The Sundial Primer - "Dialling Guides"
Polar Sundial

created by
Carl Sabanski

The purpose of the "Dialling Guides" is to provide an easy method for laying out the hour lines for a number of polar sundials located at any latitude in either the Northern or Southern Hemispheres. The polar sundial is a universal sundial and can be used anywhere in the world. All that is required is to tilt the dial plate so the gnomon points to the celestial pole. The relative distance of the hour lines from the gnomon is the same for any polar sundial regardless of its size. Please go to "The Sundial Primer" and visit the "Polar Sundial" page for more details.

The "Dialling Guides" are very easy to use and will help you lay out a variety of polar sundials. They come in two sizes if printed out at full scale. One set can be printed on 8-1/2" by 11" paper and the other on 11" by 17" paper. The scaling is in inches and will help in determining the required size of the dial plate. The "Dialling Guides" can be printed to any size but then the scaling in inches is no longer valid. This gives you the flexibility to create any size of "Dialling Guide" you need to meet your requirements. The following summarizes the polar sundial "Dialling Guides" available:

1. Sizes: 6 to 18 inches in 1/2 inch increments; Time Range: 7 a.m. to 5 p.m.; Time Increment: 10 minutes
2. Sizes: 6 to 18 inches in 1/2 inch increments; Time Range: 7 a.m. to 5 p.m.; Time Increment: 15 minutes
3. Sizes: 14 to 18 inches in 1/2 inch increments; Time Range: 6:30 a.m. to 5:30 p.m.; Time Increment: 10 minutes
4. Sizes: 14 to 18 inches in 1/2 inch increments; Time Range: 6:30 a.m. to 5:30 p.m.; Time Increment: 15 minutes
5. Sizes: 18 to 30 inches in 1/2 inch increments; Time Range: 7 a.m. to 5 p.m.; Time Increment: 5 minutes
6. Sizes: 24 to 30 inches in 1/2 inch increments; Time Range: 6:30 a.m. to 5:30 p.m.; Time Increment: 5 minutes

First determine the size of polar sundial you wish to create. The size indicated on the "Dialling Guides" is the dial plate width based only on the space required for the hour lines. The gnomon thickness, which will be discussed later, and any extra space required at either end of the dial plate for aesthetics must also be considered. Select the appropriate "Dialling Guide" based on the desired time range and increment. Some of the "Dialling Guides" have hour lines extending beyond the normal defined time range. This was done whenever paper space permitted and it is up to you whether or not to include these additional time lines. Once you have the "Dialling Guide" you need it requires a little preparation before it can be used. For example, let's say we want to make a polar sundial with a width of 13 inches, time range of 7 a.m. to 5 p.m. and 15 minute time increments. Figure 1 shows the "Dialling Guide" that will be used.

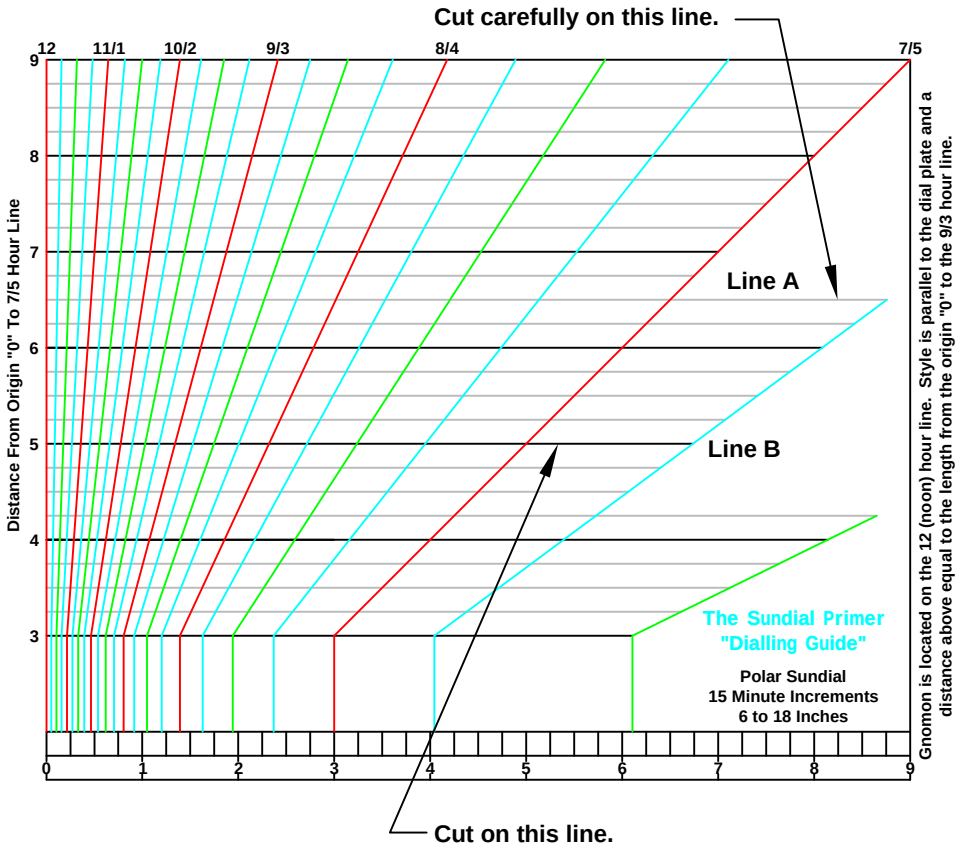

Figure 1

This "Dialling Guide" provides the layout of the hour lines for 25 polar sundials. Line "A" contains the required information for the hour lines of a 13 inch polar sundial. Extend this line to the right and cut carefully on the line. Extend and cut along line "B". This is done only to make the Guide easier to handle and line "B" can be any line you choose. All the margin information is lost when you cut out the Guide so write the numbers at each of the hour lines. It's just that easy!

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Figure 2 shows the "Dialling Guide" ready for use. Note that the available time range is 6:45 a.m. to 5:15 p.m. should you wish to include an extra 15 minutes. For this example the extra 15 minutes will not be included. The point "X" will be used later to help in laying out the hour lines.

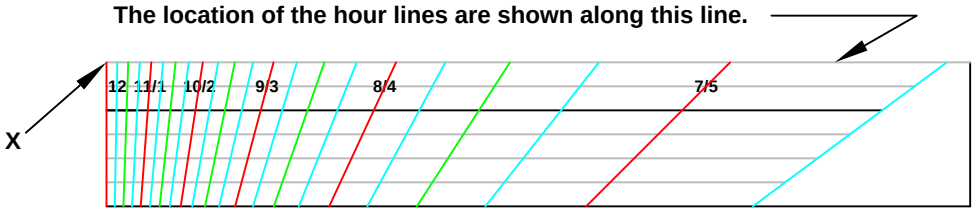

Figure 2

The size of the dial plate must be determined. To lay out the hour lines the dial plate must be 13 inches wide plus the thickness of the gnomon. The gnomon for a polar sundial can be rectangular and attached directly to the dial plate. For it to be secure it must have some thickness to accept fasteners. Assume a thickness of 1/4 inch. The dial plate is now 13.25 inches wide. At this width the 7 a.m. and 5 p.m. hour lines will lie on the two edges of the plate. Let's add 3/4 inch to each end. The dial plate is now 14.75 inches wide. Now for the length. Let the hour lines lie between two lines 3.5 inches apart and add 3/4 inch to the top and bottom. The selection of 3.5 inches is not entirely arbitrary. The selection of a dial plate length is discussed later. The final size ot the dial plate is 14.75 inches wide by 5 inches long as shown in Figure 3.

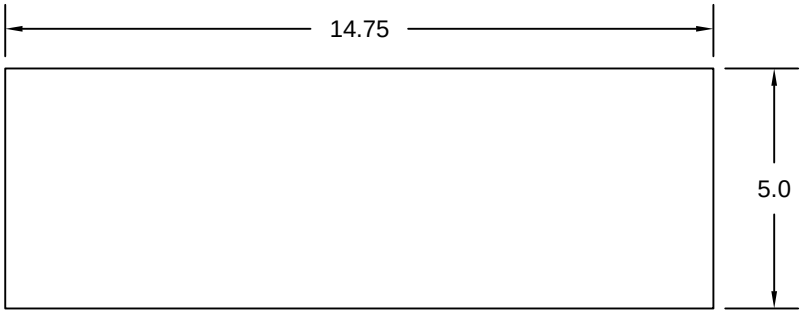

Figure 3

Draw a horizontal line across the centre of the dial plate. Draw the parallel lines "AB" above and "CD" below this horizontal centre line at a distance of 1.75 inches. Draw a vertical line down the centre of the dial plate. Draw the parallel lines "EF" to the left and "GH" to the right of this vertical centre line at a distance of 1/8". These lines will be spaced by the width of the gnomon. This must be done so the hour lines can be shifted to compensate for the width of the gnomon. If you do not do this a significant error will be introduced into the sundial. Before solar noon the shadow will be cast by the west edge of the gnomon's style and after solar noon the shadow will be cast by the east edge. Don't miss this step! Figure 4 illustrates the above discussion.

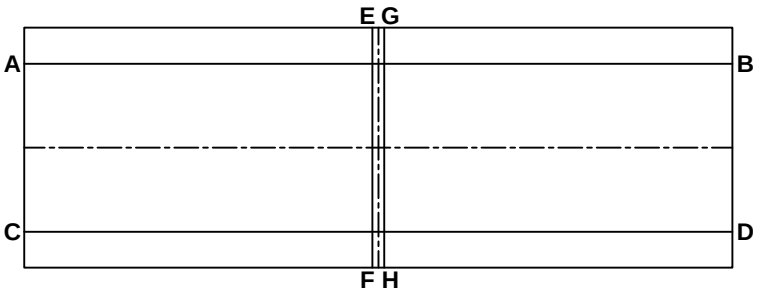

Figure 4

The dial plate is now ready to have the hour lines marked. This step is carried out the same way whether you are designing a polar sundial for the Northern or Southern Hemisphere. The "Dialling Guide" shown in Figure 2 will be used. Marking the points for the hour lines is a four step process as shown in Figure 5. These steps can be carried out in any order. The 12 (noon) hour line must always lie against one side of the gnomon and the point "X" placed in the four positions shown. After all the desired hour lines are marked the points can be joined to create a series of vertical lines as shown in Figure 6. These are the hour lines. All that is left is to label the hour lines.

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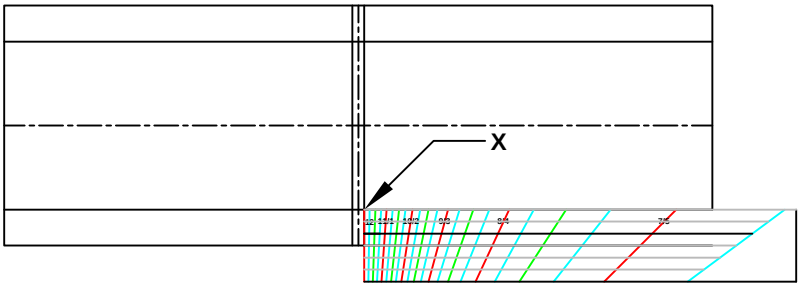
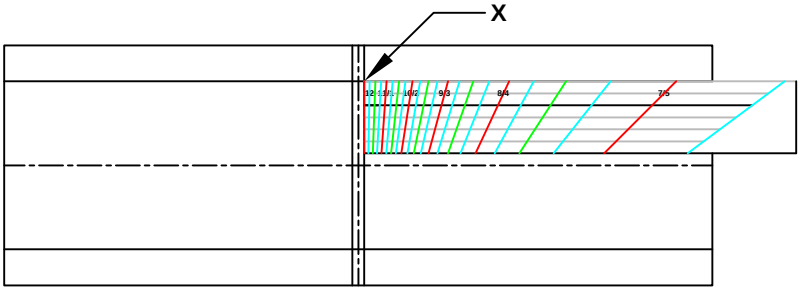
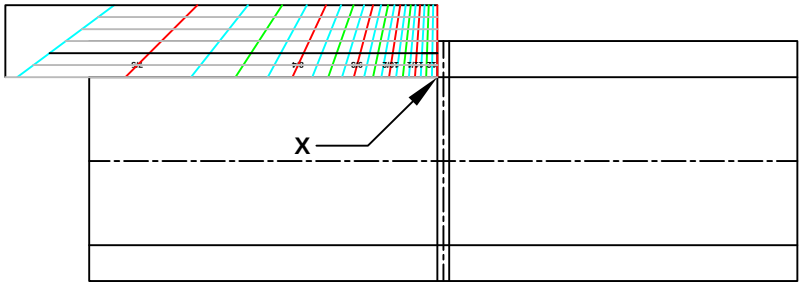
Step 1



Step 2



Step 3



Step 4

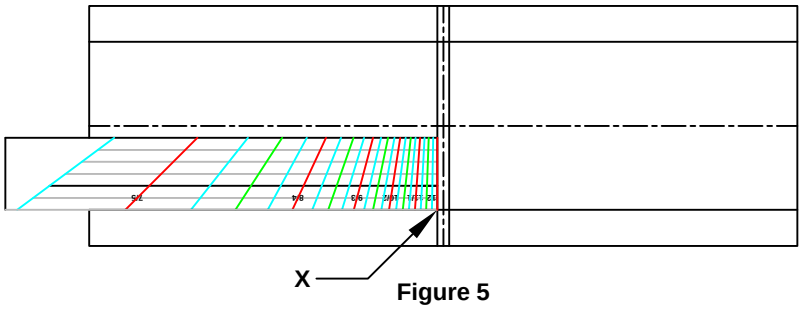


Figure 5

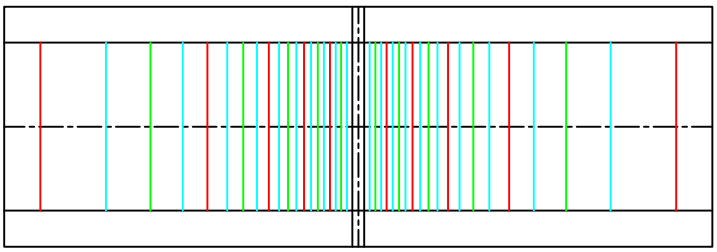


Figure 6

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The hour lines are numbered as shown in Figure 7. In the Northern Hemisphere the top edge of the dial plate faces north and the sun moves from right to left, east to west. In the Southern Hemisphere the top edge of the dial plate faces south and the sun moves from left to right, again east to west. As a result the order of the hour numbers is reversed between the two sundials.

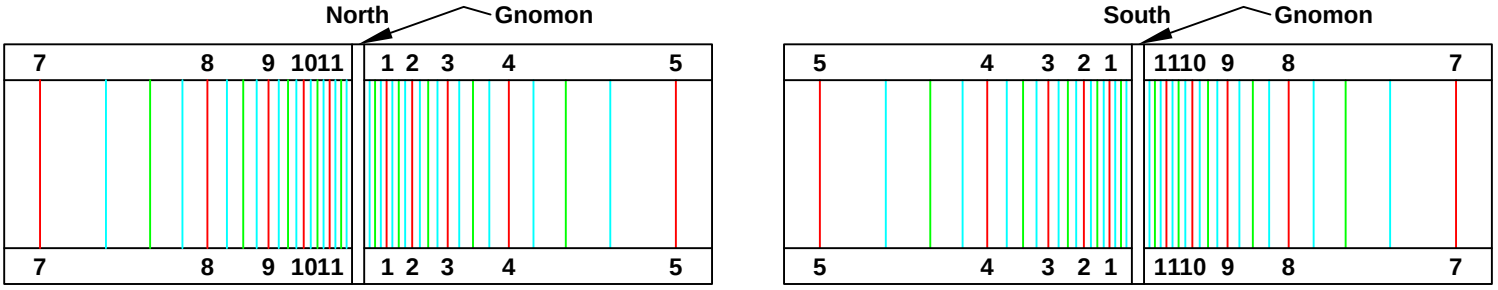

Figure 7

There are a couple of variations of the polar sundial that can be constructed. The first is a double gnomon polar sundial and is illustrated in Figure 8. Rather than having a single gnomon at the centre of the dial plate, there are two gnomons. These are located at each end of the dial plate. Remember that the shadow will be cast by the inner edge of the the style and so this is the line to use when positioning the "Dialling Guide".

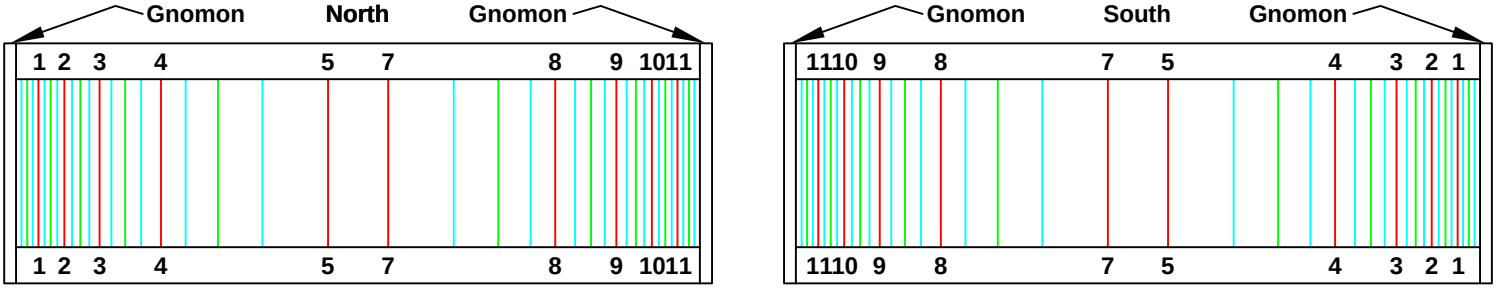

Figure 8

The second alternate method of construction is called the stacked double gnomon polar sundial and is illustrated in Figure 9. This variation results in a polar sundial half the width of the one shown in Figure 8. This configuration allows you to construct a polar sundial with smaller time increments within a narrower width than would be required with the single gnomon polar sundial. The layout of the hour lines for this sundial is the same as that in Figure 8. If the width of the dial plate is doubled it is possible to include an extra half hour in the morning and evening. It is even possible to carry the hour lines up the gnomons to have the sundial indicate the time from 6 a.m. to 6 p.m.

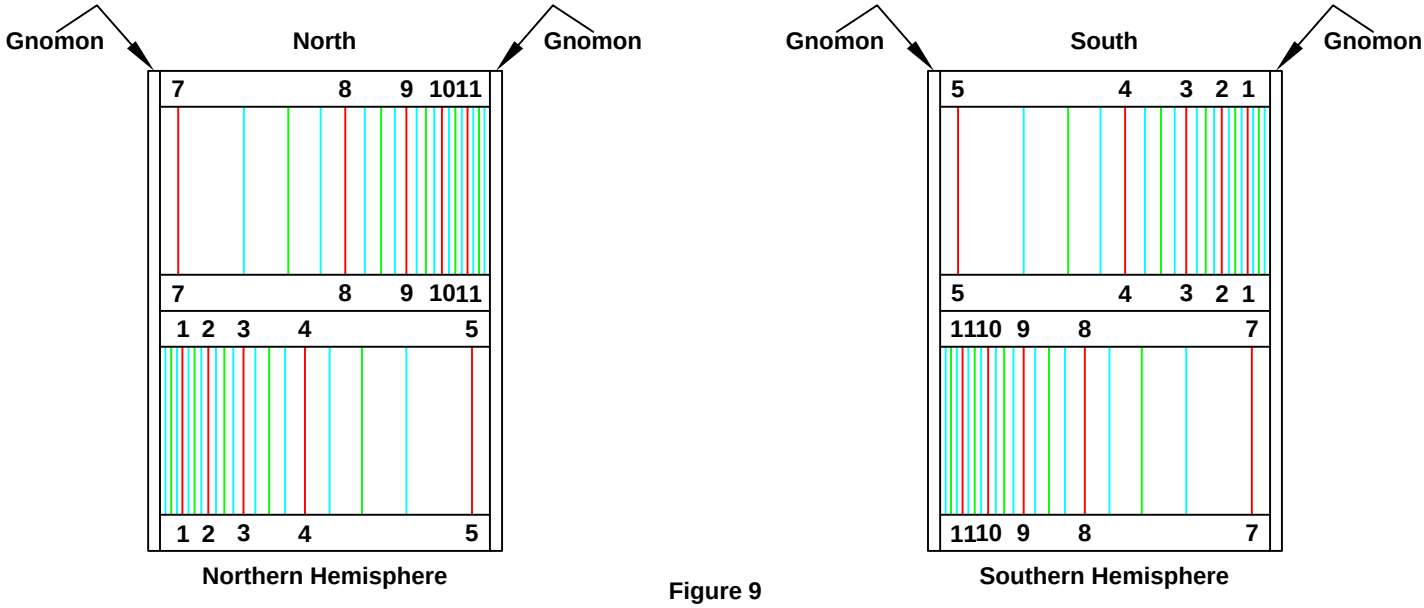

Figure 9

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The next item that will be discussed is the gnomon. The gnomon is positioned on the 12 (noon) line and its style or shadow casting edge is parallel to the dial plate. One type of gnomon that can be used for a polar sundial is a simple rectangle. Figure 10 illustrates this gnomon. The height "H" is always equal to the distance from the 12 (noon) hour line to the 9/3 hour line. You can use the "Dialling Guide" to obtain this length as shown in Figure 11. In this example the height of the gnomon or "H" is approximately 1.74 inches. The thickness "T" of the gnomon must be known before the sundial design is started. This is the distance that the two halves of the dial plate must be separated as was discussed earlier.

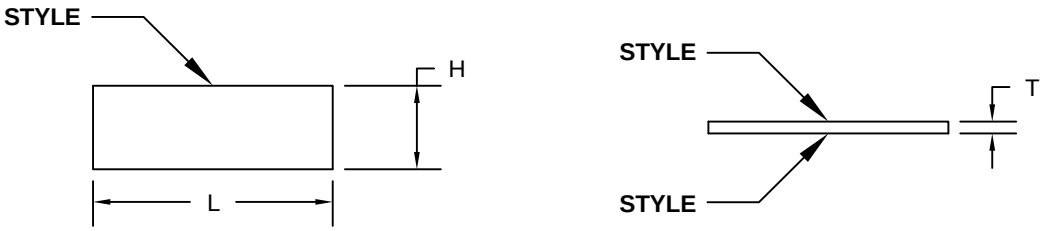

Figure 10

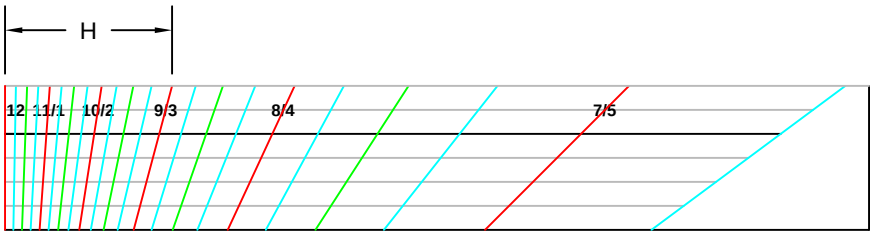

Figure 11

As long as the style is not altered the remainder of the gnomon can take on any form you like.

The length of the style "L" and in turn the dial plate will vary according to the gnomon height "H". Declination lines can be drawn on a polar sundial as illustrated in Figure 12 from a single point or nodus located above the centre of the dial plate. Only the lines for the solstices and equinoxes are shown.

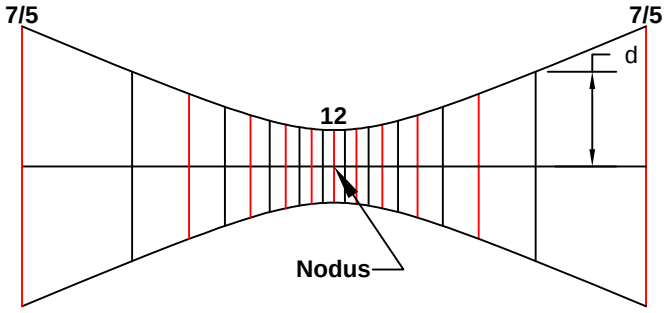

Figure 12

The distance "d" along any hour line to a declination line for a particular day is given by:
d = H x tan (DEC) / cos (h) where

- "DEC" is the declination of the sun for any given day.
- "h" is the hour angle and is the angle corresponding to the sun's position around its daily (apparent) orbit.
  h = (T24 - 12) x 15° where T24 is the time in 24-hour clock notation (hours after midnight) in decimal hours.

The declination line is furthest away at the solstices and the extreme time limits of the day. The length of the dial plate must equal at least this distance if the time is to be read throughout the year. The distance "d" must be calculated at the solstice when the sun's declination is 23.44° and at the most extreme time shown on the dial plate. In our example this is at 7 a.m. or 5 p.m.. Let's use 5 p.m. or 17:00 hr. (T24) and remember H equals 1.74 inches.

d = 1.74 x tan (23.44) / cos [(17-12) x 15] = 2.92 inches

This means that the shadow cast by a point on the style at the centre of the 13 inch polar sundial will move 2.92 inches above and below the horizontal centre line, or equinox line, during the year. If a rectangular gnomon with a length "L" of 2.92 inches is positioned on a dial plate with hour lines equal to 2.92 inches the time can be read throughout the year. The shadow cast by the two ends of the gnomon will move up and down by 2.92 inches but will always be on an hour line. Add a little extra and the value of 3.5 inches discussed earlier is reasonable.

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Figure 13 attempts to illustrate this point. First examine the sundial on the left. The length of the gnomon is equal to the length of the hour lines. As the gnomon has a finite thickness it will have to styles, one casting a shadow in the morning and the other in the afternoon. The shadows cast by the four corner points of the gnomon at the summer and winter solstices are shown. The limiting factor that determines whether the sundial will indicate the time throughout the year is the position of the gnomon's shadow at the extreme times of the day, in this case 7 a.m. and 5 p.m.. Let's examine 5 p.m.. At the winter solstice the top right point of the gnomon will cast a shadow at point A and the bottom right point will cast a shadow at point A'. The shadow cast by the afternoon style at 5 p.m. will be from points A to A'. As point A' is on the hour line the time can be read. The same reasoning applies for the summer solstice and points B and B'. If the hour lines were shorter it is possible for the points A' and B' to move far enough away that they would not lie on an hour line and it would be difficult to tell the time for some period of the year.

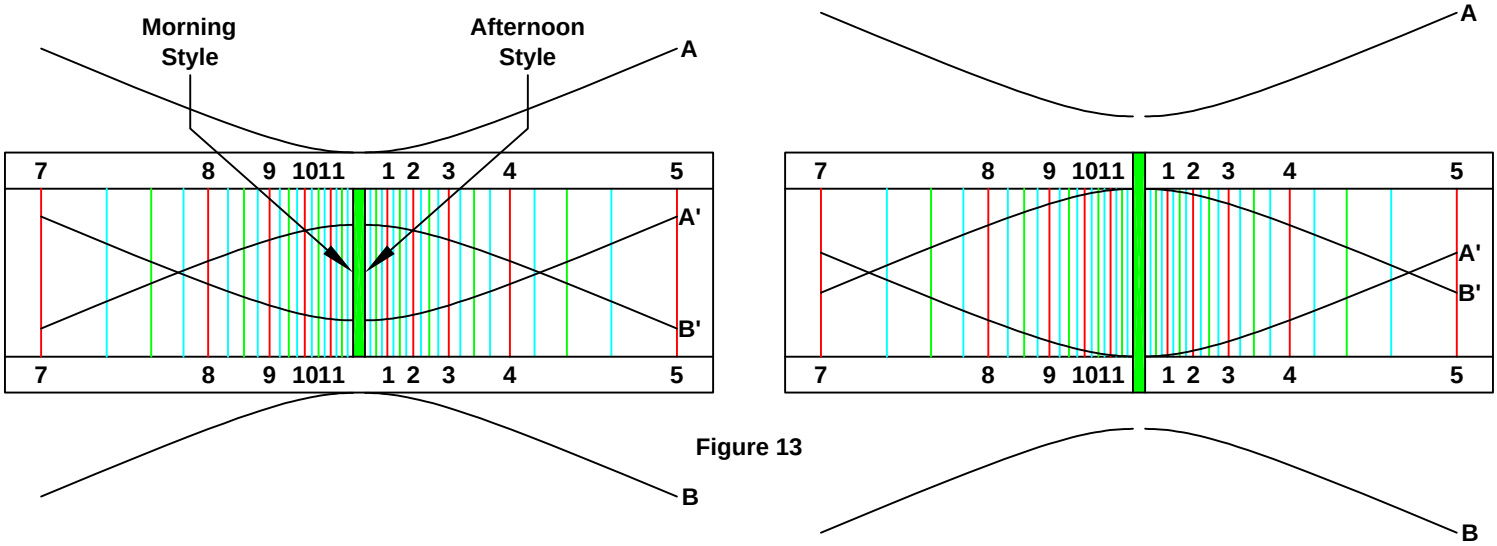

Figure 13

Now examine the sundial on the right. The length of the hour lines is equal to the sundial on the left but the length of the gnomon extends to the end of the dial plate. The solstice lines are drawn from the new corners of the gnomon. Examining this sundial it can be seen that the style's shadow is even further on to the hour line at 5 p.m., making it even better.

As these are "Dialling Guides", I don't imagine that you are too interested in calculating how long the hour lines and gnomon should be to ensure that you can use your polar sundial throughout the year. Two tables are available for you. Table 1 provides you with values of "H" and "L" for the "Dialling Guides" that have time ranges from 7 a.m. to 5 p.m. and Table 2 for the "Dialling Guides" that have time ranges from 6:30 a.m. to 5:30 p.m.. You will notice that the tables cover more dial sizes than are available but the additional information is provided at no extra cost and may be of interest.

As was mentioned before, some of the "Dialling Guides" have hour lines beyond the stated time range. This was done because they would fit on the paper sizes used. However, if you plan to use these additional lines the length of the hour lines and gnomon will need to be extended. Table 3 lists the multipliers to be used on the value of "L" obtained from Table 1 or 2 to obtain the hour line and gnomon length required to read the additional times.

Table 3

Time Range: 7a.m.-5 p.m.		
a.m.	p.m.	Multiplier
6:55	5:05	1.09
6:50	5:10	1.20
6:45	5:15	1.33
6:40	5:20	1.49
6:35	5:25	1.70
6:30	5:30	1.98
6:25	5:35	2.38
6:20	5:40	2.97
6:15	5:45	3.96
6:10	5:50	5.93
6:05	5:55	11.86

Time Range: 6:30a.m.-5:30p.m.		
a.m.	p.m.	Multiplier
6:25	5:35	1.20
6:20	5:40	1.50
6:15	5:45	2.00
6:10	5:50	2.99
6:05	5:55	5.98

The polar sundial created using these "Dialling Guides" will indicate local apparent or solar time. To obtain clock time the sundial reading must be corrected for longitude and the Equation of Time. To help you with this check out the "Correct-A-Dial" at "The Sundial Primer".

Happy Dialling!

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Dial Size	H	L	Dial Size	H	L	Dial Size	H	L	Dial Size	H	L	Dial Size	H	L
6.00	0.80	1.35	11.00	1.47	2.47	16.00	2.14	3.59	21.00	2.81	4.71	26.00	3.48	5.84
6.25	0.84	1.40	11.25	1.51	2.52	16.25	2.18	3.65	21.25	2.85	4.77	26.25	3.52	5.89
6.50	0.87	1.46	11.50	1.54	2.58	16.50	2.21	3.70	21.50	2.88	4.83	26.50	3.55	5.95
6.75	0.90	1.51	11.75	1.57	2.64	16.75	2.24	3.76	21.75	2.91	4.88	26.75	3.58	6.00
7.00	0.94	1.57	12.00	1.61	2.69	17.00	2.28	3.82	22.00	2.95	4.94	27.00	3.62	6.06
7.25	0.97	1.63	12.25	1.64	2.75	17.25	2.31	3.87	22.25	2.98	4.99	27.25	3.65	6.12
7.50	1.00	1.68	12.50	1.67	2.81	17.50	2.34	3.93	22.50	3.01	5.05	27.50	3.68	6.17
7.75	1.04	1.74	12.75	1.71	2.86	17.75	2.38	3.98	22.75	3.05	5.11	27.75	3.72	6.23
8.00	1.07	1.80	13.00	1.74	2.92	18.00	2.41	4.04	23.00	3.08	5.16	28.00	3.75	6.28
8.25	1.11	1.85	13.25	1.78	2.97	18.25	2.45	4.10	23.25	3.11	5.22	28.25	3.78	6.34
8.50	1.14	1.91	13.50	1.81	3.03	18.50	2.48	4.15	23.50	3.15	5.27	28.50	3.82	6.40
8.75	1.17	1.96	13.75	1.84	3.09	18.75	2.51	4.21	23.75	3.18	5.33	28.75	3.85	6.45
9.00	1.21	2.02	14.00	1.88	3.14	19.00	2.55	4.26	24.00	3.22	5.39	29.00	3.89	6.51
9.25	1.24	2.08	14.25	1.91	3.20	19.25	2.58	4.32	24.25	3.25	5.44	29.25	3.92	6.56
9.50	1.27	2.13	14.50	1.94	3.25	19.50	2.61	4.38	24.50	3.28	5.50	29.50	3.95	6.62
9.75	1.31	2.19	14.75	1.98	3.31	19.75	2.65	4.43	24.75	3.32	5.55	29.75	3.99	6.68
10.00	1.34	2.24	15.00	2.01	3.37	20.00	2.68	4.49	25.00	3.35	5.61	30.00	4.02	6.73
10.25	1.37	2.30	15.25	2.04	3.42	20.25	2.71	4.54	25.25	3.38	5.67			
10.50	1.41	2.36	15.50	2.08	3.48	20.50	2.75	4.60	25.50	3.42	5.72			
10.75	1.44	2.41	15.75	2.11	3.53	20.75	2.78	4.66	25.75	3.45	5.78			

Table based on "Dialling Guides" with a time range of 7 a.m. to 5 p.m.. "Dial Size", "H" and "L" are in inches.

Table 1

Dial Size	H	L	Dial Size	H	L	Dial Size	H	L	Dial Size	H	L	Dial Size	H	L
6.00	0.39	1.31	11.00	0.72	2.41	16.00	1.05	3.50	21.00	1.38	4.59	26.00	1.71	5.69
6.25	0.41	1.37	11.25	0.74	2.46	16.25	1.07	3.55	21.25	1.40	4.65	26.25	1.73	5.74
6.50	0.43	1.42	11.50	0.76	2.51	16.50	1.09	3.61	21.50	1.42	4.70	26.50	1.74	5.79
6.75	0.44	1.48	11.75	0.77	2.57	16.75	1.10	3.66	21.75	1.43	4.76	26.75	1.76	5.85
7.00	0.46	1.53	12.00	0.79	2.62	17.00	1.12	3.72	22.00	1.45	4.81	27.00	1.78	5.90
7.25	0.48	1.59	12.25	0.81	2.68	17.25	1.14	3.77	22.25	1.46	4.87	27.25	1.79	5.96
7.50	0.49	1.64	12.50	0.82	2.73	17.50	1.15	3.83	22.50	1.48	4.92	27.50	1.81	6.01
7.75	0.51	1.69	12.75	0.84	2.79	17.75	1.17	3.88	22.75	1.50	4.97	27.75	1.83	6.07
8.00	0.53	1.75	13.00	0.86	2.84	18.00	1.18	3.94	23.00	1.51	5.03	28.00	1.84	6.12
8.25	0.54	1.80	13.25	0.87	2.90	18.25	1.20	3.99	23.25	1.53	5.08	28.25	1.86	6.18
8.50	0.56	1.86	13.50	0.89	2.95	18.50	1.22	4.05	23.50	1.55	5.14	28.50	1.88	6.23
8.75	0.58	1.91	13.75	0.91	3.01	18.75	1.23	4.10	23.75	1.56	5.19	28.75	1.89	6.29
9.00	0.59	1.97	14.00	0.92	3.06	19.00	1.25	4.15	24.00	1.58	5.25	29.00	1.91	6.34
9.25	0.61	2.02	14.25	0.94	3.12	19.25	1.27	4.21	24.25	1.60	5.30	29.25	1.93	6.40
9.50	0.63	2.08	14.50	0.95	3.17	19.50	1.28	4.26	24.50	1.61	5.36	29.50	1.94	6.45
9.75	0.64	2.13	14.75	0.97	3.23	19.75	1.30	4.32	24.75	1.63	5.41	29.75	1.96	6.50
10.00	0.66	2.19	15.00	0.99	3.28	20.00	1.32	4.37	25.00	1.65	5.47	30.00	1.97	6.56
10.25	0.67	2.24	15.25	1.00	3.33	20.25	1.33	4.43	25.25	1.66	5.52			
10.50	0.69	2.30	15.50	1.02	3.39	20.50	1.35	4.48	25.50	1.68	5.58			
10.75	0.71	2.35	15.75	1.04	3.44	20.75	1.37	4.54	25.75	1.70	5.63			

Table based on "Dialling Guides" with a time range of 6:30 a.m. to 5:30 p.m.. "Dial Size", "H" and "L" are in inches

Table 2