Adjusting A Horizontal Sundial For Standard Time

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Do you own a nice horizontal dial, and would like to orient it so that it approximates Standard Time, rather than reading Local Solar Time? This article describes a method for setting a horizontal dial to read solar time for the meridian of your time zone, even if the dial is designed for a different latitude than yours. This means that, after correcting for the equation of time, your dial will tell Standard (watch) Time; and on the 4 days of the year that the equation of time equals zero, the dial will read Standard Time directly. The method involves setting 3 screws in the pedestal (or any supporting surface) at proper heights to mimic the plane of your time zone meridian. The calculations can be made using a hand held calculator with trigonometric functions. The derivation of these formulas follows thereafter, for those who are interested in the mathematics of this method.

<u>The Method</u>

Determine the true North/South meridian by the solar noon method or by compass (correcting for magnetic deviation from true north). Place 2 roundhead screws, 20 threads per inch, on the north/south meridian, separated by distance D (Distance D is determined by you. It should be a little less than the diameter of your sundial, if round, or a little less than the shortest dimension if rectangular). Screw number 1 is your reference height. A third screw is placed eastward of the midpoint between screws 1 and 2 by a distance equal to D/2, as seen in figure 1. Using a level, all three screws are initially adjusted to the same height. Then screw number 2 is adjusted higher or lower than screw number 1 as determined by the following formula

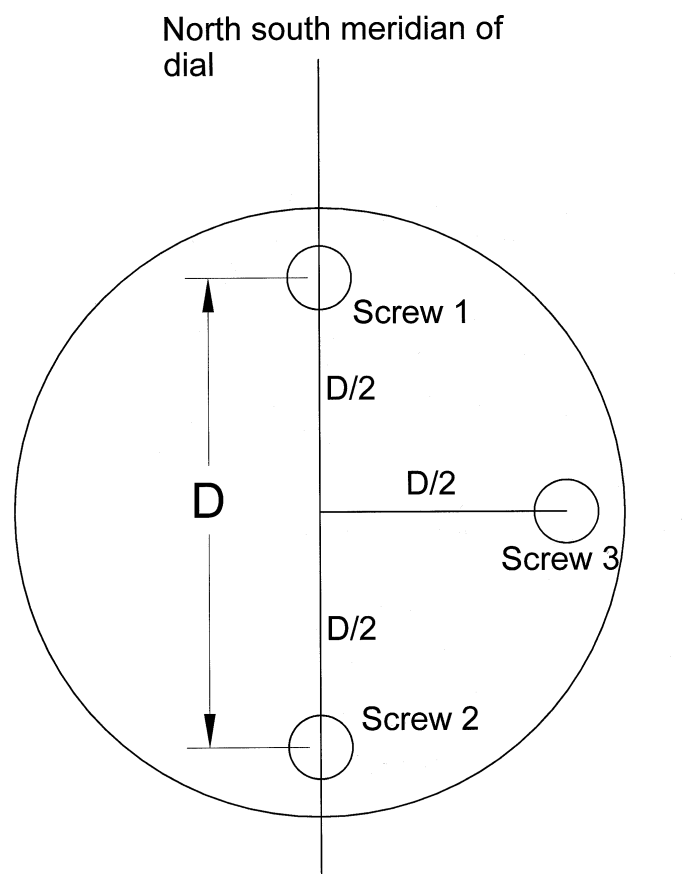


Figure 1

Height of Screw 2 above Screw 1 =D*Tan(R2+Ld-Li)

Likewise, the height of screw 3 is calculated as:

Height of Screw 3 above Screw 1 = 0.5*D*Tan(R3+Ld-Li)

Where:

Ld= Latitude for which dial was designed
Li=Latitude of Installation
T=Longitude at installation-Longitude of time zone meridian.
A=ArcSin[Sin^2 Ld + Cos^2 Ld *Cos T]
Q=ArcTan[-Sin Ld * Tan T/2]
R2=ArcTan[ABS(Sin Q /Tan A)]
R3=ArcTan[(ABS(Q)/Q)*SQRT(2)*Sin(45+Q)/Tan A]

It should be easy to achieve excellent accuracy in setting these heights, knowing that each rotation of a 20 pitch screw equals 0.05 inches. Note that roundhead screws, or roundhead allen bolts, are preferable to hex-bolts, in that hex-bolts will introduce minor errors depending on what part of their hexagonal top the dial makes contact with.

It is likely that one edge of the dial will dip too low to allow the dial to seat properly on the new plane defined by these three screws, or that the dial may rest too high. The remedy is to raise or lower all screws the same amount, *e.g.* the same number of turns each, until the lowest part of the dial just touches the base. In this manner, the new orientation is preserved.

As a final step, the dial must be rotated in its new plane until it reads the solar time for your time zone meridian, and you're done. The solar time for your time zone meridian is the Standard time corrected for the equation of time, *e.g.* on November 1st add 16 minutes to Standard Time to get the solar time for your time zone meridian (If you set the dial on Sept 1, December 25, April 15, or June 13, then you do not need to make an adjustment for the Equation of Time). To read Standard time off of your dial, you will still have to correct for the equation of time.

Derivation

The steps involved in this derivation are:
1) Use spherical trigonometry to calculate the Altitude and Azimuth of an imaginary rod, perpendicular to the dial plate, after the dial has been rotated along the polar axis an amount equal to its longitudinal distance from the time zone meridian.
2) From this imaginary rod, it is simple to calculate the slope and azimuth of a wedge to be placed under the dial to convert it to standard time.
3) Calculate how tall each of the Screws need to be to mimic this wedge, since really we are making this correction with screws, and not a wedge.
4) Finally, make a correction which allows a dial made for any latitude to be used at the users' latitude.
Details of each step now follow:

Step 1.

Subtract the longitude of the appropriate time zone meridian (75 for EST, 90 for CST, 105 for MST, and 120 for PST) from the longitude at the site of installation. If this angle is positive, then Standard time is faster than Local Solar time. If negative, then Standard time is slower than Local Solar time. Call this angle T.

T = Longitude at installation-Longitude of time zone meridian.

The dial will be rotated along the polar axis (the upper edge of the gnomon) an amount equal to T (Figure 2). The change in the orientation of the dial's plate is best described by imagining the tilt of a rod arising perpendicular to that plate. Before the adjustment, the rod's altitude (A) is 90 degrees, and its azimuth (Z) is unmeasurable. After the adjustment, the rod's altitude and azimuth will tell us exactly how the dial

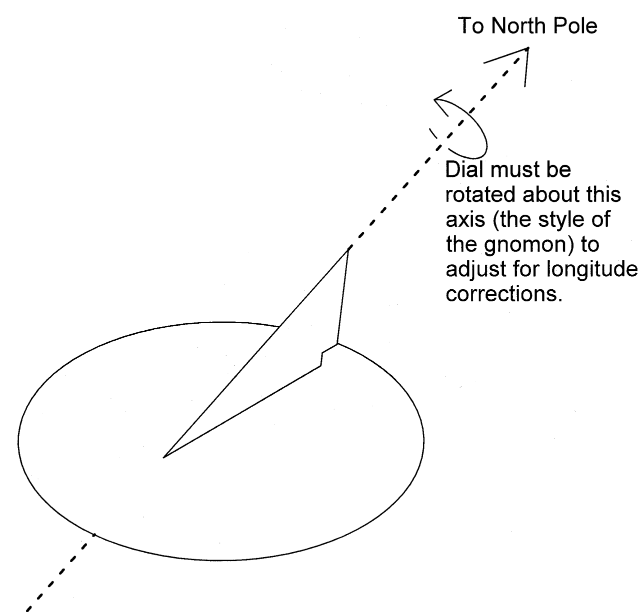


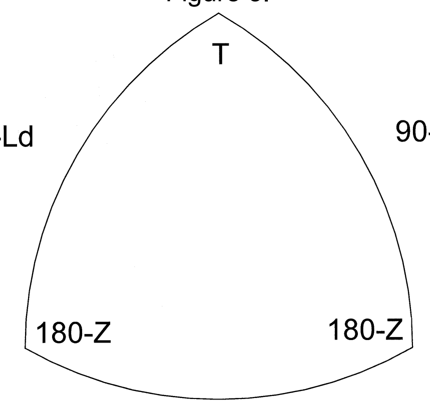
Figure 2

plate is now oriented in space (Figure 4). The pertinent spherical triangle construction is shown in figure 3. This is an isosceles spherical triangle, allowing us to solve for Sin(A) and Tan(Z) as follows:

$$Sin(A) = Sin^2(Ld) + Cos^2(Ld)*Cos(T)$$

$$Tan(180-Z) = 1/[Sin(Ld)*Tan(T/2)]$$

Figure 3.



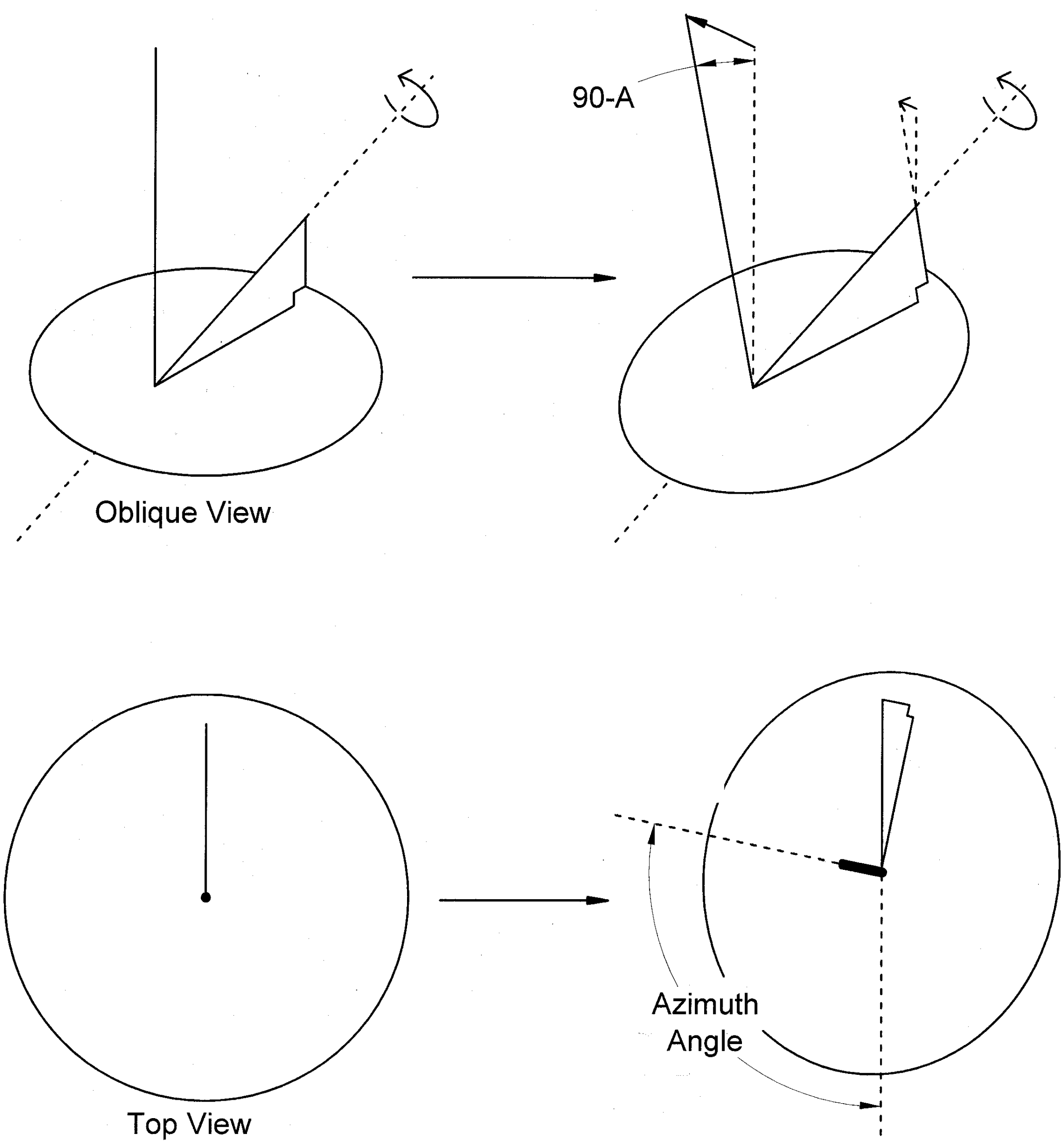
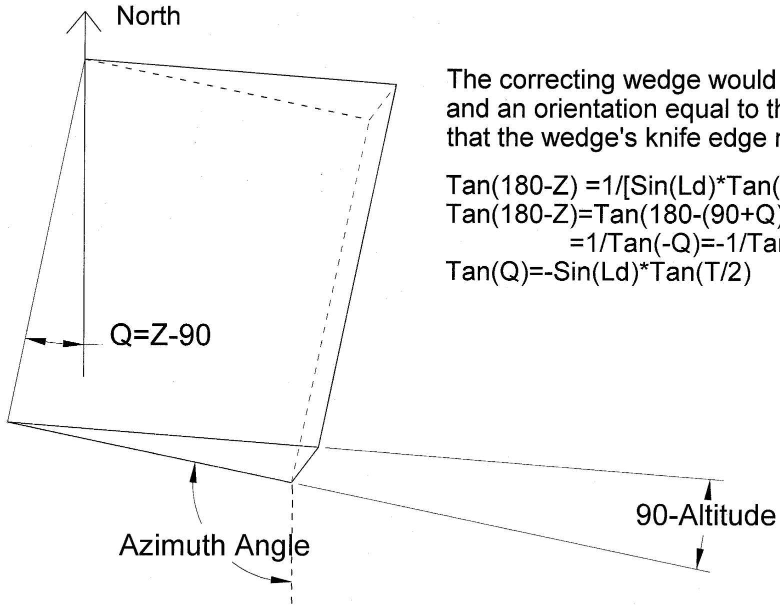


Figure 4



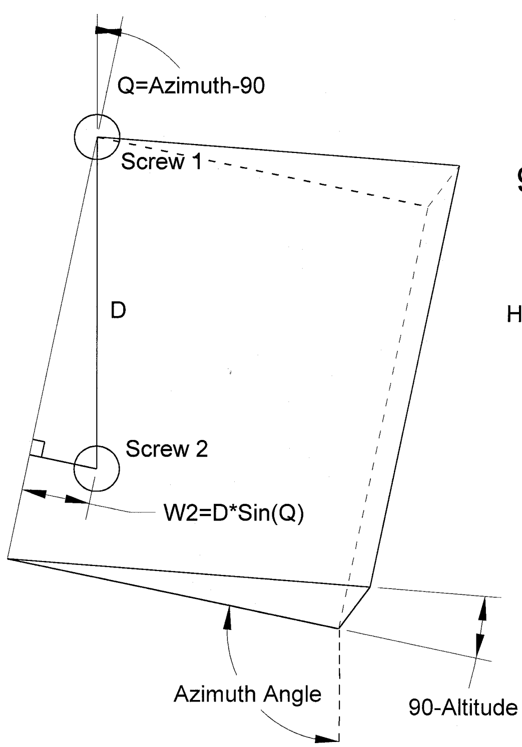
The correcting wedge would have an incline equal to 90-Altitude, and an orientation equal to the Azimuth Angle (Z). Q is the angle that the wedge's knife edge makes with the meridian.

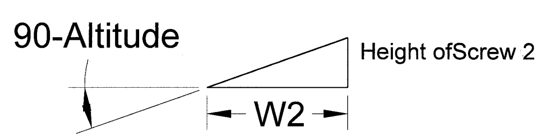
Tan(180-Z) =1/[Sin(Ld)*Tan(T/2)]
Tan(180-Z)=Tan(180-(90+Q))=Tan(90-(-Q))
=1/Tan(-Q)=-1/Tan(Q)
Tan(Q)=-Sin(Ld)*Tan(T/2)

Figure 5.

Step 2.

This is easy. 90-A defines the slope, and Z defines the azimuth orientation, of a wedge which would reposition the dial to the desired orientation. Angle Q is defined as the angle that the knife edge of the wedge makes with the meridian: Q=Z-90. This is shown in figure 5. Angle Q will be necessary for determining the heights of the screws.





Height of Screw 2 = Height of Screw 1 +ABS[W2*Tan(90-A)]
=Height of Screw 1 + ABS[W2/Tan(A)]
=Height of Screw 1 + ABS[D*Sin(Q)/Tan(A)]

Figure 6.

Step 3.

Height of Screw 2 can now be calculated by the formula in Figure 6, and the height of Screw 3 can be calculated by the formula in Figure 7. W2 and W3 are distances measured along the bottom of the wedge, perpendicular to its knife edge. [The inclusion of the ABS (absolute value) function is to make sure that the sign of the answer is correct. At this point in the construction, the height of Screw 2 is always positive (always taller than Screw 1). Screw 3 is taller than Screw 1 when Q is positive, and shorter than Screw 1 when Q is negative. This awkward correction is necessary in this construction because the wedge changes its direction by 180 degrees when Q goes from positive to negative.]

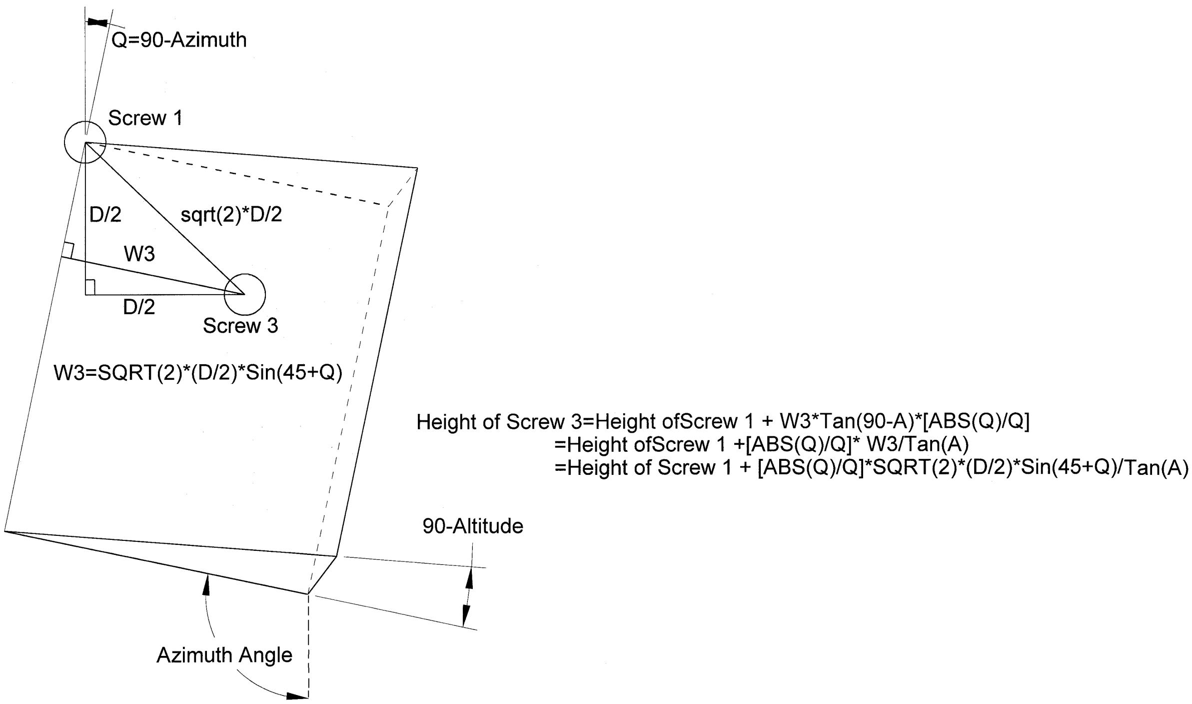


Figure 7.

Step 4.

If the Dial is designed for the users' latitude, then we are done. In most cases, however, the dial will have been designed for a different latitude. A correction is made by sliding an imaginary "Latitude correcting wedge" (figures 8 and 9) under the Altitude/Azimuth wedge that we just solved, and then recalculating the heights of Screws 2 and 3. The Latitude correcting wedge is aligned with its knife-edge running East/West along the north side of the wedge, and with a slope equal to the Latitude of the dial's design (Ld) minus the Latitude of installation (Li). As an intermediate step in this construction, we must determine R3, a wedge angle originating at an East/West meridian passing through screw 1, and passing directly south through Screw 3 (see figure 8). Similarly, R2 is a wedge angle originating at an East/West meridian passing through screw 1, and passing directly south through Screw 2. The remainder of the construction is shown in figure 9. Note that after this final step, Screw 2 may be lower than Screw 1, if the dial is being used at a location of higher latitude than for which it was designed.

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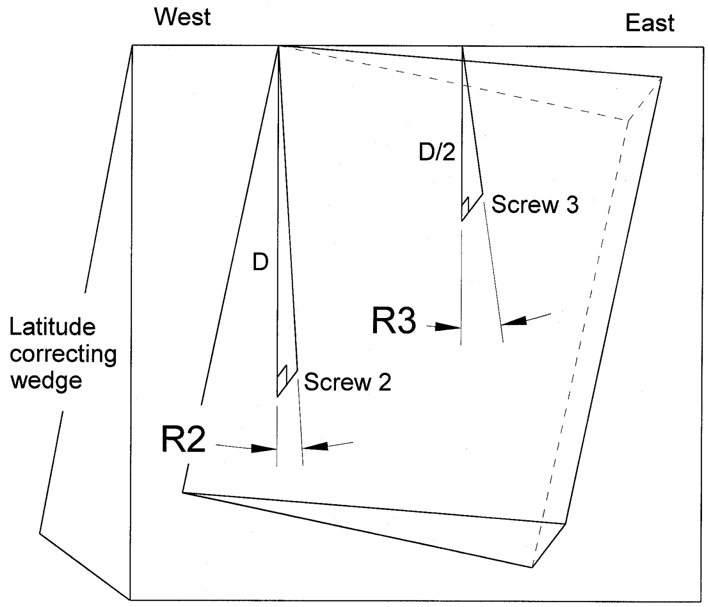
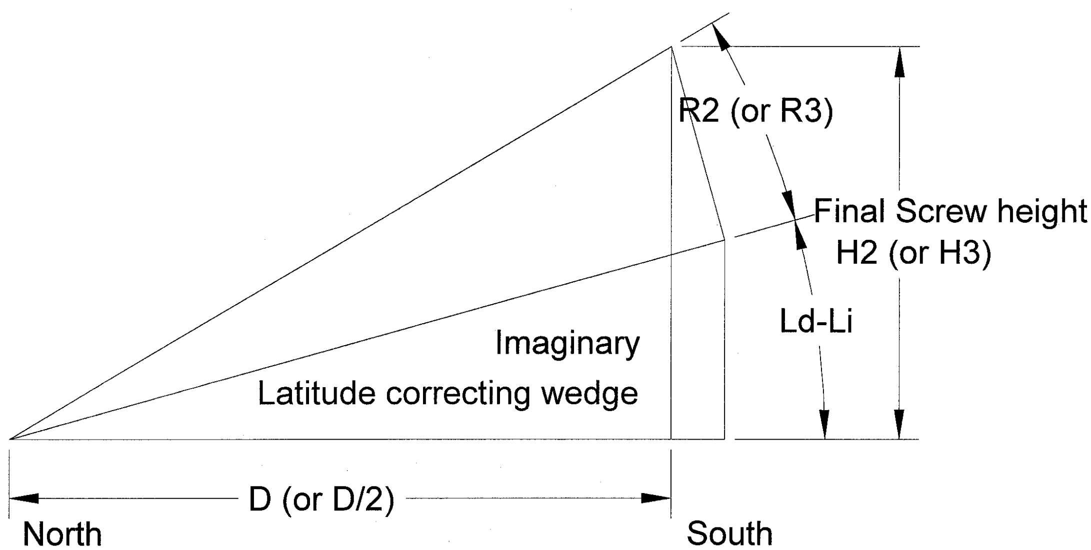
Figure 8.



Tan R2=H2/D=ABS[Sin(Q)/Tan(A)]

Tan R3=H3/(D/2)=[ABS(Q)/Q]*SQRT(2)*Sin(45+Q)/Tan(A)

H2 is the height of screw 2 above screw 1, and H3 is the height of screw 3 above screw 1.



Height of Screw 2 above Screw 1=D*Tan(R2+Ld-Li)

Height of Screw 3 above Screw 1=0.5*D*Tan(R3+Ld-Li)

Figure 9.