the date. Like the Cylinder Dial, time is read from the downward shadow of the tip crossing the temporary hour line.

The Ham of Portici's hour lines run across the dial to tell temporary hours, and are doubled up for morning and afternoon hours. The lines are from top to bottom are for sunrise, $1^{st}/11^{th}$, $2^{nd}/10^{th}$, $3^{rd}/9^{th}$, $4^{th}/8^{th}$, $5^{th}/7^{th}$, and at bottom, the 6^{th} hour line for mid-day.

The fall of the Roman Empire started in 376 CE when the Goths seized cities in the Roman Empire. Its demise was complete in 476 CE when the German strongman Odoacer deposed the last emperor of the Western Roman Empire. No later manuscripts on dialing survive from the Graeco-Roman period.

Fig. 4. The Venerable Bede: a late 12th century image from 'Lives of St Cuthbert' – Yates MS 26 f.2r at the British Library.

Prior to the Este dial being identified, Hermannus Contractus, Herman the Lame (1013-1054), a monk from the monastery at Reichenau at Lake Constance, was regarded as the inventor of the Cylinder Dial [9]. He wrote a short work *Demonstratio Componendi cum Convertibile Sciotero Horologici Viatorum Instrumenti* that was included in a treatise about the astrolabe [10]. But earlier works are now known.

The Venerable Bede (627-735 CE) is credited with a short treatise *Libellus de Mensura Horologii* (*A Book on the Measurement of Shadows*). Strictly speaking, 'Horologium' translates as 'clock', but this was accomplished by a sundial. This treatise became known as part of Bede's body of work when it was published in 1563 by Iohannes Hervagius (Johann Herwagen) and reprinted in the 19th century by J.P. Migne [11]. It is actually a collection of a number of texts, of which only some refer to gnomonics. In one text, Bede explained how to construct a Cylinder Dial by the use of a semicircular tool and described the dial as being valid for only the latitude for which it was designed.

It may be that the author was not Bede, but possibly Byrhtferth of Ramsey (c. 970 – c. 1020). "Bryhtferth's signature appears on only two published manuscripts, his Latin and Old English *Manual* and Latin *Preface*" [12]. Bryhtferth studied with Abbo of Fleury who created a new horologium, telling time by one's shadow. Bryhtferth may have been significantly influenced by Abbo to write about cosmology, history, logic, and mathematics. In Bryhtferth's *Manual* are two short statements, "the sun ascends point by point on the sundial", and "observe, o clerk, how the sun ascends point by point on the sundial." This may be the first reference to a portable Ham or Cylinder Dial since Vitruvius.

Fig. 5. Canterbury Pendant Replica. Photo from Canterbury Cathedral Shop.

In 1938 a silver pendant was found in the cemetery of the cloister at Canterbury Cathedral. It is dated to the 10th century making it one of the oldest pocket timepieces in the world. Like the Ham of Portici, it has a flat face, but like a Cylinder Dial, the gnomon has to be repositioned according to the time of year. The name Flag Dial is sometimes used for this design. The Canterbury example has three columns of month pairs on each side of the pendant. The gnomon is a pin that fits into one of three holes at the top of the pendant, setting it for the month of the year. When not in use, the pin is stored in the bottom of the pendant.

In each column is a pair of dots. One dot indicates the 3rd/9th hour (mid-morning/min-afternoon) and a lower dot indicates the 6th hour for midday [13]. The pendant is held by a chain and rotated until the pin faces the sun and the shadow falls in the selected monthly column.

Geoffrey Chaucer, the writer of *The Canterbury Tales* at the end of the 14th century included many astronomical references. In *The Shipmannes Tale* a “gentil [and lustful] monk” approached a merchant’s wife:

> *For I wol bringe yow an hundred frankes.’ [Line 1391]*
> *And with that word he caughte hir by the flankes,*
> *And hir embraceth harde, and kiste hir ofte.*
> *‘Goth now your wey,’ quod he, ‘al stille and softe,*
> *And lat us dyne as sone as that ye may;*
> *For by my chilindre it is pryme of day.*
> *Goth now, and beeth as trewe as I shal be.’ [14]*

During the Middle Ages these ‘chilinder’ portable dials were popular throughout England and continental Europe because they were easy to construct, because as altitude dials they did not need to be oriented to north, and because they were conveniently portable. Yet only a few of these dials survive, probably because they were most likely made of wood or bone and easily destroyed over the years by rot from dampness and fungi.

From the Renaissance onwards, sundials were depicted in paintings. One of the most famous is *The Ambassadors,* a 1533 painting by Hans Holbein the Younger. Although two Frenchmen, now known to be Jean de Dinteville and Georges de Selve, are the subjects of the painting, the painting is known for its rich depiction of musical instruments, globes, and instruments of science, including sundials.

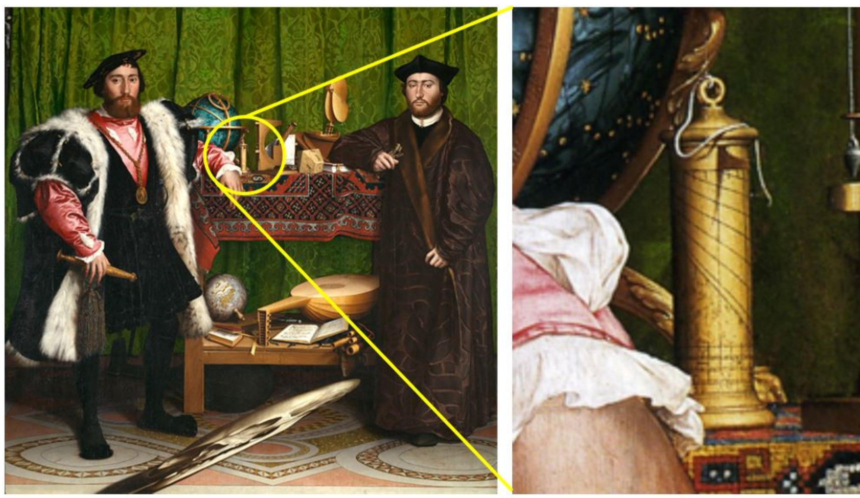

Fig. 6. Hans Holbein The Younger painting of "The Ambassadors" 1533 at left. At right is exquisite detail of the Cylinder Dial on the top shelf of heavenly objects. Photo credit: The National Gallery, UK.

On the top shelf all the items have to do with the heavenly ideals (a Celestial Globe, a Cylinder Dial, a polyhedral dial, quadrants, and a torquetum), and those on the lower shelf, are all to do with the earthly life, including slight imperfections (a globe showing Dinteville's province, a book on geometry, a lute with one broken string, a Lutheran hymn book, implying the church schism). Holbein may have been advised by Nicholas Kratzer, astronomer to King Henry VIII, for the selection of the scientific instruments. In fact, in 1528 he painted Kratzer's portrait, using many of the instruments and sundials that appear on *The Ambassadors* top shelf.

At the bottom of the painting is an anamorphic drawing of a skull as a reminder of eventual death. This *memento mori* was often inserted in paintings as a small skull, but nothing so prominent as Holbein's skull. Why such a large and puzzling image (only correctly seen by looking slantwise at the painting from the lower left)? Perhaps because Dinteville's personal motto was 'remember thou shalt die.'

By the 18th century Cylinder Dials had acquired the name of the 'Shepherd's Dial' or even the 'Shepherd of the Pyrenees' dial, suggesting that shepherds in the border areas between France and Spain made use of Cylinder Dials. In 1823, the German scholar and traveler Fredrich von Parrot published *Reise in den Pyrenäen* (Journey in the Pyrenees) in Berlin. In a later edition of this work he concluded,

> *I have never seen this so-called Shepherd of the Pyrenees Sundial in the hands of any shepherd in the Pyrenees and when I have shown one to a shepherd, his reaction has been of total ignorance, not only about what it was, but also about how such an object should be used. The Shepherd's Sundial of the Pyrenees is a genuine example of Pyrenean folklore, [and] is a myth that does not hold.*

We may conclude that the profusion of these Cylinder Dials in areas like the Pyrenees, while possibly offered pilgrims traveling to Lourdes a souvenir, is without any basis of local tradition.

Let's step quickly into the modern age. Woodruff 'Woody' Sullivan, Professor Emeritus at University of Washington, and Ron Monnat designed a unique tapered Cylinder Dial in 2002 for University Prep Academy (NASS Sundial Registry #746). At first it appears to be a traditional Shepherd's Dial, but closer examination reveals a clever twist on an old design. The cylinder is fixed with the noon hour line pointed south along the meridian. The gnomon at the top of the 10 ft. (3 m) cylinder rotates by means of a crank.

There are no date marks at the top of the dial, but like a traditional Cylinder Dial, the gnomon is turned until it makes a thin vertical shadow.

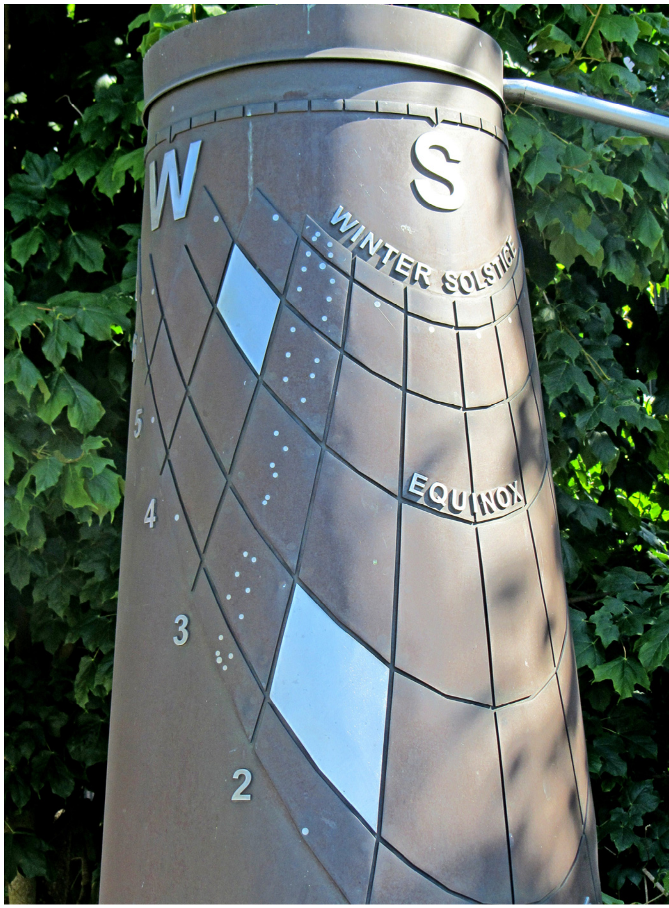

Fig. 7. Tapered Cylinder Dial – Seattle WA. Designed by Woody Sullivan and Ron Monnat. NASS Registry #746.

Now comes the surprise. Near the far end of the gnomon a square hole that lets a beam of sunlight through. The sunlight spot tells the time using the near vertical hour lines, and the date can be estimated from the position of the spot relative to the curved zodiac lines (three of which are labelled: winter solstice, equinox, and summer solstice).

For modern sensibilities a dotted analemma (also provided graphically on a plaque as the Equation of Time) allows one to correct Solar Time to Civil Time.

In the next issue of THE COMPENDIUM, we'll present Part II examining how the Cylinder Dial is made in antiquity and in modern times.

Further Reading

See Helmut Sonderegger's article "Sundials On Cylinders", *The Compendium*, 16(4), Dec, 2009 (which is Ref. 9 below).

[If you do not already own issue 16(4), you can obtain it by buying a CD containing the first 27 years of *The Compendium*, including Helmut's article for $30 USD. Visit the NASS Shop at https://sundials.org/index.php/nass-shop2/2-publications.]

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The Astronaut's Sundial: A Universal Sundial

Fabio Savian (Paderno Dugnano, Milano, Italy)

This sundial, an evolution of the Shepherd's Sundial, uses the height of the Sun to indicate the time, operating at any latitude and with any inclination of the ecliptic.

The idea of having a portable sundial often implies that it is universal, meaning that it can work at any latitude to avoid its portability being restricted to a limited area.

Usually, this capability requires knowledge of some local values, such as latitude, the direction of North, the declination of the Sun, or the height of the Sun. This arises because all instruments that indicate time by the Sun resolve the astronomical triangle, the spherical triangle formed by six angles, where three angles are needed to derive the other three, including the Hour Angle.

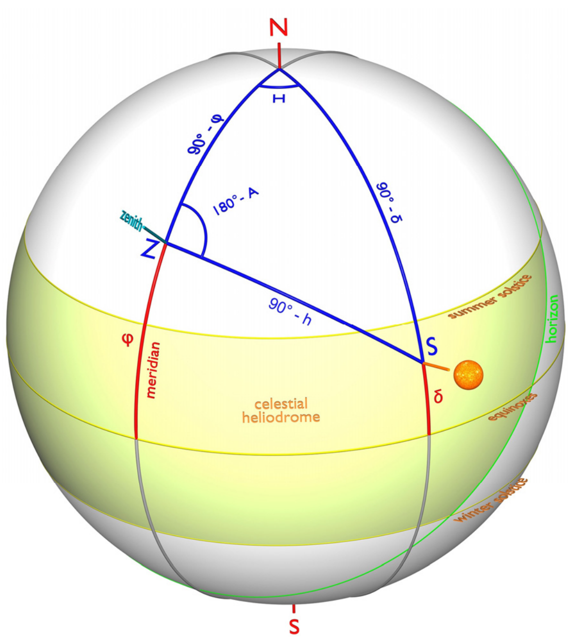


Fig. 1. Astronomical triangle NZS on the trigonometric sphere.

The astronomical triangle has as its vertices the North Pole *N*, the position of the sundial *Z* and that of the Sun *S* (see Fig. 1).

The angles of this triangle are:

NZ	90° complement of latitude (90° − φ)
ZS	90° complement of the height of the Sun (90° − h)
NS	90° complement of the Sun's declination (90° − δ)
ZNS	Hour Angle H
NZS	180° complement of azimuth from south (180° − A)
NSZ	The Parallactic Angle that does not have a particular usable meaning.

For the dial to 'calculate' the hour angle, the instrument must be set with three of the other four angles: latitude, azimuth, height of the Sun, or declination of the Sun.

The most easily-known angle is the declination of the Sun, since it is easily recalled through a calendar table. Small variations from one year to the next can be taken as irrelevant in calculating the time. Therefore, it is one of the most easily available angles, so much so that it is often reported on the instruments by the date.

Latitude is the other essential angle since the portability of a sundial needs precisely this information: the location in which it is being used.

This value can be obtained by measuring the height of the Sun at noon and then subtracting the declination of the Sun, or by measuring the height of the Polar Star. A map or a table with coordinates of the main cities may also suffice; in this case a small error in the decimals can be considered irrelevant.

What remains is to select the third angle, i.e., to choose between the Sun's height and azimuth.

The azimuth could be obtained with a magnetic compass but the errors could become significant: a compass indicates Magnetic North not Geographic North, Earth's magnetic field is not uniform, and it is easily influenced by metal masses. Compass azimuth errors can be significant.

The height of the Sun, on the other hand, is easily measured with precision.

It is also necessary to point out a limitation of an altitude dial, since this quantity has identical values for instants in the morning and afternoon, requiring the user to be able to distinguish the passage of noon. Readings also become difficult around noon because changes in the Sun's height are minimal compared to the variations in the hour angle, and it is objectively difficult to distinguish between morning and afternoon.

One universal instrument that can operate with these angles is the astrolabe (Fig. 2), where the latitude must be set by selecting the relevant timpan to be placed under the net.

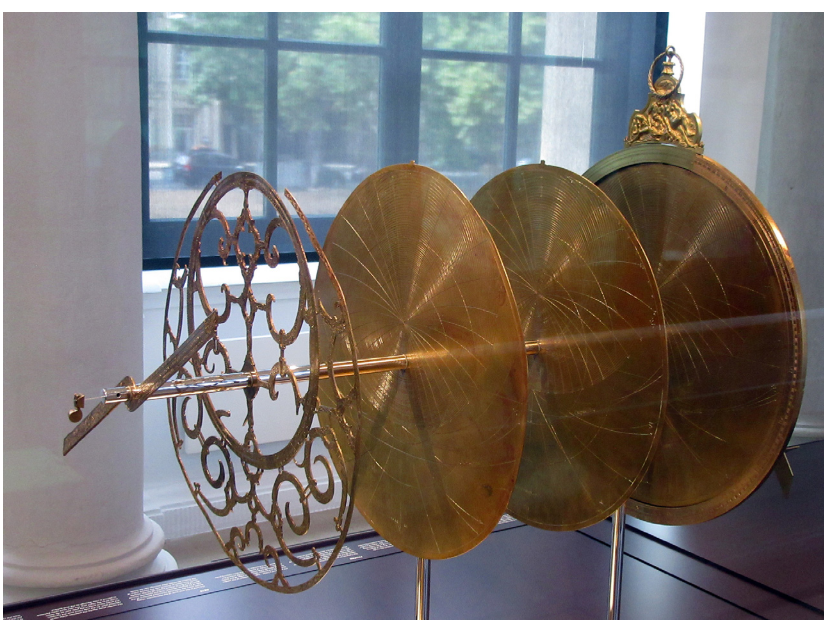


Fig. 2. Exploded view of an astrolabe showing, from left to right, the alidade, the net, a set of timpans for different latitudes, and the mater, where all these parts are brought together. Photo by the author: Mathematisch-Physikalischer Salon, Zwinger, Dresden, Germany.

The alidade, that is the rotating ruler hinged in the center of the astrolabe, can also be useful for measuring the height of the Sun.

The astrolabe is a sophisticated project, the birth of which is traced back to Hipparchus in the 2nd century BCE, and used by astronomers and sailors for nearly two millennia.

However, it is a complex instrument, certainly not popular, and cannot be considered a sundial as it lacks a gnomon to give readings by a shadow. It is rather a tool for solving the astronomical triangle.

Fig. 3. Regiomontanus sundial. Photo by the author: Queen's House, Greenwich, United Kingdom (Sundial Atlas, UK2039).

In the 14th or 15th century CE a universal sundial appeared, usually called a Regiomontanus Dial from the Latinized name of the German astronomer and mathematician Johannes Müller of Königsberg (Unfinden, 6 June 1436 - Rome, 6 July 1476) who first described it in detail. It is an altitude dial with an articulated arm adjustable for latitude and declination of the Sun (Fig. 3).

Sundials that use the height of the Sun, such as the Capuchin Dial (Fig. 4) and the Shepherd's Dial (Fig. 5), are instead linked to the latitude chosen in the project.

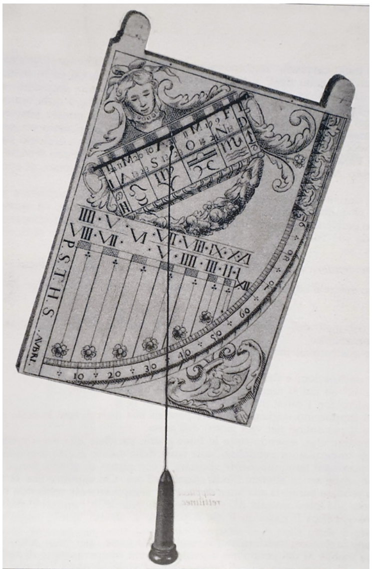


Fig. 4. 17th c. ivory Capuchin Dial. Photo: 'Orologi solari', Girolamo Fantoni. Rome: Technimedia.

Fig. 5. Shepherd's Dial. Photo by the author: Museo Galileo, Firenze, Italy (Sundial Atlas, IT20442).

Just as the Regiomontanus Dial was the evolution of the Capuchin to make it universal, so the Astronaut's Dial presented here is the universal evolution of the Shepherd's Dial.

The Shepherd's Dial owes its name to the idea that it was used by shepherds in the Pyrenees, although some finds date back to Roman times. It is also known as a Pillar Dial or Cylinder Dial.

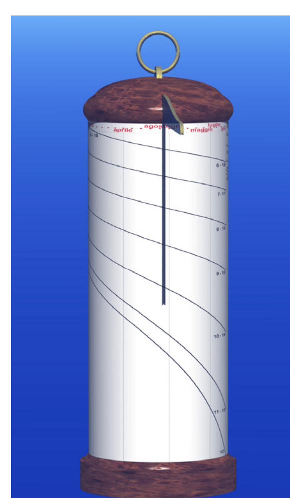
The instrument consists of a cylinder on which curves are drawn corresponding to the hours. The upper section of the cylinder had a scale of declinations of the Sun or, alternatively, a calendar of dates.

At the top of the cylinder there is a revolving element, a lid or cap, from which protrudes a perpendicular rod, i.e., a gnomon which will be horizontal when the cylinder is held vertically. Setting the dial requires that the cap is turned to line up with the declination of the Sun graduated on the cylinder (Fig. 6).

Fig. 6. Setting the gnomon position to match the declination of the Sun, by means of the calendar.

Once the stylus has been set, the user rotates the whole instrument so that the gnomon is towards the Sun. This produces a shadow of a length that depends on the height of the Sun. The tip of the shadow indicates the time (Fig. 7).

Fig. 7. When the perpendicular rod is turned towards the Sun a straight vertical shadow shows the time.



Proper orientation towards the Sun is easily confirmed by observing its perfectly straight shadow on the cylinder, suspended vertically.

Note also that this orientation towards the Sun allows you to ignore its azimuth, confirming the three angles involved: the latitude, inherent in the plotting of the hourly curves, the declination of the Sun, set on the instrument, and the height of the Sun, detected from the shadow.

The dial design is pretty simple. Considering that each declination value of the Sun corresponds to a vertical line on the cylinder, on this line you can find the points corresponding to the Hour Angle as a function of the length of the shadow, i.e., the height of the Sun.

Points of the same Hour Angle value can then be joined to form the relevant curve.

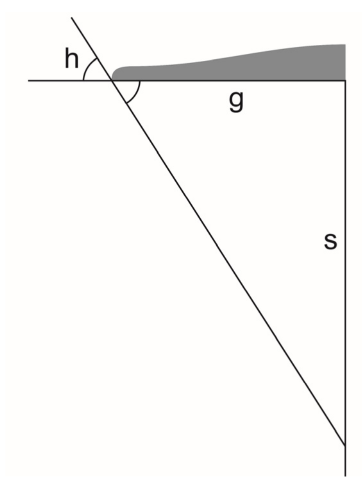


Fig. 8. The length of the shadow depends on the length of the gnomon and the height of the Sun.

To trace the curves, the height angle h is translated into a segment whose length s also depends on the length of the perpendicular rod g (Fig. 8):

$$s = g \tan(h) \tag{1}$$

The calculation of the height given Hour Angle H is

$$\sin(h) = \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\cos(H) \tag{2}$$

As can be seen, for latitude φ and given the declination δ, height h corresponds to an Hour Angle H. By means of (1) we then pass from the angle h to the segment s which represents H.

Imagine replacing the straight rod by a curved gnomon, such that its curvature produces a shadow length equal to the sine of h instead of its tangent.

This shape is known as an astroid and is represented by Fig. 9; a segment *AB*, 1 unit long, is made to rotate with its ends constrained by the two adjacent sides of a square, including the angle *C*. The vertical side, placed against the cylinder, includes the segment *CA* equal to the sine of the angle *CAB*, i.e., the height of the Sun h.

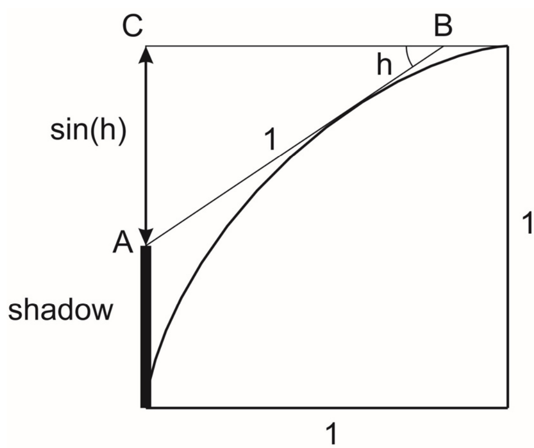


Fig. 9. The astroid curve needed to get a shadow linked to the sine of the height of the Sun.

The curve can be obtained graphically by plotting its envelope with a suitable number of segments *AB* for different angles h, or by using its formula:

$$y = 1 - \sqrt{(1 - \sqrt[3]{x^2})^3} \quad (3)$$

Thanks to this type of gnomon, we can restate (2) to provide shadow length s directly, that is

$$s = \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\cos(H) \quad (4)$$

Note that the projection of the shadow occurs in the opposite way to the usual one, i.e., the length s, equal to the sine of the height of the Sun, is the illuminated part of the vertical side considered in Fig. 9. Its length is still defined by the edge of the shadow.

In (4), in the second addend we can express a new variable k such that

$$k = \cos(\varphi)\cos(\delta) \tag{5}$$

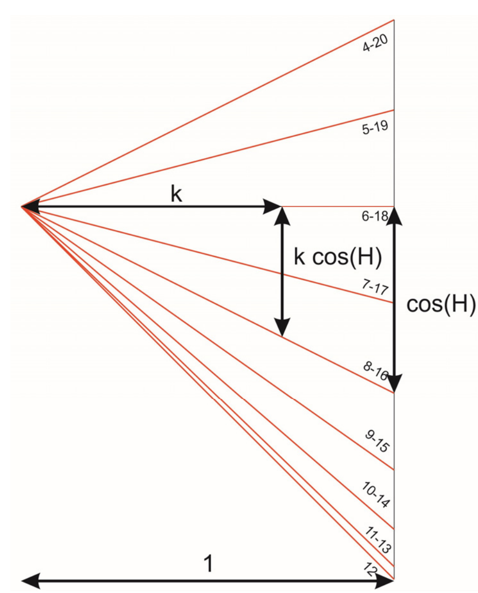
There are infinite combinations of φ and δ which produce the same coefficient k, which can vary between zero and one.

By temporarily ignoring the first addend of (4), we can think of using k**,** instead of the declination of the Sun, δ, as the graduation for setting the gnomon position.

In this way, each vertical line of the cylinder corresponds to a value k, a value of no astronomical significance (but that does not preclude its use.)

Continuing to ignore the first addend of (4), with $k = 1$ the shadow length s is equal to the cosine of the hour angle H and decreases in proportion to k until it reaches the null value for any H.

Fig. 10. The dial of the hour.



All this allows us to describe the hour angle curves as straight lines originating from the same point when $k = 0$, until reaching the relative value of the cosine of H when $k = 1$, as shown in Fig. 10.

This construction must be integrated with the first addend of (4), so far ignored, which we can also identify with a coefficient, that is

$$q = \sin(\varphi)\,\sin(\delta) \qquad (6)$$

This allows (4) to be rewritten as

$$s - q = k\cos(H) \qquad (7)$$

That is, the segment s will have to move vertically by the distance q so that it can indicate the correct line H.

Setting the instrument therefore requires a rotation of the gnomon by the value k and a vertical displacement equal to q.

To bring the gnomon into the correct position involves setting up two families of curves, one relating to the declinations of the Sun and the other to latitudes, such that they intersect each other at abscissa k and ordinate q.

To find these curves we set up a system of equations

$$\begin{aligned} x &= \cos(\varphi)\,\cos(\delta) \\ y &= \sin(\varphi)\,\sin(\delta) \end{aligned} \qquad (8)$$

The curves of latitude can be solved by eliminating δ and obtaining

$$\frac{x^2}{\sin(\varphi)^2} + \frac{y^2}{\cos(\varphi)^2} = 1 \qquad (9)$$

This equation represents ellipses with a major axis equal to $\sin(\varphi)$ and a minor axis equal to $\cos(\varphi)$.

The set of curves that express all latitudes between −90° and +90° produces a family of ellipses inscribed in a square and with the appearance shown in Fig. 11.

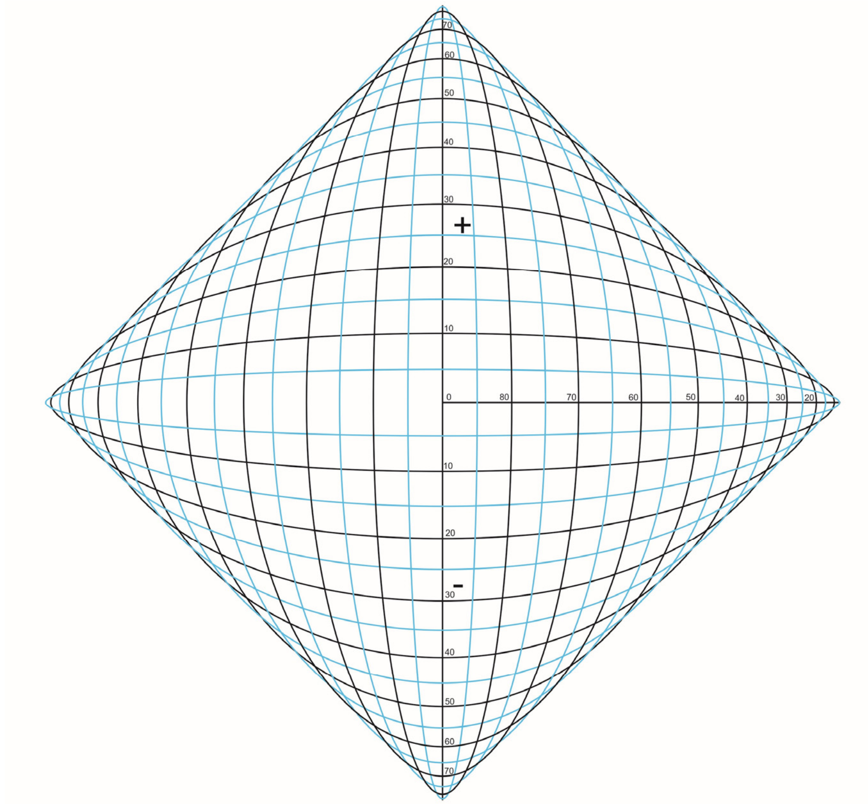


Fig. 11. The graph with the latitude and declination curves.

Due to the symmetry of (8), the declination curves are exactly identical to those of latitude. Therefore, there are not two families of intersecting curves, but a single family of curves based on the same angular values with two different meanings.

Squaring of variables *x* and *y* doubles the graph's area. Its symmetry means only the right half of the diagram in Fig. 11 needs to used.

Each curve corresponds to a value between −90° and +90°. Therefore, for the curve corresponding to the current declination value and the curve corresponding to the latitude, the intersection is the point where the index, or base point, of the gnomon is to be placed.

There are two points of intersection but they can be easily separated by using the branch of the ellipse above the horizontal axis for positive values of φ or δ, and the lower branch for negative values. This is due to the squaring of the functions of φ and δ.

For the southern hemisphere, it is necessary to consider the negative values as being in the upper quadrant and the positive values in the lower one. Doing this maintains the same functionality of latitude and declination with the hour lines.

Particular cases can occur in the Tropics where the declination of the Sun can have the same value as the latitude.

When the curves being considered have similar values, the intersection point approaches the envelope, reaching it when they have identical values. In these cases, the point of tangency of the curve with the envelope will then be considered.

This can be confirmed by considering that $\varphi = \delta$ produces

$$y = -x + 1$$

which is the line that delimits the diagram at the top.

The null value q implies that we are at the equator ($\varphi = 0$) or that the observation takes place at the equinox ($\delta = 0$).

When both conditions are met, k equals 1 so the point of attack of the curved gnomon would be at the '12' position indicating solar noon with the sun at its zenith, because it is the equinox at the equator.

In all other cases with $q = 0$, the point of attack remains at the same height y implying only a rotation k, which need not be 1.

These considerations verify that the two diagrams, that of the latitude and declination curves and that of the hours, are bordered by the upper side of the envelope and the hour line for 12 (Fig. 12).

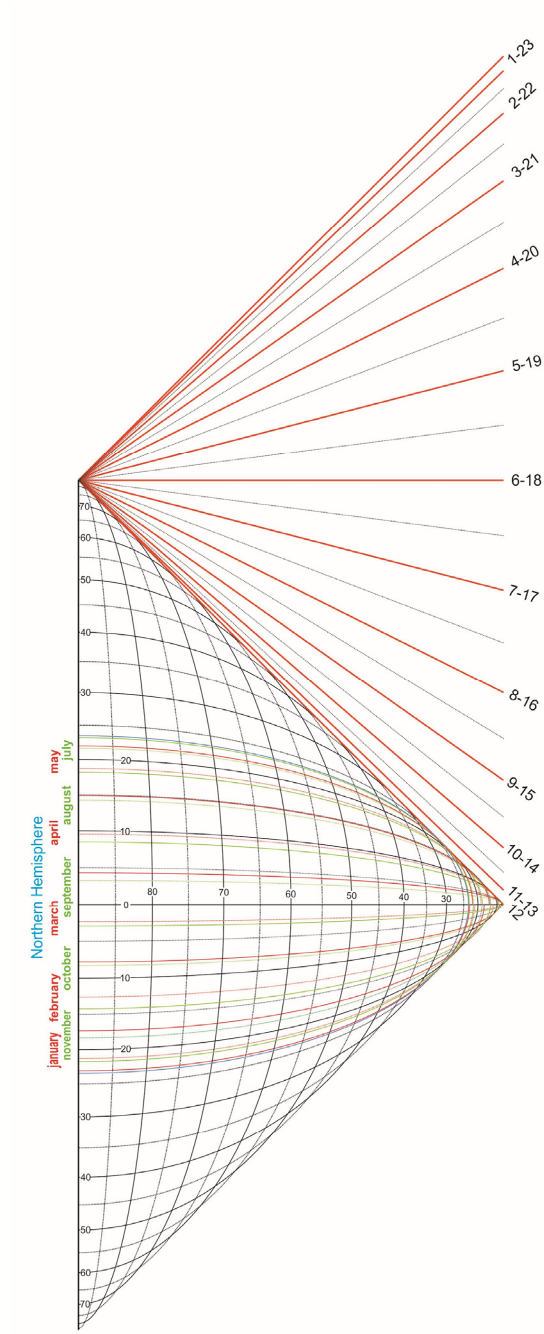


Fig. 12. The hour's dial with the graph of latitude versus declination. Declination curves delimiting the months, for the Northern Hemisphere, are included.

At the poles, k becomes null and q will depend only on the declination of the Sun, with a value such that the time indication always falls at the same point: the origin of the hour lines. This confirms that the hour angle is indistinguishable at the poles.

The highest resolution of the time occurs on the $k = 1$ line. Declination values and latitudes tending to zero are therefore required to approach this direction.

Once the gnomon has been set, the upper horizontal line, i.e., *AC* of Fig. 9, intercepts the hour dial at the time of sunrise and sunset, corresponding to zero height of the Sun.

Each hour line corresponds to an hour in the morning and an hour in the afternoon, characterized by the same Hour Angle (if sign is ignored) when the height of the Sun is the same.

Since each vertical line has its own operation independent of the others, it is also possible to perform a vertical shift. The over result is a vertical geometric distortion of the diagram without altering its functionality.

In Fig. 13, the hour line for 24 becomes horizontal and so does the lower line of the envelope of the latitude-declination diagram. The result occupies the whole of a rectangular area with no unused areas, effectively covering the entire area of a cylindrical surface.

In Fig. 14, the graph for latitude–declination and the hour diagram now have a vertical separation that reflects a slight extension of the gnomon. The gnomon touches the cylinder at its lower end but to maintain it in the correct position requires an additional straight segment, an extension that helps the gnomon grip the cylinder. This segment lowers the tip, the index, used to locate the required intersection on the latitude-declination diagram, so a gap of the same length must be inserted between this diagram and one with the hour lines.

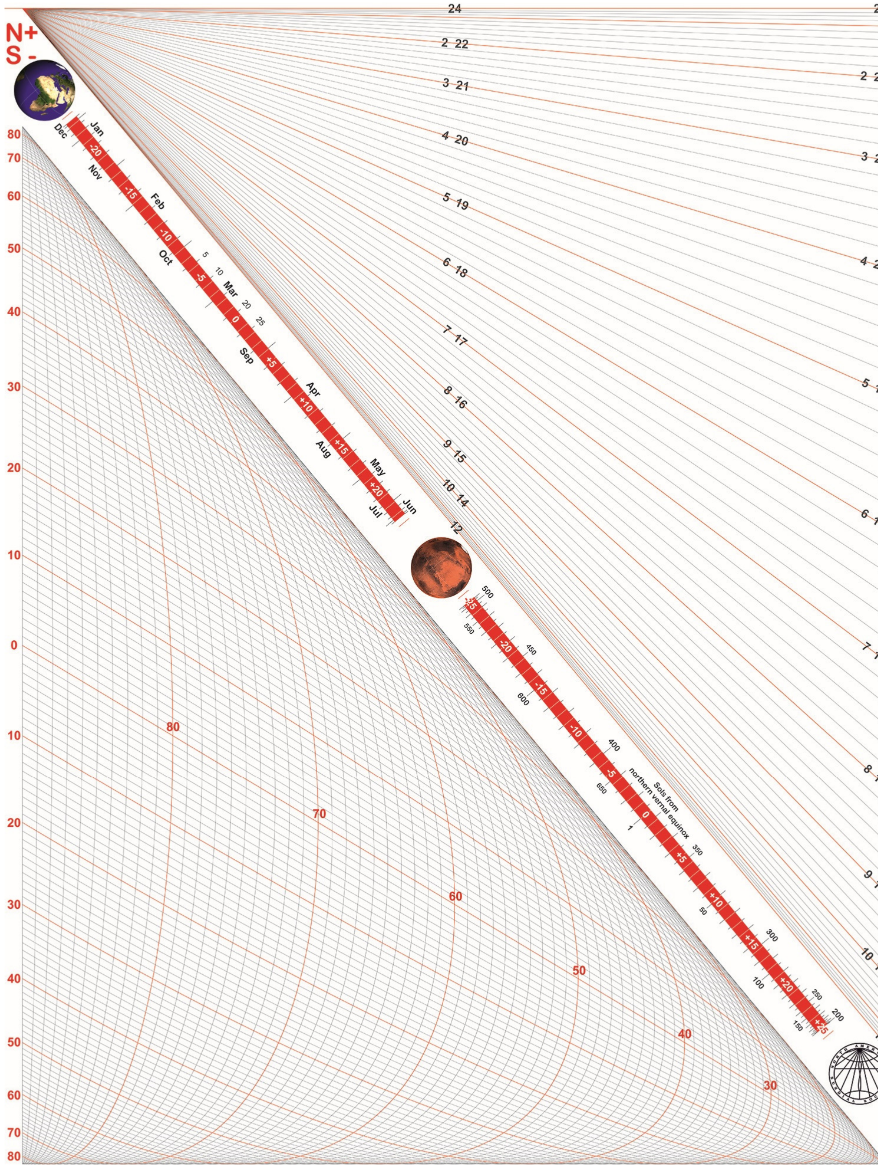


Fig. 13. The complete dial of Fig. 12 with vertical distortion to become rectangular.

A calendar inside the gap shows the declination of the Sun, allowing this value to be used on the latitude–declination graph. The plus and minus signs are reminders for how to use the graph for the Northern and the Southern Hemisphere.

By focusing on the design of the prototype, I associated the curve of the gnomon with the tail of a rooster, an animal often associated with temporal events such as dawn (Fig. 14).

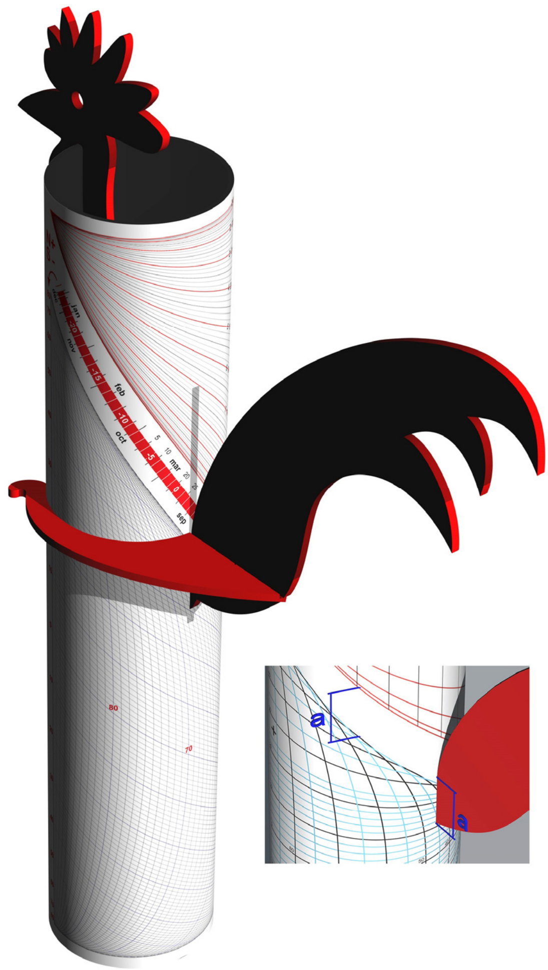


Fig. 14. The curve of the gnomon interpreted as the tail of a rooster, showing an extension below the index [the bottom of the gnomon curve] to improve the adhesion of the gnomon to the cylinder.

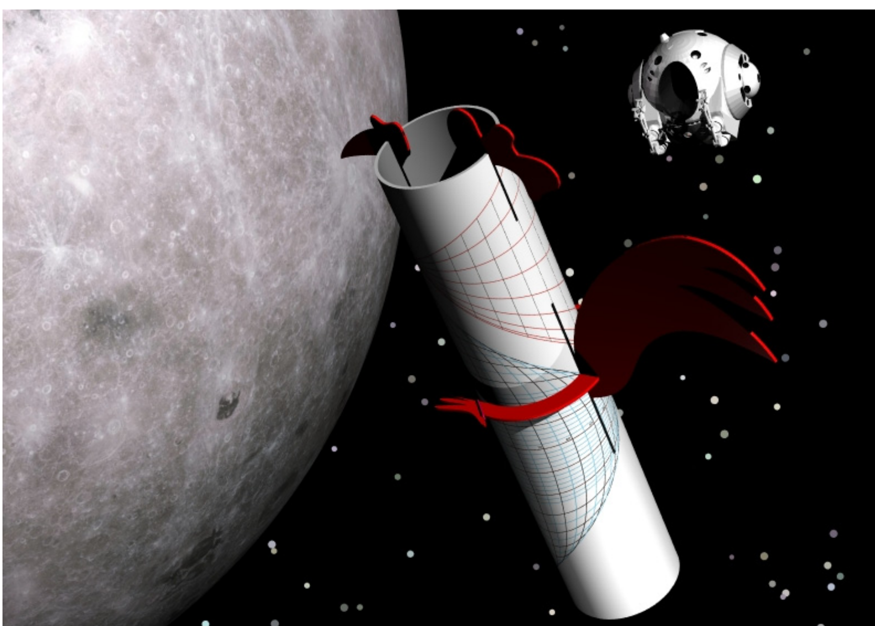
The prototype gnomon also has a vertical extension, segment *a* in Fig. 14, which is useful for obtaining greater grip and therefore correct positioning of the gnomon against the cylinder. This extension requires the introduction of the same gap distance *a* between the latitude-declination graph and the hour graph.

Since the declination curves of the Sun coincide with those of latitude, it follows that the sundial can work on any planet, that is, with any inclination of its rotation axis with respect to the orbital plane, having available declination curves from −90° to + 90°.

This universality of use prompted me, in a surge of enthusiasm, to call it the Astronaut's Sundial.

By defining a Martian calendar and associating it with the declination values of the Sun, the Astronaut's Sundial would work equally well on Earth and Mars, assuming that the Martian residents adopt a division in 24 hours for their day.

Fabio Savian *fabio.savian@nonvedolora.it*



Thanks to Fabio and the Sundial Atlas, you can visit www.sundialatlas.net/atlas.php?ori=52 to obtain the templates needed to make an Astronaut's Sundial.

A Dialist's Parlor Trick
(A Latitude-Independent Sundial)

Fred Sawyer (Manchester CT)

Note: This article introduces a simple latitude-independent sundial. It derives from the author's talk 'A Dialist's Sundial', delivered at the 2022 NASS Conference in Nashville TN. This is the first of two articles; the second will provide more background and introduce yet another form of latitude-independent sundial.

Background

The inspiration for this article goes back 40 years. At that time, I knew only six or seven people in the world who were interested in sundials as I was, and I was in the habit of sending copies of my research and new ideas to this small audience. However, in the early 1980's I received a letter from Larry Jones, one of these friends, who asked why I had not distributed any new material recently. I replied that I thought the well had run dry; I did not think at the time that there was anything more about sundials that I would be able to come up with. (Happily, over time I have been proven wrong).

I did offer just one idea that I had not shared earlier but that I thought he might find interesting. I had not mentioned it earlier because it was not really a sundial; it was a graphical construction, a way of drawing things out to solve a problem. I enjoyed playing with it because it gave me the feeling that some magic was occurring – and I knew that Larry enjoyed magic tricks.

I had come up with a graphical construction that started with the shadow of a vertical pin and converted it into an angle or arc that indicated the current time of day. What was 'magical' was that the same procedure worked on any horizontal plane at any latitude, without requiring that I know what the latitude was. In moments when I might otherwise waste my time doodling, I would instead use the time more constructively by running through this 'analog computer' procedure to determine the time.

<u>The Construction</u>

Begin (Fig. 1) with a north-south line *NO* of length *g* as radius of a

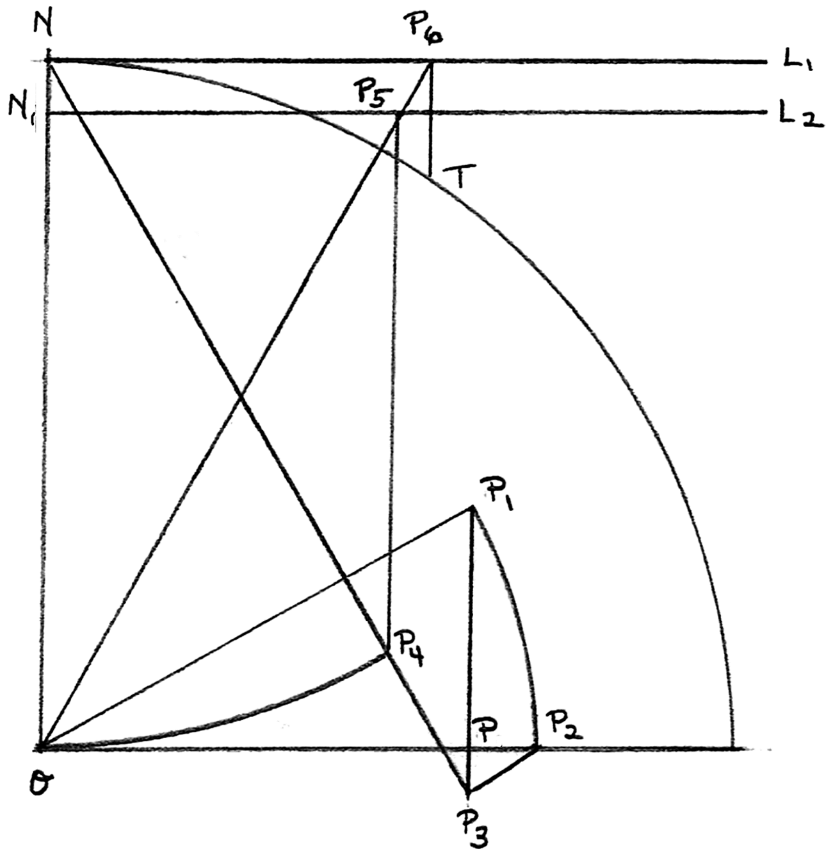


Fig. 1

quadrant, with a vertical pin gnomon also of length *g* at *O* casting a shadow P_1. With OP_1 as radius and *O* as center, draw the circular arc P_1P_2 intersecting the east-west line OPP_2. With center *N* and radius NP_2, draw the arc P_2P_3 intersecting the north-south line P_1PP_3. With center *N* and radius *NO* draw the arc OP_4 intersecting the line NP_4P_3. Draw lines NL_1 and N_1L_2 perpendicular to *NO* with the length N_1O equal to the length *g* of the gnomon times the cosine of δ, the sun's declination for the given date.

Draw lines P_4P_5 (perpendicular to $N_1P_5L_2$) and OP_5P_6 (intersecting line NP_6L_1). Draw line P_6T perpendicular to NP_6L_1 intersecting the quadrant NT. The arc NT has the same angular measure as the sun's hour angle t (assuming t has absolute value less than 90°). Note that we have required the direction of north and a value for the sun's declination – but the latitude remains unknown and unneeded.

Proof: We know from the sine law of spherical trigonometry that $\sin t = \sin z \cos\alpha / \cos\delta$. Now consider the construction…

$$NO = NP_4 = g \qquad OP_1 = OP_2 = g\cot\alpha \qquad \angle NOP_1 = \angle OP_1P = z$$

$$NP_3 = \sqrt{NO^2 + OP_2^2} = \sqrt{g^2 + g^2\cot^2\alpha} = g/\sin\alpha$$

$$OP = OP_1 \sin z = g\sin z/\tan\alpha \qquad \alpha = \text{altitude}$$

$$\sin NT = NP_6/NO \qquad NP_6 = N_1P_5 \cdot NO/N_1O \qquad z = \text{azimuth}$$

$$\sin NT = N_1P_5/N_1O \qquad N_1O = g\cos\delta$$

$$N_1P_5 = OP \cdot NP_4/NP_3 = \left(g^2 \sin z/\tan\alpha\right)/\left(g/\sin\alpha\right) = g\sin z\cos\alpha$$

$$\sin NT = \sin z\cos\alpha/\cos\delta = \sin t \quad \text{(by the sine law).}$$

<u>The Sundial</u>

I recently had occasion to review this construction in an old notebook in my attic, and it quickly became clear to me that I could in fact turn it into a sundial of sorts. I had to rearrange the arcs so they were all drawn from the same center and I replaced some of the construction with simple scales on an alidade. The result may look very different, but the mathematics of the dial is essentially the same as the justification for my old construction.

The dial is pictured in Fig. 2. It consists of a set of parallel north-south lines, all capped by two concentric circular arcs. The time is indicated by another set of parallel lines between the arcs. Pivoting at the center of the arcs is a transparent alidade with three simple scales marked along its center line. A vertical pin gnomon is placed at the pivot point; its length equals the distance from the pivot to the 0 mark on scale 2. And each date of the year is associated with a single number on the short scale 3 at the end of the alidade.

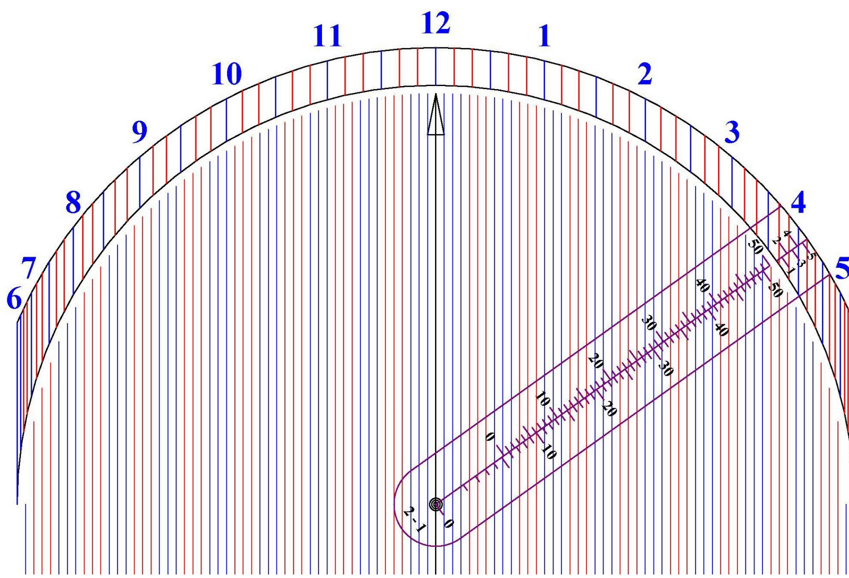


Fig. 2

To use the dial, the magician or dialist places it on a horizontal surface with the long parallel lines oriented north-south, and the gnomon is allowed to cast a shadow. The alidade is rotated until its center line covers the shadow, and notice is taken of which of the parallels passes through the shadow's end point and what number is indicated on scale 1 at that point. The alidade is now turned (reducing the alidade's angle with the noon line) until that same number on scale 2 lies on the selected parallel line. Finally, at the extreme end of the alidade, we note the point corresponding to the number on scale 3 associated with today's date. That point's position among the hour lines indicates the current time. Simple. And the crowd roars its approval as the magician takes a few bows before proceeding to explain how the device is constructed and how it all works.

Dial Construction

The north-south parallel lines are laid out at arbitrary equi-spaced intervals; their only function is to guide the selection of a point directly north of the shadow's end point. Choosing a color scheme for the lines (*e.g.* three lines of one color, followed by three of a different color) can help the eye to keep track of which of the many lines is selected.

The lines are capped by two circular arcs with radii r_1 and r_2 such that $r_1/r_2 = \cos 23.44^\circ$. Time is indicated by north-south lines between these arcs situated so that the lowest point on each line hits the inner arc at an angle from noon equal to the hour angle *t*.

The alidade has 3 scales (Fig. 3); scale 1 is shown to the right, 2 to the left, and 3 at the alidade's end between the circular arcs.

Scale 2 is blank from the pivot out to a distance equal to *g*, the length of the gnomon; the remainder of the scale is numbered at arbitrary equal intervals.

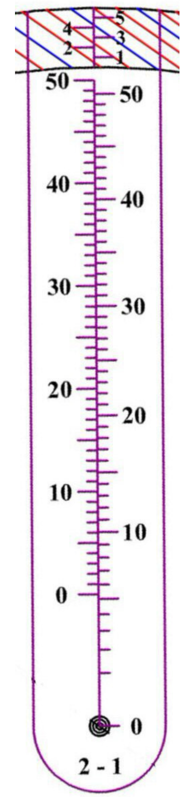


Fig. 3

The distance (*Dist*1) from the pivot for any number on scale 1 is defined in relation to the corresponding distance (*Dist*2) for that same number on scale 2 by the equation $Dist1 = \sqrt{Dist2^2 - g^2}$.

Scale 3 is marked by dividing the space between the circular arcs into arbitrary equal intervals (*e.g.* 0 - 6). Dates of the year are associated with each mark on the scale according to the sun's declination on that date; the distance r_δ from the pivot corresponds to declination δ when

$r_1/r_\delta = \cos\delta$. So, for example, for the dial and scale 3 pictured here, we would have:

6	Dec 21		Jun 21		6
5	Jan 13	May 29	Jul 15	Nov 30	5
4	Jan 23	May 18	Jul 27	Nov 19	4
3	Feb 02	May 08	Aug 06	Nov 09	3
2	Feb 12	Apr 27	Aug 16	Oct 31	2
1	Feb 23	Apr 16	Aug 28	Oct 19	1
0		Mar 21		Sep 21	0

Proof

Set the dial horizontal with the noon hour line pointing north (assuming the northern hemisphere) and suppose the gnomon's afternoon shadow falls as in Fig. 4.

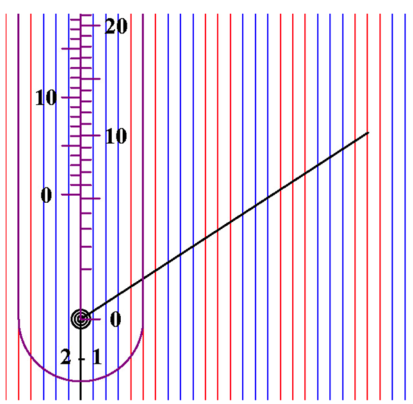


Fig. 4

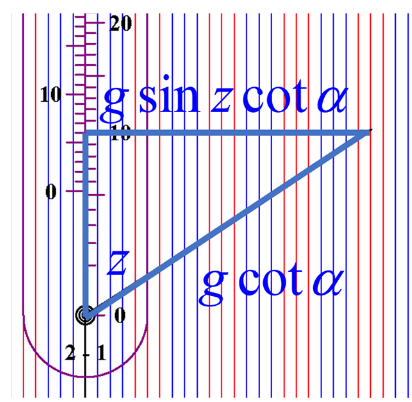


Fig. 5

With this arrangement, we have the triangle with sides and angle as indicated in Fig. 5, where *g* is the gnomon length, *α* the solar altitude and *z* the solar azimuth. Move the alidade to cover the shadow as in Fig. 6 and note the north-south line touched by the end point and the entry (24.5) on scale 1 at that point. Rotate the alidade until the same number (24.5) on scale 2 lies on the selected north-south line (Fig. 7); this action gives us a new triangle (Fig. 8) whose hypotenuse is given by the equation relating the two scales: $Dist1 = \sqrt{Dist2^2 - g^2}$ and $g \cot \alpha = \sqrt{(g/\sin \alpha)^2 - g^2}$.

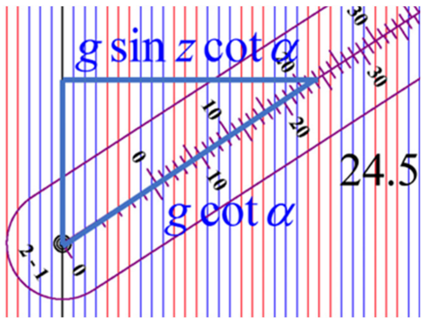


Fig. 6

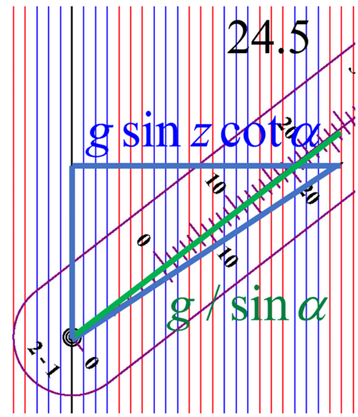


Fig. 7

The length of the hypotenuse is $g/\sin \alpha$.

Extend the hypotenuse to the date-specific point between the circular arcs (Fig. 9); by construction, the new length (distance from the pivot) is $r_1/\cos \delta$.

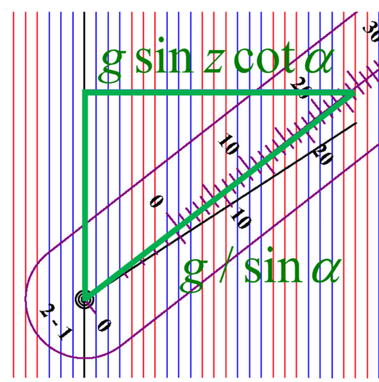


Fig. 8

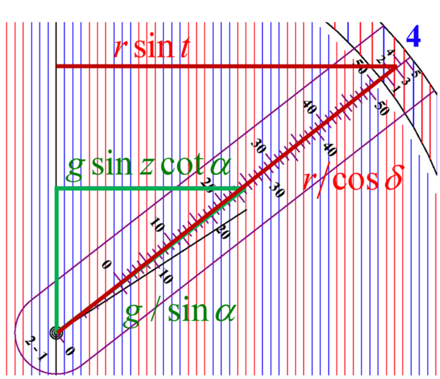


Fig. 9

Again, by construction, we know that the distance of the t hour line from the noon line is $r_1 \sin t$. So, to complete the proof, it suffices to show that the red horizontal line (Fig. 9) does in fact have length $L = r_1 \sin t$.

By the simple trigonometry of similar plane triangles, we have:

$$L = \frac{(r_1/\cos\delta)(g\sin z\cot\alpha)}{g/\sin\alpha}$$

$$= r_1\frac{\sin z\cos\alpha}{\cos\delta}$$

$$= r_1\sin t \quad \text{By the sine law of spherical trig.}$$

Because the date in the pictured example corresponds to number 3 on scale 3, the indicated time is 3:40 pm.

Conclusion & Trailer

Thus, we have a horizontal sundial that is designed and functions independently of the latitude of the location. The design relies on the same basic equation that underlies (almost)[1] all such dials. And because that equation essentially solves only for $\sin t$ and not for t itself, the device does not distinguish between times before and after 6 o'clock. The sine for 4 o'clock is the same as for 8 o'clock; this dial relies on the dialist to be perceptive enough to distinguish between those two readings. That is a challenge that does not often cause the dialist any difficulty, but the chore becomes increasingly more difficult as the two possible readings get closer to 6 o'clock. Distinguishing between 5:30 and 6:30 may be problematic if the dialist does not have a pocket watch at hand.

The second article in this pair, *A Latitude-Independent Hectemoral Sundial*, will introduce another variation on this type of dial – a variation specifically intended to address this shortcoming when dealing with readings around 6 o'clock.

Fred Sawyer *fwsawyer@aya.yale.edu*

[1] For an example of a dial based on a different equation, see Dial 2 in Fred Sawyer's *Ptolemaic Coordinate Sundials*, The Compendium, Sep 1998, 5(3):17-24.

An Interesting London Horizontal Sundial

Fred Sawyer (Manchester, CT)

On a recent trip to London, my brother Peter Sawyer came across an interesting horizontal sundial in Brompton Cemetery. Brompton is a garden cemetery, one of the so-called Magnificent Seven burial grounds of London, established in 1840, owned by the Crown and now the final resting place of over 205,000 people.

The sundial sits on a pedestal at the gravesite of Ann Harriet Crisp[1] who died 8 October 1925, aged 57 years. One feature of the dial that

[1]Ann Harriet (Burkett) Crisp was born in July 1868 in Marylebone, London. She married Robert Crisp in 1890 and the couple lived in Chelsea. Ann died in 1925 having given birth to three sons, all of whom died between 1962 and 1968. The restoration of her memorial sundial may have been the work of a more recent generation of Crisps.

makes it unusual is that, despite being a monument nearly a century old, sitting among thousands of other monuments, it has recently been cared for. A photo of the dial taken by a Mr. Leo Reynolds in 2006 (https://www.flickr.com/photos/lwr/413015701/) shows a forlorn dial plate with a missing gnomon. However, Peter's recent photo shows what appears to be the original gnomon still in place – or replaced. Old cemetery monuments that lose a major structural item rarely enjoy an act of restoration.

The more interesting feature of the sundial is its unusual layout of the gnomon and hour lines. The intent of the designer was obviously to make the sides of the square dial face run parallel to the lanes and burial plot boundaries among which it would be placed, but the correct placement of the gnomon and noon line(s) could not be similarly parallel. Nor could they lie along either of the diagonals of the square face.

So the horizontal dial was drawn with a pleasingly unusual asymmetric layout. The hour lines, the noon gap, and the recently replaced gnomon are correctly placed according to the elementary rules of dial construction, but the asymmetry gives the dial a flair that makes even the knowledgeable gnomonist linger ‘yet a little while’ to appreciate a moment of artistic inspiration preserved for a century (and obviously still cared for).

Yet a little while is the light with you. Walk while ye have the light, lest darkness come upon you: for he that walketh in darkness knoweth not whither he goeth.

(John 12:35, King James Bible)

Thanks to Peter Sawyer for his vigilance in finding the truly interesting bits of London.

Fred Sawyer *fwsawyer@aya.yale.edu*

Steve Lelievre (Victoria, BC)

This postscript to our recent series of articles about Hevelius dials is prompted by a report of an example with an earlier date than any other known.

An inquiry sent to the British Sundial Society's Help and Advice Service earlier this year related to the wooden altitude dial shown above. Analysis of the dial, carried out by Sue Manston and me, suggests that it is probably a Hevelius dial, albeit one with an incorrect layout for the hour scale [1]. Unfortunately, the dial is undated.

The dial is of particular interest for two reasons: first, it is the only non-modern wooden Hevelius dial that I am aware of; second, the scale on the left, used for setting the dial, uses the hour of sunrise as a proxy for solar declination (as opposed to the usual calendar scale). A table on the back of the dial gives the time of sunrise for various dates throughout the year.

It turns out that owner François Juge has another Hevelius Dial in his collection. It is the metal dial shown below and is marked 'Anno 1616'. This is important to us because, assuming the dial is genuine, it predates every other Hevelius dial listed in the inventory prepared by Rob van Gent and later updated by Claude Guicheteau [2, 3].

What's more, it presents a minor challenge to the naming of this class of dials as Hevelius Dials. This naming can be traced back at least to the 1960s. For example, Tadeusz Przypkowski, a noted Polish Historian of Art and Science (and enthusiastic dialist) asserted that:

"Johannes Hevelius in 1638 constructed a new type of sundial, reproduced many times in the XVIIth - XIXth centuries" [4]. Similar claims are found in other sources from the early to mid-1960s.

In fact, Mr. Juge's 1616 dial is not the only one that raises doubts about Hevelius being the inventor of these dials. There is an example at the Museum Boerhaave in Leiden which, although undated, has an epact scale starting at the year 1615, when Hevelius was only four years old, and ending with 1634, four years before the date marked on Hevelius' own dial [2].

In short, we can continue to call these dials 'Hevelius Dials' in honor of the famous and accomplished astronomer, but we should be cautious when it comes to identifying the actual inventor.

References

The photographs in this article are reproduced courtesy of François Juge.

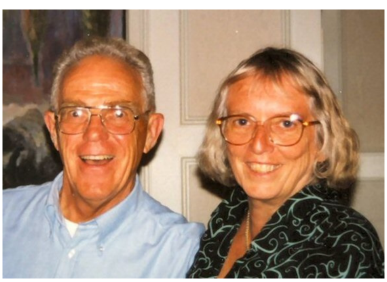
1. Lelievre, Steve, and Manston, Sue. The Belgian Altitude Dial: A Hevelius Dial. *BSS Bulletin* (forthcoming).
2. Van Gent, Robert H. (n.d.) Early Dutch-German Altitude Dials. https://webspace.science.uu.nl/~gent0113/sundial/sundial.htm
3. Guicheteau, Claude. (2022). The Planar, Vertical Hevelius Altitude Dial. *The Compendium 29*(1), pp.57-76. [From a French original.]
4. Przypkowski, Tadeusz. (1967). The art of sundials in Poland from the thirteenth to the nineteenth century. *Vistas in Astronomy 9*(1), pp.13-23.

Steve Lelievre *steve.lelievre.canada@gmail.com*

The Honorable William Peter Van Wyke

The Honorable William Peter Van Wyke died on Sunday, August 14th, 2022, at his home in Maryland. William was a man of infinite curiosity and passion for the world; his interests ranged from sailing to poetry to baking bread to building sundials, and much more besides. William was a long-term member of NASS and occasional conference attendee.

Albert 'Mac' Oglesby



We are saddened to report the passing of Mac Oglesby on August 24th, 2022. Mac joined NASS in our very first year. He was a frequent attendee at early conferences, was the recipient of the Sawyer Dialing Prize for 2007, authored over 30 articles for The Compendium, and fashioned many of the novel sundials Fred Sawyer designed. His public dials are found across southern Vermont. Mac was particularly fond of Hours to Sunset dials, such as NASS Registry #366, which he designed for the airstrip where he used to fly his small experimental aircraft. He supported NASS by sending memberships to each of his daughters and son-in-law, and insisted on paying for his own membership well into his 90's. He and his late wife Claire were well-known for their efforts to teach school students the basics of dialing. Mac always seemed to be happiest when working on a sundial. We will all miss him.

F.S.

THE TOVE'S NEST

Maciej Lose has published a booklet about vertical stereographic sundials and related instruments. Download it for free from Cursiva Publishers (https://tinyurl.com/47r6rk2d) or from Academia (https://tinyurl.com/yfuzc7ar, registration required). It is also included in this issue's Digital Bonus.

Luigi Ghia posted on the *Sundial List* a link to a video about the work of American shadow artist Larry Kagan. See https://www.youtube.com/watch?v=dSdkrzkcu20 (and refer to Luigi's post of 2022-08-04 for other links). Willy Leenders followed up by posting a copy of his article on using the sun for 'shadow writing'. Willy's paper is included in this issue's Digital Bonus.

Dan-George Uza, via the *Sundial List*, draws our attention to an news item from Ordinance Survey, the UK mapping agency, describing the rare (and temporary) alignment of magnetic north, true north, and OS Grid North over the UK. See https://tinyurl.com/yc8z9cke.

DIGITAL BONUS

This time round, the Digital Bonus contains:

- A PowerPoint file for Fred Sawyer's presentation relating to his article 'A Dialist's Parlor Trick', p.70, introducing a new latitude-independent dial.
- A PDF version of Maciej Lose's booklet about vertical stereographic sundials, as mentioned in The Tove's Nest.
- Willy Leender's PDF paper on shadow writing, as mentioned in The Tove's Nest.

In the right light, at the right time, everything is extraordinary.

- Aaron Rose