ILLUSTRATING SHADOWS

Print edition 1 updates

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Thank you for acquiring this book. Any work that provides formulae and tables, and uses spreadsheets, will introduce various rounding and other formulae approximations which are discussed in the book, and these can be compounded when approximations are made for latitude, longitude, day of year in the leap cycle, and the equation of time (EOT) formula. This book intentionally uses two different EOT formulae.

Page 96 had a graphical typo, so its replacement is attached.

Page 141 had a graphical typo so its replacement is attached, and two bonus clarifying pages are attached.

Page 163, table A2.10 for the meridian and polar dial has factors for hour line distances and declination point on hour lines. The table showed only one significant digit, and dial design is better served by two or three significant digits, so its replacement is attached.

Some tables also had a Julian day of 304 when it should have been 305, and while not correct, is well within the errors introduced by leap year averaging. Those references may be changed for aesthetic purposes.

The web site contains an up to date "all-updates.pdf" file, and many spreadsheets. If the web site does not have the spreadsheet you wish, simply email the author and you will receive by email that which you seek.

Please also send the author your suggestions, changes, or other ideas so they may be incorporated both here and in the second edition.

This book was designed with the web site in mind. Thank you for acquiring this book, and please use the web site for updates or clarifications. You may wish to join the North American Sundial Society, whose web site is accessible on this book's web site.

Please check: www.illustratingshadows.com/any-updates regularly for updates, typos, clarifications, or corrections, and download the articles, templates, or spreadsheets you desire. The acrobat file of all updates is: www.illustratingshadows.com/all-updates.pdf and an all purpose spreadsheet covering most dialing functions is: www.illustratingshadows.com/a-sun-dial-aid.xls

A backup web site is: www.geocities.com/illustratingshadows/ . . .

Please click on the VRML link on the main web page to see how to add a VRML browser easily that works and then to view some manipulatable 3d dials on the internet!

Simon Wheaton-Smith
Silver City
New Mexico
December 29, 2006

clarified figures: 15.1, a7.6, a8.3

replacement pages: 96, 141(and bonuses), 163

TECHNICAL CORRECTIONS:-

Page 27 ~ the example says -15:46 for an EOT but then uses 12:46. The EOT should be 15:46 and the end result should be: 11:57:02 4/2/05

Page 96 ~ replacement page attached, it cleans up the pictorial, and corrects the radius of the circle 4/8/05

Page 141 ~ replacement page attached, the gnomon on the auxiliary horizontal dial is shown at the bottom. It should be at the top of the auxiliary horizontal dial. 4/8/05

HELPFUL CLARIFICATIONS:-

Page 111 ~ The formula has the horizontal line was displaced slightly, should read as follows

$$= \text{asin}\left(\frac{\tan(dec) * \sin(\text{atan}(\tan(lat) * \cos(dec)))}{\tan(lat)} \right)$$

Page 214 and Page 220, fig A7.6 and A8.3, lines "h" and "e" were not labeled. "e" is the lowest horizontal line ~ tan(lat)=f/e, and, "h" is the other line forming the "dec" ~ tan(sl) = f/h see below

Page 221 formula A8.29 ~ The EOT formula is shown correctly as:-
-1*(9.84*SIN(RADIANS(2*(360*(mm1+dd-81)/365))) - 7.53*COS(RADIANS(360*(mm1+dd-81)/365)) - 1.5*SIN(RADIANS(360*(mm1+dd-81)/365)))-0.3
but the value mm1 and dd were not defined. The definitions are:-

mm1 is the number of days prior to this month's day 1, So Jan is 0,
Feb is 31, Mar is 59, April is 90, etc, assuming a non leap year.
dd is the day of the month, being 1 to 31

Page 163 ~ replacement page attached, Table A2.10 shows one significant digit however two or three would be better. A table A2.10 with three digits is available.

And: appendices 2, 4, and 6, specifically, tables A2.10, A2.11, A4.1 and A4.2 and A6.3 had a value of pi of 3.146 and it should have been a value of 3.1416, and tables A2.10, A4.1 and A4.2 and A6.3 had a julian day of 304 for Nov 1 and it should have been 305. Net change is trivial:

The largest declination change when corrected in affected charts was:- 0.2 degrees
The maximum solar altitude change in tables A4.1 was: 0.2 degrees
The maximum solar azimuth change in table A4.2 was: 0.2 degrees
The maximum sunset or sunrise change in table A6.3 was: 1 minute

And the above figures are within the range of data in other publications because different publications use different formulae, leap year considerations apply, as well as other approximations.

Pages 105, 186, and 196 ~ the bottom two boxes of gnomons are correct as far as direction goes, the top two boxes should have the gnomons in the other direction. See following. 6/11/05

TYPOS:-

Page 22 ~ "shown in figures 3.4 and 3.6 respectively" should say 3.5 and not 3.6 4/2/05
Page 31 ~ "the equinoxes (June 21 and December 21, approximately)." should read "the equinoxes (March 21 and September 21, approximately)."
Page 32 ~ equinoctial line and is sloped because the wall does *not* run purely east to west. 9/13/05
Page 34 ~ figure 5.5 has two pictorials, the one on the left should have a note stating that the hours depicted when drawn from the pole's base produce hours that are NOT the same from day to day 2/16/06.
Page 44 ~ third para from bottom says " So, at 15 minutes to 3 the styles shadow", should be "15 minutes to 2"
Page 55 for the meridian dial, second paragraph, "and its distance from noon" should read "and its distance from 6am or 6pm"
Page 54 ~ figure 7.8 has "12 o'clock line" on the top, it should be "6 o'clock line" 4/4/05
Page 63 ~ figure 8.6 ~ the hours "1 2 3" shown above the AB line should be shifted left the "1" being on the hour line with no time marked, the "2" where the 1 was, and the "3" moved to where the 2 was. 7/16/05

Page 72 ~ The sample dial for latitude 40 should have the following hour line angles 5/13/05

8am and 4pm	48.07 degrees	9am and 3pm	32.73 degrees	
10am and 2pm	20.36 degrees	11am and 1pm	9.77 degrees	etc

Page 76 ~ para 2 says "... the dial plate points upwards", it should say "... the gnomon's style points upwards"

Page 81 ~ AUXILARY POLAR DIAL should say AUXIIARY EQUATORIAL, AND A POLAR DIAL or as attached 8/19
Page 91 ~ very last sentence says "declination, xyd directly" and it should be "declination, xyz directly"
4/7/05

Page 96 ~ second para from bottom, letters " ls " should be " js " replacement page is attached

Page 117: item 4 says "4. the 45 degree lines", this should be the 15 degree lines, see below.

Page 138 ~ Figure 16.5 shows an angle of .5 degrees, it should be 23.5 degrees 4/9/05

Page 145 says "chapter 17" expounds on declination lines, that should be "chapter 16".

Page 208 has sunset correctly as 5:30pm, but says sunrise is 6:30pm, it should be 6:30 am!

Appendices: Some pages in part 3 had the function cost() which should be cos(), they are on pages 171 and 208.

Appendices and other parts: Some pages in part 3 had the value of pi printed as 3.146, of course it should have been printed as 3.1416, they are on pages 137, 165, 227, and 228

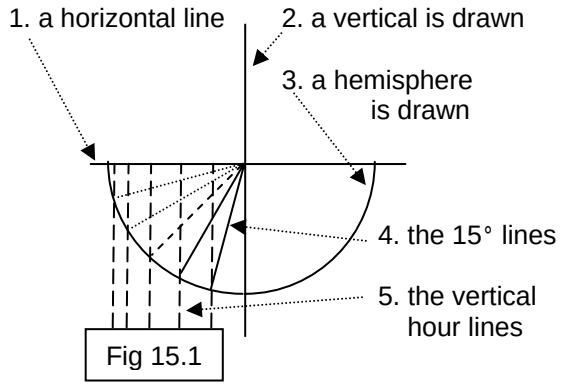
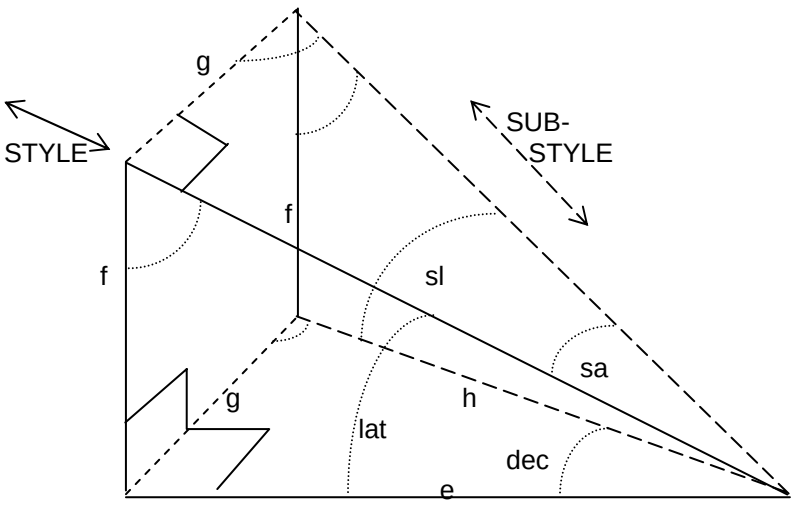


Fig 15.1

Page 117: Fig 15.1 item 4

This is the first part of the design, and is nothing more than the hour line construction.

There are 5 added vertical lines, 6 if you include the very first vertical, and those 6 lines together with the place where the semicircle meets the horizontal on the left form the hour lines, 12 noon on the left and then 11am and 1pm next, then 10am and 2pm, etc.



Page 214: Fig A7.6
Page 220: Fig A8.3

THE GEOMETRICAL METHOD FOR A HORIZONTAL DIAL

Consider a dial plate ABCD. In its center draw a noon line XY. From X draw a line XZ that makes an angle with XY equal to the latitude. In essence this is the gnomon's style rotated 90 degrees and thus is lying flat on the surface of the dial plate as if the wind blew it over, resting peacefully.

Draw a line perpendicular to the style that goes to Y, that point on the style is labeled Z. Or, from Y draw a line to Z, the angle XYZ being the co-latitude, and thus intercepts the style at 90 degrees.

Our gnomon is WXZ when rotated back vertically. ZY is the path the sun's rays travel at the equinox at solar noon. ZY would be where the trigon we used in the empirical method would lie.

Rotate YZ to the top as YR, and then draw a semi-circular protractor LYM centered on R.

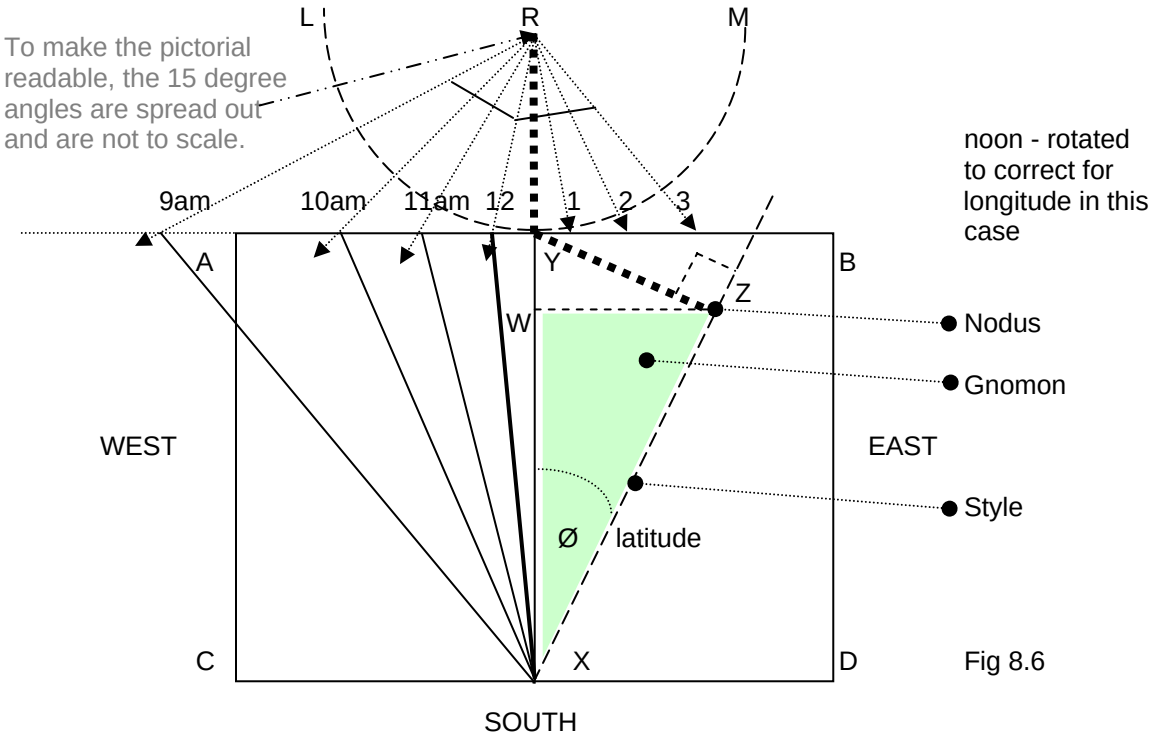


Fig 8.6

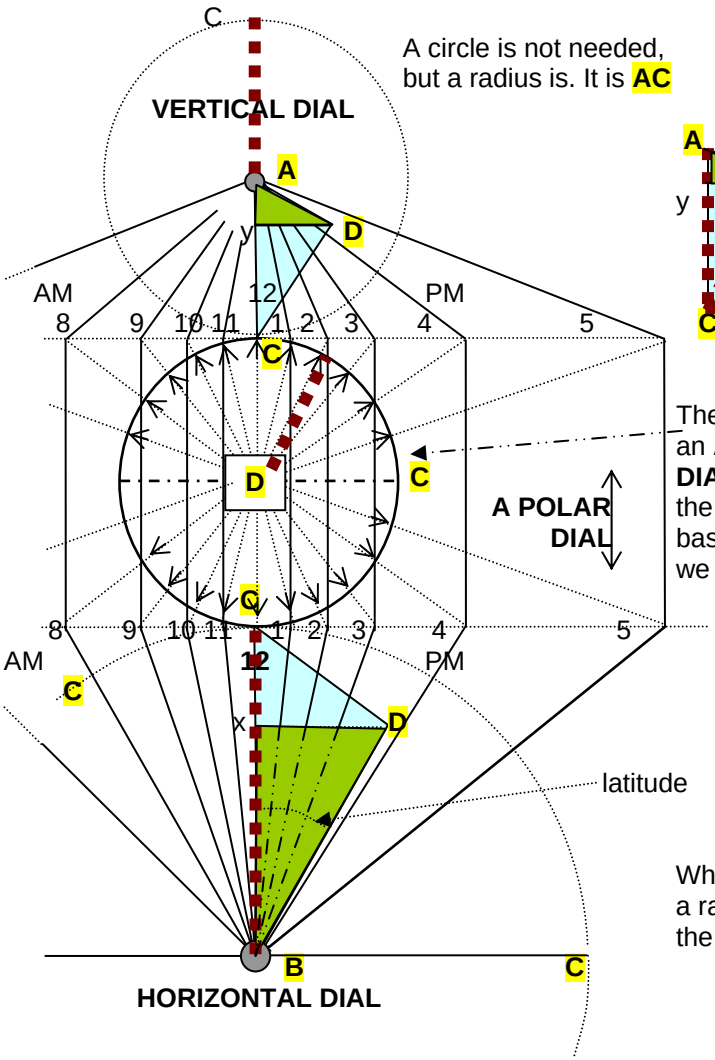
Then mark off 15 degree marks on the protractor LYM, rotating them by the longitude difference is so desired, and extend the protractor's 15 degree lines to AB. A longitude correction with the protractor rotated west or clockwise is shown. One rotates the protractor west (clockwise) when the dial's location is west of the standard legal time meridian. Finally, the hour lines are drawn from the dial center up to where the protractor lines meet the west to east line AB.

Notice that the noon line is offset to the west because the longitude correction was for a location west of the standard meridian. Another way of verifying this is that noon on the legal standard meridian happens before noon on the dial's meridian when the dial is west of the standard. So, noon must be shown before solar noon where the dial is installed. Finally, the equation of time, EOT, is managed mentally by a printed table for the sundial observer to consider.

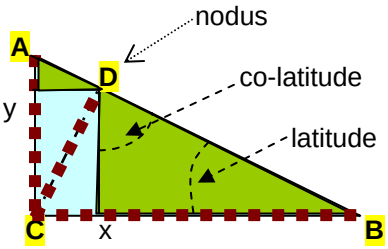
As always, the longitude correction need not be incorporated as above, but instead blended into a EOT table that would be location specific.

A GENERAL GEOMETRIC MODEL OF THE PREVIOUS DIALS

We have now seen the geometric methods for designing the armillary and equatorial dial, the polar and meridian dials (true east or true west), as well as the vertical (true south) and the horizontal dial. We can blend all those concepts into one easy to remember model. This is intended to show a natural symmetry in geometric dial design.



A circle is not needed, but a radius is. It is **AC**



The radius of this circle, which is an **AUXILIARY EQUATORIAL DIAL** is the orthogonal line from the style's **nodus** to the style base. A circle is needed because we draw 15 degree arcs. It is **CD**

latitude

While a circle is not needed as such, a radius is needed for the center of the hour lines. The radius is **BC**

Fig 10.1

The above general geometrical model shows a symmetry in the design of the polar, vertical, and horizontal dials in the context of their gnomon's style. For a polar or a meridian dial, CD is the linear height of the style's nodus above the dial plate. In this model, CD does different things depending on dial type.

For a horizontal dial, this model is based on the ratio of the DC to CB. For a vertical dial the ratio is based on DC to CA. In all cases, DC is the equinoctial ray going to the dial plate at C from nodus D.

To draft the hour lines using the rotated sub-style

Drawing the hour lines is as follows. First, BN is the part of the gnomon, sub-style, attached to the vertical yet declining wall. Angle NBZ is the style angular height, termed style height or "SH". MBN is the style angular distance termed style distance or "SD". Here, height and distance are angular, whereas in some earlier dial designs in this book they were sometimes linear.

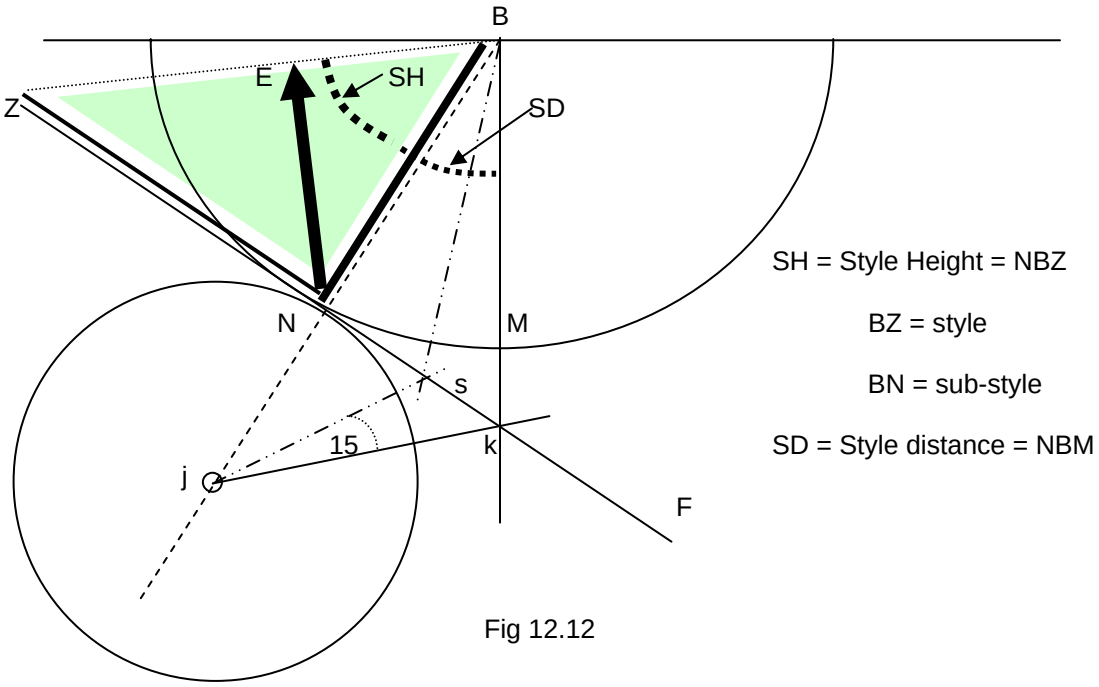


Fig 12.12

Having established the rotated gnomon NBZ, draw a line ZNF perpendicular to line BN, BN is the extension of the sub-style. This new line ZNF parallels the equinox line, should one be drawn.

From N draw a line perpendicular to BZ, meeting it at E.

Draw a circle meeting the line ZNF at point N, whose radius is "jN" is equal to EN.

Draw a line from the circle's center to meet the noon vertical line (BM extended) where BM extended meets the line ZNF, this is the line "jk".

Line "jk" is the base line for noon on the circle, and draw 15 degree lines on either side of "jk", these being the 11 am and the 1 pm hour points when extended to meet line ZNF, which in turn provide the hour lines when connected to the dial center "B".

The 11am line is shown. Noon line on the circle is "jk", thus 15 degrees back is "js", and the line "sB" is the hour line for 11am for the vertical decliner.

Thus angle "sBM" is the hour line angle for 11am on the vertical decliner. Other hour lines are found similarly.

Thus the equinox line is simply drafted as long as a 6 o'clock line is in place.

Another technique can be used for a vertical decliner's calendar lines. Again, the extended sub-style line is used, along with a horizontal auxiliary dial. This technique assumes the gnomon has been rotated using the Style Distance techniques discussed in chapter 8.

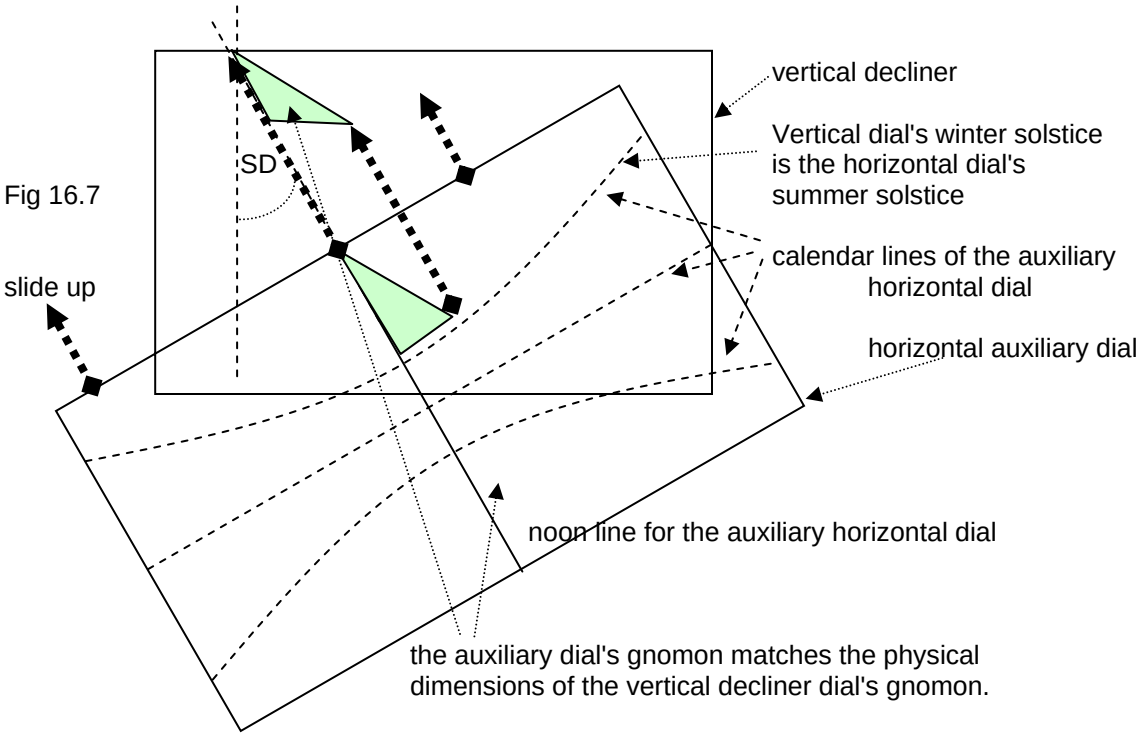


Fig 16.7

A horizontal dial is built whose latitude is the vertical dial's style height, and the horizontal dial's gnomon dimensions equal those of the vertical dial's gnomon. The entire set of lines from the auxiliary dial is slid up such that it's equinox line overlays the equinox line for the vertical decliner drawn using the methods of the previous page, or the horizontal dial is slid up so it's gnomon blends with the rotated vertical dial's gnomon, same end result. The vertical dial's winter solstice is the horizontal dial's summer solstice, and the vertical dial's summer solstice is the horizontal dial's winter solstice.

Thus a vertical decliner at latitude 32, where the wall is South 10 degrees West would provide the following date from Appendix A5.1b:-

15.5	**SD**
56.6	**SH**
18.4	**DL**
1.2	**DL**
83.8	**AV**

SD is 15.5 degrees, and the noon line of the auxiliary sundial will merge with the extended sub-style line.

SH is 56.6 degrees, thus the horizontal dial is designed for latitude 56.6 degrees. The physical dimensions of the vertical decliner's rotated gnomon are exactly used as-is on the auxiliary horizontal dial.

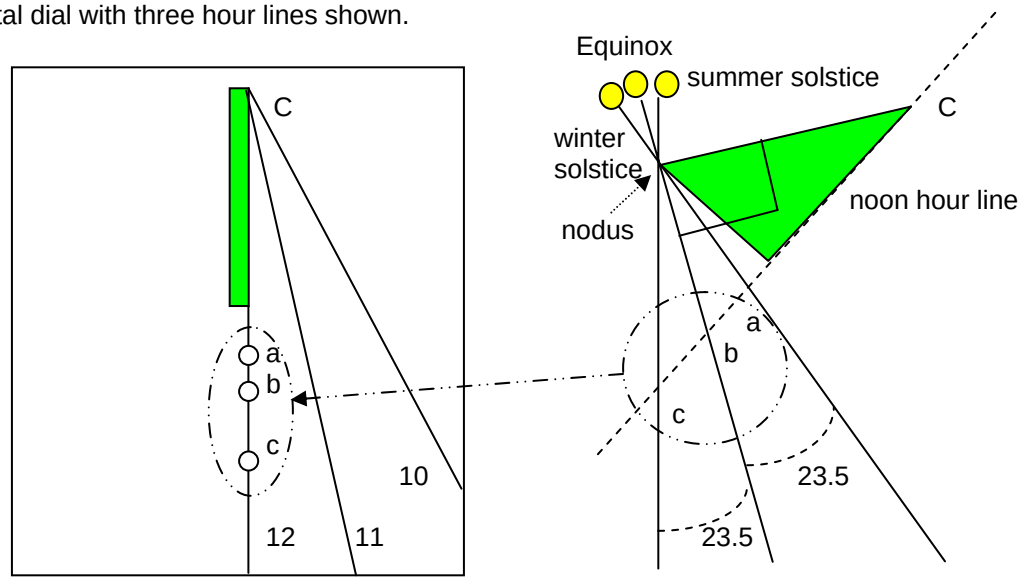
Consider double checking your design using software such as SHADOWS.

In summary, while some calendar or declination line processes may require some work, this chapter encapsulated the processes in order of complexity. The tables in the appendices facilitate calculation of the angles, and out of these lines comes the basis for exotic hours lines such as the Italian and Babylonian which need an equinox and solstice line for their construction.

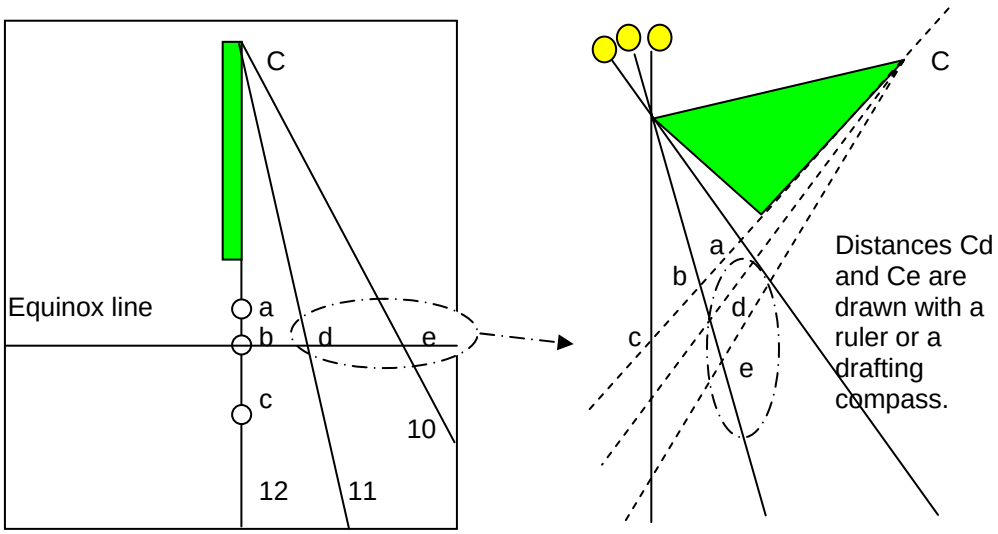
Declination lines for the horizontal (or vertical) dial using geometry.

This duplicates two pages from the chapter on horizontal dials – step by step

A horizontal dial with three hour lines shown.

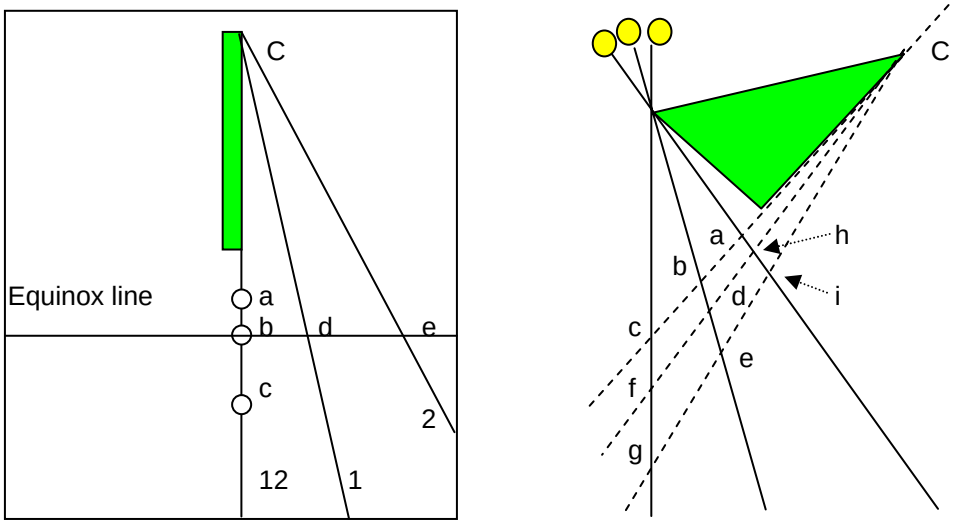


First, draw a gnomon for the dial center "C". From the nodus draw the equinox line (90 degrees to the style), and from that the solstice lines (approx 23.5 degrees on either side).The three lines (equinox and the solstices) intersect the gnomon's base line extended, or the noon line, at points a, b, and c. These three points whose distances from the dial center are Aa, Ab, and Ac are then transcribed to the dial plate (right pictorial to left pictorial).

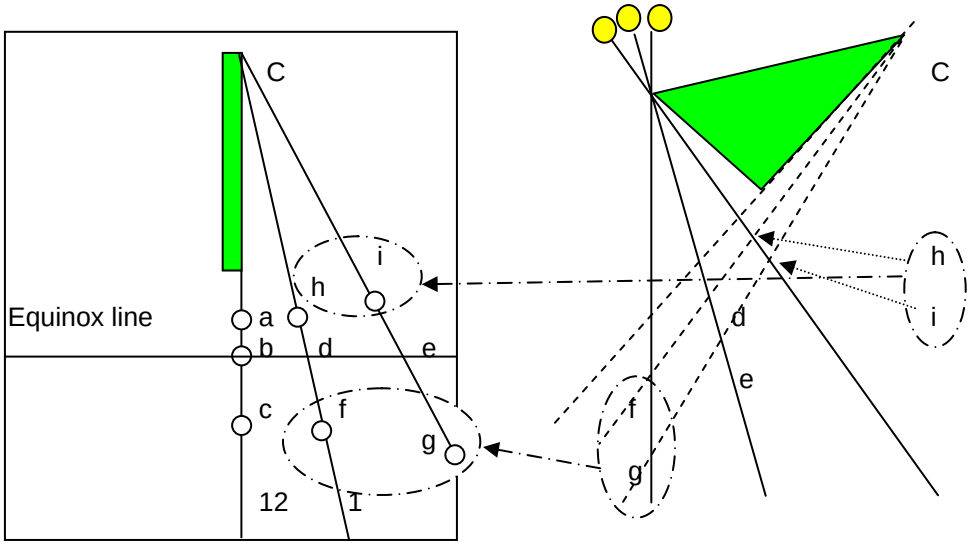


The equinox line is then drawn perpendicular to the noon line, and it produces three equinox intercepts for those additional hour lines, d and e. Distances Cd and Ce are then located from the left dial plate to the right hand picture on it's equinox line. This produces two more hour lines on the right hand side picture, Cd and Ce. Those hour lines on the right hand side do not have angles that match their hour lines on the dial plate, and this is because this is a projection.

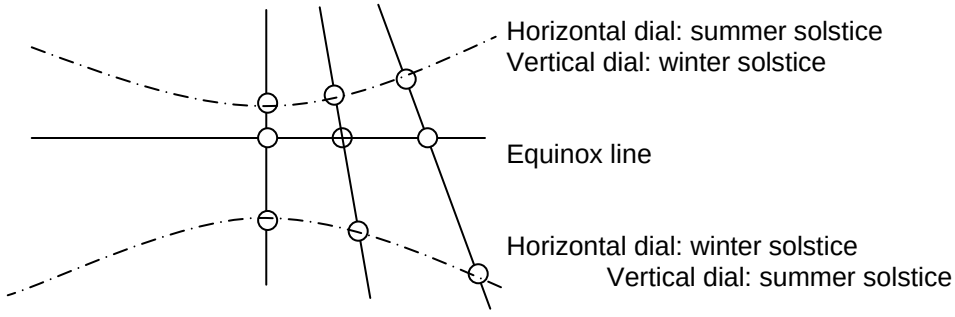
Now that there are two more hour lines, or as many as you choose, this produces intercept points for the solstice lines, namely points f, g, h and i.



Points f, h, g, and i are now transferred back to the dial plate, from the right projection pictorial to the left picture.



When this process is completed for as many hour lines as desired, the dots are connected and then the declination lines drawn.



POLAR DIAL AND MERIDIAN DIAL HOUR LINE DISTANCE AND CALENDAR POINT DISTANCE UP AN HOUR LINE

A2.10

POLAR AND MERIDIAN HOUR LINE AND DECLINATION DISTANCES relative to style linear height.

A2.10

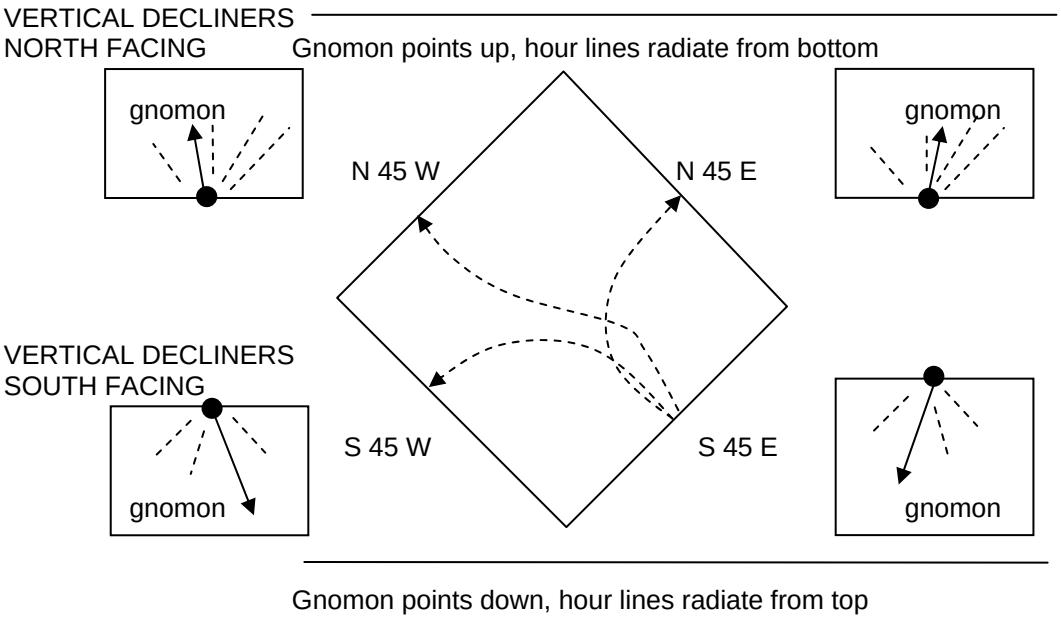
* Hour and calendar relative distances are based on the linear style height.

* Hour baseline is from noon if polar, 6 o'clock if meridian.

		Meridian	6pm	5pm	4pm	3pm	2pm	1pm	1:30pm
			6am	7am	8am	9am	10am	11am	11:30am
		Polar	noon	11am	10am	9am	8am	7am	6:30am
			noon	1pm	2pm	3pm	4pm	5pm	5:30pm
Hour line from sub-style:			0.00	0.27	0.58	1.00	1.73	3.73	7.60
			0	1	2	3	4	5	5.5
Date	Julian	decl	Relative distance on hour line to calendar point						
1/1	1	-23.1	-0.426	-0.441	-0.492	-0.602	-0.851	-1.645	-3.261
1/10	10	-22.1	-0.406	-0.420	-0.468	-0.574	-0.811	-1.567	-3.107
1/20	20	-20.3	-0.370	-0.383	-0.427	-0.523	-0.740	-1.429	-2.834
2/1	32	-17.3	-0.312	-0.323	-0.360	-0.441	-0.624	-1.206	-2.391
2/10	41	-14.6	-0.261	-0.270	-0.301	-0.369	-0.521	-1.007	-1.998
2/20	51	-11.2	-0.198	-0.205	-0.229	-0.280	-0.396	-0.765	-1.517
3/1	60	-7.9	-0.138	-0.143	-0.160	-0.196	-0.277	-0.535	-1.060
3/10	69	-4.4	-0.077	-0.080	-0.089	-0.109	-0.154	-0.298	-0.590
3/20	79	-0.5	-0.008	-0.008	-0.009	-0.011	-0.016	-0.031	-0.062
4/1	91	4.2	0.074	0.077	0.086	0.105	0.148	0.287	0.568
4/10	100	7.7	0.134	0.139	0.155	0.190	0.269	0.519	1.030
4/20	110	11.2	0.199	0.206	0.230	0.281	0.398	0.768	1.523
5/1	121	14.8	0.265	0.274	0.306	0.374	0.530	1.023	2.028
5/10	130	17.4	0.314	0.325	0.362	0.443	0.627	1.211	2.402
5/20	140	19.8	0.360	0.373	0.416	0.509	0.720	1.392	2.760
6/1	152	21.9	0.403	0.417	0.465	0.570	0.806	1.557	3.087
6/10	161	23.0	0.424	0.439	0.489	0.599	0.847	1.637	3.246
6/20	171	23.4	0.434	0.449	0.501	0.613	0.867	1.675	3.322
7/1	182	23.2	0.428	0.443	0.494	0.605	0.856	1.654	3.280
7/10	191	22.4	0.411	0.426	0.475	0.581	0.822	1.589	3.150
7/20	201	20.8	0.380	0.394	0.439	0.538	0.761	1.469	2.914
8/1	213	18.2	0.329	0.341	0.380	0.466	0.658	1.272	2.522
8/10	222	15.8	0.283	0.293	0.327	0.400	0.566	1.093	2.168
8/20	232	12.7	0.226	0.233	0.260	0.319	0.451	0.871	1.728
9/1	244	8.6	0.151	0.156	0.174	0.213	0.301	0.582	1.155
9/10	253	5.2	0.092	0.095	0.106	0.130	0.184	0.355	0.703
9/20	263	1.4	0.025	0.026	0.028	0.035	0.049	0.095	0.189
10/1	274	-2.9	-0.050	-0.052	-0.058	-0.071	-0.100	-0.193	-0.384
10/10	283	-6.3	-0.111	-0.115	-0.128	-0.157	-0.222	-0.429	-0.850
10/20	293	-10.1	-0.177	-0.184	-0.205	-0.251	-0.355	-0.685	-1.359
11/1	305	-14.2	-0.253	-0.262	-0.292	-0.358	-0.506	-0.977	-1.937
11/10	314	-16.9	-0.305	-0.315	-0.352	-0.431	-0.609	-1.177	-2.334
11/20	324	-19.5	-0.355	-0.367	-0.410	-0.502	-0.709	-1.371	-2.718
12/1	335	-21.7	-0.398	-0.412	-0.459	-0.563	-0.796	-1.537	-3.047
12/10	344	-22.8	-0.421	-0.436	-0.486	-0.596	-0.842	-1.627	-3.227
12/20	354	-23.4	-0.433	-0.448	-0.500	-0.612	-0.866	-1.672	-3.316

typo pages 105, 186, and 196

the bottom two boxes of gnomons are correct as far as direction goes, the top two boxes should have the gnomons in the other direction.



KEY UPDATE: Illustrating Shadows has some notes on altitude and azimuth dials not being latitude portable. The following note is more accurate. 11/1/06

Hour angle dials use the hour angle around the style and can easily be latitude corrected by tilting. Italian and Babylonian hours are not corrected when a dial is tilted because they depend on the Earth's curvature [which causes sunset/rise] at a specific latitude. Azimuth and altitude dials may be ported across latitudes but rigid polar alignment must be retained.

THE END