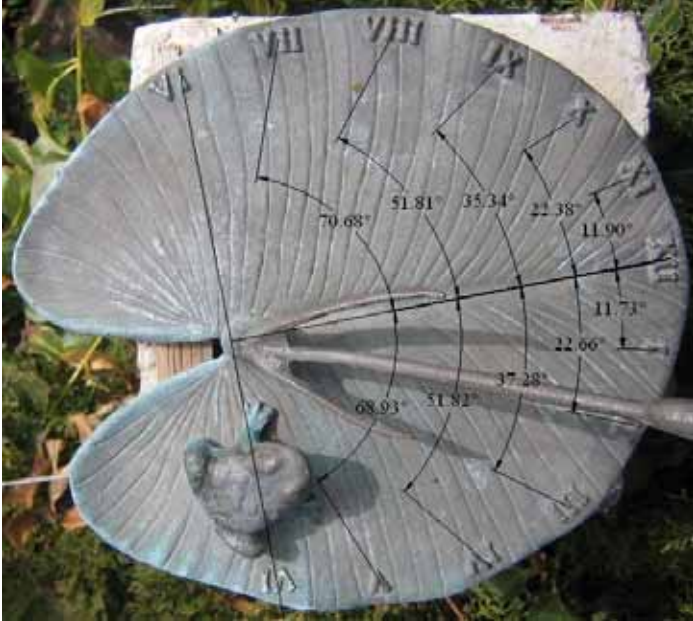


REVERSE ENGINEERING STORE-BOUGHT GENERIC DIALS

Have you ever purchased a delightful sun dial for your garden, but found it does not work. No problem. Take a photograph of the plan view and the profile, and on the plan view mark the noon and 6 o'clock lines, thus providing the dial center. Then measure the angles of the hour lines, and average the pairs, thus 11am and 1pm are averaged, 10am and 2pm, and so on. Then select the hour angle tables in the appendix for horizontal dials, and see if any latitude column comes close to those hour line angles.



Measuring the gnomon's style angle may confirm the latitude for which the dial was designed. Assuming a dial design latitude was found, then adjust the gnomon to that latitude.

Then place the dial on a surface with a wedge so that while the gnomon points true north, the style is adjusted by that wedge to match your location's latitude.

A few artistic dials are simply incorrect. The 6 o'clock hour lines may not be contiguous, not 90 degrees to noon, there may be no apparent dial center, the gnomon

latitude may be incorrect, and where it meets the dial may not be at dial center. Sadly, success is not readily to hand. Keep it out of the sun and enjoy it's art work. Time telling is not it's forte!

| HORIZONTAL DIAL LATITUDE | | | | | | | | | | | |
|--------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
| TIME | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | noon |
| 1 | 11.60 | 11.76 | 11.92 | 12.08 | 12.23 | 12.38 | 12.52 | 12.67 | 12.80 | 12.94 | 11 |
| 2 | 23.86 | 24.17 | 24.46 | 24.75 | 25.04 | 25.31 | 25.58 | 25.84 | 26.09 | 26.33 | 10 |
| 3 | 37.45 | 37.85 | 38.24 | 38.61 | 38.97 | 39.32 | 39.66 | 39.99 | 40.30 | 40.60 | 9 |
| 4 | 53.00 | 53.39 | 53.77 | 54.14 | 54.49 | 54.82 | 55.15 | 55.46 | 55.75 | 56.04 | 8 |
| 5 | 70.72 | 70.98 | 71.22 | 71.45 | 71.67 | 71.89 | 72.09 | 72.28 | 72.47 | 72.64 | 7 |
| 6 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 6 |
| | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | |

| HORIZONTAL DIAL LATITUDE | | | | | | | | | | | |
|--------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
| TIME | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | noon |
| 1 | 9.77 | 9.97 | 10.16 | 10.36 | 10.54 | 10.73 | 10.91 | 11.09 | 11.26 | 11.43 | 11 |
| 2 | 20.36 | 20.75 | 21.12 | 21.49 | 21.85 | 22.21 | 22.55 | 22.89 | 23.22 | 23.54 | 10 |
| 3 | 32.73 | 33.27 | 33.79 | 34.29 | 34.79 | 35.26 | 35.73 | 36.18 | 36.62 | 37.04 | 9 |
| 4 | 48.07 | 48.65 | 49.21 | 49.75 | 50.27 | 50.77 | 51.25 | 51.71 | 52.16 | 52.58 | 8 |
| 5 | 67.37 | 67.78 | 68.18 | 68.55 | 68.91 | 69.25 | 69.57 | 69.88 | 70.17 | 70.45 | 7 |
| 6 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 6 |
| | 50 | 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | |

The above dial appears to be a good fit for a design latitude of 46 or 47 degrees. The gnomon showed a design latitude of about 40 degrees.

With a dial plate for latitude 46 degrees, and a style set at 40 degrees, it may be assumed this dial was not designed as a true sun dial, or, that the gnomon was damaged in transit. However, if you can adjust the style to be 46 degrees then the dial would work for latitude 46 degrees. And a



wedge may be used to tilt the entire dial such that the final style is tilted at your latitude. Living at latitude 32 degrees, I needed a wedge of 14 degrees.

A temporary wedge was built, and tested in the real sun, and when fully satisfied, a permanent wedge was designed, thus providing life to an otherwise useless sundial.

The end result was a dial designed for latitude 46 with a wedge to thus emulate latitude 32, and the sun dial that was being neglected due to its inability to indicate the time consistently, now becomes not only a delightful garden ornament, but also a functional time piece.

Why commercial sundial vendors do not provide a simple sheet of paper showing how to do this amazes many purchasers.

Of course the EOT needs to be considered, and the longitude correction may be included in a tailored EOT chart, or shown as a separate figure to adjust the apparent time. Or, using Atkinson's Theorem, the dial could be rotated about the polar axis by an amount matching the longitude difference, although the end result might look strange, and the wedge might become more complex.



Alternatively, a spread sheet can be used that reverses the hour line angle formula

REVERSE ENGINEERING

$H = \text{atan}(\sin(\text{lat}) * \tan(\text{lha}))$
 thus $\text{lat} = \text{asin}(\tan(\text{hour line angle}) / \tan(\text{hour} * 15))$
 or... $\text{lat} = \text{DEGREES}(\text{ASIN}(\text{TAN}(\text{RADIANS}(C7)) / \text{TAN}(\text{RADIANS}(15 * C5))))$

| | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
|-----------|-----|-------|-------|-------|-------|-------|-------|
| angle | 0 | 11.90 | 22.66 | 37.28 | 51.82 | 68.93 | 90.00 |
| lat a | xxx | 51.9 | 46.3 | 49.6 | 47.2 | 44.1 | xxx |
| lat b | xxx | 50.8 | 45.5 | 45.2 | 47.2 | 49.8 | xxx |
| avg a & b | | 51.3 | 45.9 | 47.4 | 47.2 | 47.0 | |

Final average **47.8**

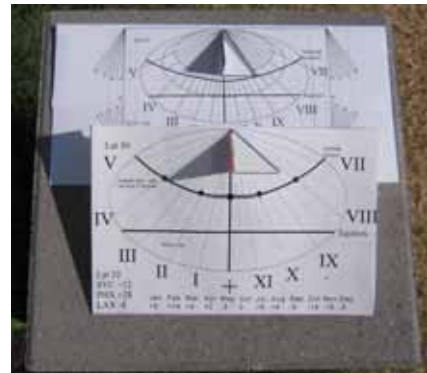
| | 0 | 11.22 | 23.14 | 36.51 | 52.05 | 70.10 | 90 |
|---------|-----|-------|-------|-------|-------|-------|-----|
| hla | 0 | 11.22 | 23.14 | 36.51 | 52.05 | 70.10 | 90 |
| delta a | xxx | 0.68 | 0.48 | 0.77 | 0.23 | 1.17 | xxx |
| delta b | xxx | 0.51 | 0.76 | 1.17 | 0.24 | 0.58 | xxx |

Max error **1.17** degrees

And when the hours are plugged in for times other than 6 o'clock and 12 o'clock (which for a dial not corrected for longitude) are 0 degrees and 90 degrees regardless of latitude, we see the average latitude for the hour line angles for each hour, and the average latitude for all the hours.

In this case, latitude 47.8 is suggested. This agrees with the use of the tables above, however, the gnomon clearly was designed for latitude 40, and those 7 degrees of difference between the gnomon design latitude and the hour line angle design latitude is significant. The gnomon needs to be adjusted to reflect 7 more degrees, and the dial is then tilted to cause the resulting gnomon angle to match your latitude. The above spreadsheet is available on the website's reference page.

From chapter 11 it may be recalled that the example was given of a latitude 50 dial reclined by 18 degrees produced a style with a resulting angle of 32 degrees, and the picture to the right shows the two. The upper dial was designed for latitude 32, the lower for latitude 50. They both agree on the time.



The latitude 50 paper dial is reclined by virtue of two protractors that have been cut to recline the dial by 18 degrees.

THE ABOVE SPREADSHEET IS AVAILABLE ON THE WEB SITE AS A GENERAL SPREADSHEET FOR ALL SORTS OF SUN DIALS

APPENDIX 3

TABLES THAT CONSIDER LOCATION

HORIZONTAL AND VERTICAL DIAL HOUR LINE ANGLES

| HOUR LINE ANGLES | | Horizontal or vertical dial | | | | | | | | | |
|------------------|--|-----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| hour angle | DEGREES(ATAN(TAN(RADIANS(15*time))*SIN(RADIANS(lat)))) | | | | | | | | | | |
| hour angle | H = atan (sin(lat) * tan (ha)) | | | | | | | | | | |
| | HORIZONTAL DIAL LATITUDE | | | | | | | | | | |
| TIME | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | noon |
| 0.25 | 1.88 | 1.93 | 1.99 | 2.04 | 2.10 | 2.15 | 2.21 | 2.26 | 2.31 | 2.36 | 11.75 |
| 0.50 | 3.77 | 3.88 | 3.99 | 4.10 | 4.21 | 4.32 | 4.42 | 4.53 | 4.63 | 4.74 | 11.50 |
| 0.75 | 5.68 | 5.85 | 6.02 | 6.18 | 6.35 | 6.51 | 6.67 | 6.83 | 6.98 | 7.14 | 11.25 |
| 1 | 7.63 | 7.86 | 8.08 | 8.30 | 8.52 | 8.74 | 8.95 | 9.16 | 9.37 | 9.57 | 11 |
| 1.25 | 9.63 | 9.92 | 10.20 | 10.47 | 10.75 | 11.02 | 11.28 | 11.55 | 11.80 | 12.06 | 10.75 |
| 1.50 | 11.70 | 12.04 | 12.38 | 12.71 | 13.04 | 13.36 | 13.68 | 14.00 | 14.31 | 14.61 | 10.50 |
| 1.75 | 13.85 | 14.25 | 14.65 | 15.03 | 15.42 | 15.79 | 16.16 | 16.53 | 16.89 | 17.24 | 10.25 |
| 2 | 16.10 | 16.56 | 17.01 | 17.46 | 17.89 | 18.32 | 18.75 | 19.16 | 19.57 | 19.97 | 10 |
| 2.25 | 18.47 | 18.99 | 19.50 | 20.00 | 20.49 | 20.97 | 21.44 | 21.91 | 22.36 | 22.81 | 9.75 |
| 2.50 | 20.99 | 21.56 | 22.13 | 22.68 | 23.22 | 23.76 | 24.28 | 24.79 | 25.29 | 25.78 | 9.50 |
| 2.75 | 23.68 | 24.31 | 24.93 | 25.53 | 26.12 | 26.70 | 27.27 | 27.82 | 28.37 | 28.89 | 9.25 |
| 3 | 26.57 | 27.25 | 27.92 | 28.57 | 29.21 | 29.84 | 30.45 | 31.04 | 31.62 | 32.18 | 9 |
| 3.25 | 29.69 | 30.43 | 31.14 | 31.84 | 32.52 | 33.19 | 33.83 | 34.46 | 35.07 | 35.66 | 8.75 |
| 3.50 | 33.09 | 33.87 | 34.63 | 35.37 | 36.08 | 36.78 | 37.45 | 38.11 | 38.74 | 39.36 | 8.50 |
| 3.75 | 36.81 | 37.63 | 38.42 | 39.18 | 39.93 | 40.64 | 41.34 | 42.01 | 42.66 | 43.28 | 8.25 |
| 4 | 40.89 | 41.74 | 42.55 | 43.33 | 44.08 | 44.81 | 45.51 | 46.19 | 46.84 | 47.47 | 8 |
| 4.25 | 45.40 | 46.24 | 47.06 | 47.84 | 48.59 | 49.31 | 50.00 | 50.67 | 51.31 | 51.92 | 7.75 |
| 4.50 | 50.36 | 51.19 | 51.99 | 52.75 | 53.47 | 54.16 | 54.83 | 55.46 | 56.07 | 56.65 | 7.50 |
| 4.75 | 55.83 | 56.61 | 57.36 | 58.07 | 58.74 | 59.38 | 59.99 | 60.57 | 61.13 | 61.66 | 7.25 |
| 5 | 61.81 | 62.51 | 63.18 | 63.80 | 64.40 | 64.96 | 65.49 | 66.00 | 66.48 | 66.94 | 7 |
| 5.25 | 68.31 | 68.88 | 69.43 | 69.94 | 70.42 | 70.87 | 71.30 | 71.71 | 72.10 | 72.46 | 6.75 |
| 5.50 | 75.25 | 75.66 | 76.05 | 76.41 | 76.75 | 77.07 | 77.38 | 77.66 | 77.93 | 78.18 | 6.50 |
| 5.75 | 82.53 | 82.75 | 82.95 | 83.14 | 83.31 | 83.48 | 83.64 | 83.78 | 83.92 | 84.05 | 6.25 |
| 6 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 6 |
| | 60 | 59 | 58 | 57 | 56 | 55 | 54 | 53 | 52 | 51 | |
| | VERTICAL DIAL LATITUDE | | | | | | | | | | |

NOTE: Values are degrees and tenths and hundredths of a degree. Thus latitude 39 at 1pm or 11am shows 9.57 degrees, not 9 degrees, 57 minutes. And 9.57 degrees converts to 9 degrees 34.2 minutes of arc, which is consistent with other publications.

HOUR LINE ANGLES Horizontal or vertical dial

hour angle DEGREES(ATAN(TAN(RADIANS(15*time))*SIN(RADIANS(lat))))
 hour angle $H = \text{atan}(\sin(\text{lat}) * \tan(\text{ha}))$

| HORIZONTAL DIAL LATITUDE | | | | | | | | | | | |
|--------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| TIME | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | noon |
| 0.25 | 2.41 | 2.46 | 2.51 | 2.56 | 2.61 | 2.65 | 2.70 | 2.74 | 2.79 | 2.83 | 11.75 |
| 0.50 | 4.84 | 4.94 | 5.03 | 5.13 | 5.23 | 5.32 | 5.41 | 5.50 | 5.59 | 5.67 | 11.50 |
| 0.75 | 7.29 | 7.43 | 7.58 | 7.73 | 7.87 | 8.01 | 8.14 | 8.28 | 8.41 | 8.54 | 11.25 |
| 1 | 9.77 | 9.97 | 10.16 | 10.36 | 10.54 | 10.73 | 10.91 | 11.09 | 11.26 | 11.43 | 11 |
| 1.25 | 12.31 | 12.56 | 12.80 | 13.03 | 13.27 | 13.50 | 13.72 | 13.94 | 14.16 | 14.37 | 10.75 |
| 1.50 | 14.91 | 15.20 | 15.49 | 15.77 | 16.05 | 16.32 | 16.59 | 16.85 | 17.11 | 17.36 | 10.50 |
| 1.75 | 17.59 | 17.93 | 18.26 | 18.59 | 18.91 | 19.22 | 19.53 | 19.83 | 20.13 | 20.41 | 10.25 |
| 2 | 20.36 | 20.75 | 21.12 | 21.49 | 21.85 | 22.21 | 22.55 | 22.89 | 23.22 | 23.54 | 10 |
| 2.25 | 23.24 | 23.67 | 24.09 | 24.50 | 24.90 | 25.29 | 25.67 | 26.04 | 26.41 | 26.76 | 9.75 |
| 2.50 | 26.25 | 26.72 | 27.18 | 27.62 | 28.06 | 28.48 | 28.90 | 29.30 | 29.69 | 30.08 | 9.50 |
| 2.75 | 29.41 | 29.91 | 30.40 | 30.88 | 31.35 | 31.80 | 32.25 | 32.68 | 33.09 | 33.50 | 9.25 |
| 3 | 32.73 | 33.27 | 33.79 | 34.29 | 34.79 | 35.26 | 35.73 | 36.18 | 36.62 | 37.04 | 9 |
| 3.25 | 36.24 | 36.80 | 37.34 | 37.87 | 38.38 | 38.88 | 39.36 | 39.83 | 40.28 | 40.71 | 8.75 |
| 3.50 | 39.95 | 40.53 | 41.09 | 41.63 | 42.15 | 42.66 | 43.15 | 43.62 | 44.08 | 44.53 | 8.50 |
| 3.75 | 43.89 | 44.48 | 45.04 | 45.59 | 46.11 | 46.62 | 47.11 | 47.58 | 48.04 | 48.48 | 8.25 |
| 4 | 48.07 | 48.65 | 49.21 | 49.75 | 50.27 | 50.77 | 51.25 | 51.71 | 52.16 | 52.58 | 8 |
| 4.25 | 52.50 | 53.07 | 53.61 | 54.13 | 54.63 | 55.11 | 55.57 | 56.01 | 56.43 | 56.84 | 7.75 |
| 4.50 | 57.20 | 57.73 | 58.24 | 58.73 | 59.19 | 59.64 | 60.07 | 60.47 | 60.87 | 61.24 | 7.50 |
| 4.75 | 62.16 | 62.64 | 63.10 | 63.54 | 63.96 | 64.36 | 64.74 | 65.10 | 65.45 | 65.78 | 7.25 |
| 5 | 67.37 | 67.78 | 68.18 | 68.55 | 68.91 | 69.25 | 69.57 | 69.88 | 70.17 | 70.45 | 7 |
| 5.25 | 72.81 | 73.13 | 73.44 | 73.74 | 74.02 | 74.29 | 74.54 | 74.78 | 75.02 | 75.23 | 6.75 |
| 5.50 | 78.43 | 78.65 | 78.87 | 79.07 | 79.27 | 79.45 | 79.63 | 79.80 | 79.95 | 80.10 | 6.50 |
| 5.75 | 84.18 | 84.29 | 84.41 | 84.51 | 84.61 | 84.70 | 84.79 | 84.88 | 84.96 | 85.04 | 6.25 |
| 6 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 6 |
| VERTICAL DIAL LATITUDE | | | | | | | | | | | |
| | 50 | 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | |

A3.1 c

HOUR LINE ANGLES Horizontal or vertical dial

hour angle DEGREES(ATAN(TAN(RADIANS(15*time))*SIN(RADIANS(lat))))
 hour angle H = atan (sin(lat) * tan (ha))

| HORIZONTAL DIAL LATITUDE | | | | | | | | | | | |
|--------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| TIME | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | noon |
| 0.25 | 2.87 | 2.92 | 2.96 | 3.00 | 3.04 | 3.07 | 3.11 | 3.15 | 3.18 | 3.22 | 11.75 |
| 0.50 | 5.76 | 5.84 | 5.92 | 6.00 | 6.08 | 6.16 | 6.23 | 6.30 | 6.37 | 6.44 | 11.50 |
| 0.75 | 8.66 | 8.79 | 8.91 | 9.03 | 9.14 | 9.25 | 9.36 | 9.47 | 9.57 | 9.68 | 11.25 |
| 1 | 11.60 | 11.76 | 11.92 | 12.08 | 12.23 | 12.38 | 12.52 | 12.67 | 12.80 | 12.94 | 11 |
| 1.25 | 14.58 | 14.78 | 14.98 | 15.17 | 15.36 | 15.54 | 15.72 | 15.89 | 16.06 | 16.22 | 10.75 |
| 1.50 | 17.60 | 17.84 | 18.08 | 18.30 | 18.53 | 18.74 | 18.95 | 19.16 | 19.35 | 19.55 | 10.50 |
| 1.75 | 20.70 | 20.97 | 21.24 | 21.50 | 21.75 | 22.00 | 22.24 | 22.47 | 22.70 | 22.91 | 10.25 |
| 2 | 23.86 | 24.17 | 24.46 | 24.75 | 25.04 | 25.31 | 25.58 | 25.84 | 26.09 | 26.33 | 10 |
| 2.25 | 27.11 | 27.44 | 27.77 | 28.09 | 28.39 | 28.69 | 28.98 | 29.27 | 29.54 | 29.80 | 9.75 |
| 2.50 | 30.45 | 30.81 | 31.16 | 31.50 | 31.83 | 32.15 | 32.46 | 32.76 | 33.05 | 33.33 | 9.50 |
| 2.75 | 33.89 | 34.28 | 34.65 | 35.01 | 35.36 | 35.69 | 36.02 | 36.33 | 36.64 | 36.93 | 9.25 |
| 3 | 37.45 | 37.85 | 38.24 | 38.61 | 38.97 | 39.32 | 39.66 | 39.99 | 40.30 | 40.60 | 9 |
| 3.25 | 41.14 | 41.55 | 41.94 | 42.32 | 42.69 | 43.05 | 43.39 | 43.72 | 44.04 | 44.35 | 8.75 |
| 3.50 | 44.95 | 45.36 | 45.76 | 46.15 | 46.51 | 46.87 | 47.21 | 47.54 | 47.86 | 48.17 | 8.50 |
| 3.75 | 48.90 | 49.31 | 49.70 | 50.08 | 50.45 | 50.80 | 51.13 | 51.46 | 51.77 | 52.06 | 8.25 |
| 4 | 53.00 | 53.39 | 53.77 | 54.14 | 54.49 | 54.82 | 55.15 | 55.46 | 55.75 | 56.04 | 8 |
| 4.25 | 57.23 | 57.60 | 57.96 | 58.31 | 58.64 | 58.95 | 59.25 | 59.54 | 59.82 | 60.09 | 7.75 |
| 4.50 | 61.60 | 61.94 | 62.27 | 62.59 | 62.89 | 63.18 | 63.45 | 63.72 | 63.97 | 64.21 | 7.50 |
| 4.75 | 66.10 | 66.40 | 66.69 | 66.97 | 67.24 | 67.49 | 67.73 | 67.96 | 68.18 | 68.40 | 7.25 |
| 5 | 70.72 | 70.98 | 71.22 | 71.45 | 71.67 | 71.89 | 72.09 | 72.28 | 72.47 | 72.64 | 7 |
| 5.25 | 75.44 | 75.64 | 75.83 | 76.01 | 76.19 | 76.35 | 76.51 | 76.66 | 76.80 | 76.94 | 6.75 |
| 5.50 | 80.25 | 80.39 | 80.52 | 80.64 | 80.76 | 80.87 | 80.98 | 81.08 | 81.18 | 81.27 | 6.50 |
| 5.75 | 85.11 | 85.18 | 85.25 | 85.31 | 85.37 | 85.43 | 85.48 | 85.53 | 85.58 | 85.63 | 6.25 |
| 6 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 90.00 | 6 |
| VERTICAL DIAL LATITUDE | | | | | | | | | | | |
| | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | |