June 23, 2006

A CUBE DIAL ON A COLUMN

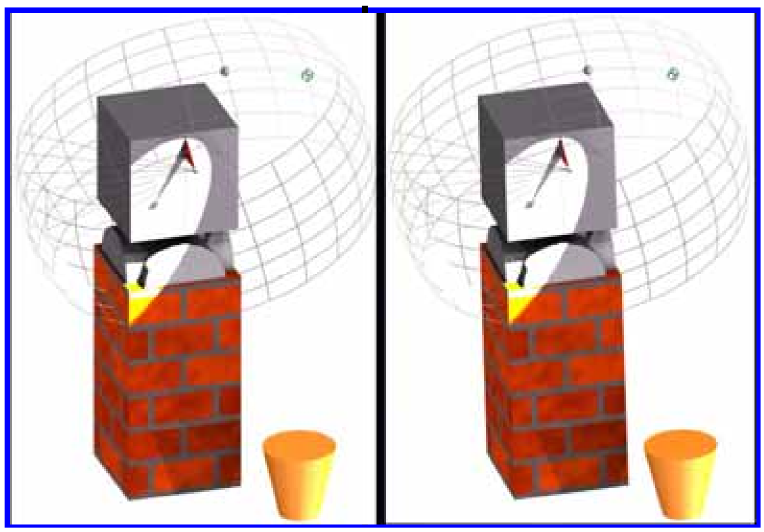
Many years ago, I lived with a lovely cube dial on a pedestal, and the time had come to recreate it as best I could.

In the background of the picture used as the cover for the book ILLUSTRATING SHADOWS is the old dial. It stood towards the east of our lawn, its gnomons were missing however the remains of the hour lines were visible.

This dial will be for Silver City, NM, whose coordinates are:

location lat:	32.75° N
location long:	108.2° W
magnetic declination:	10.6° E

Using TurboCAD 11, a model of the dial was built, only a south facing gnomon was shown, and the solar mesh used for detecting the sun's shadow at any date and time was added. The 3d stereogram shows the shadow at 10 o'clock for latitude 33, not corrected for longitude nor the equation of time.



A location was selected, and then a square base area was dug, not too deep, and the base made to parallel the road and wooden picket fence. This would mean that all dial plates would be decliners because the road was not aligned with true north.

The photo is taken from the east looking only slightly north of west.

In this supplement, SD (style distance) and style height (SH) are the angular measures for vertical declining dials.

PEDESTAL

DAY 1: The square base area is shown, and was in fact dug down a little deeper, then a concrete base was poured, but no rebar was used. While a magnetic compass would probably not be used for determining the cube's declination, there seemed little point in placing iron there.

The alignment with the road was done by first verifying that the picket fence paralleled the road, and then that the base paralleled the picket fence.

Concrete was poured and a layer of blocks positioned and set level. Alignment was ensured by using a string paralleling the picket fence, and touching the blocks visible in the picture. All in all four courses were added, and the top course had a mesh inserted in the four holes of those two upper blocks, and some concrete poured in filling the holes about half way up. Then all was allowed to set.

Those holes would be used when the rest of the column was added.

DAY 2: The column was built. This used 8 of the 8 by 8 by 16 inch concrete block, and a sack of mortar.

DAY 3: An 8 by 8 by 8 inch block was added along with some decorative mortar work.

And a 4 inch 12 by 12 inch capping block was then added.

This capping block would allow mortar or concrete to secure the 8 by 8 by 8 and the 4 inch tall 12 by 12 and be a firm base for the last 4 blocks that would form the cube that would rest on this column.

Because of the holes in the block and because of the layering, some wood was used to stop the mortar or concrete from seeping out, which in no way reducing the strength of the column.

Again, no rebar was used.

The decorative mortar work has radials on it, they are to make the column more interesting, and to deflect the eye from certain unevenness.

DAY 4: The cube itself was assembled on the column. The top four blocks were predrilled with a concrete bit, each hole being 1.5 inches from the top or bottom, and the side. These holes could be later used to affix the dial plates, each of which would be a little larger than one square foot.

Also, wood dowels were used in the mud used to affix the top cube, this would add to lateral and torsional strength wile avoiding metal rebar. Since those dowels would be completely encased, the chance for rot was substantially reduced.

The cube has four faces that are predominantly north, south, east, and west. The top could be used but giants are few and far between, so the more visible faces will only be used.

The street was not true north aligned nor was the pedestal, and the cube was off a bit as well.

So the next step was the determination of the south facing vertical surface's declination.

And then what medium would be used for the dial plate.

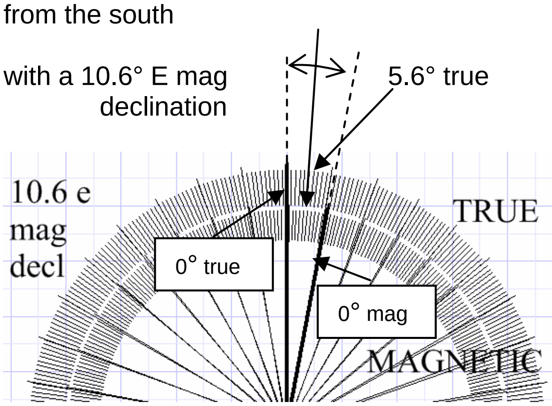
And then get on and do it!

ALIGNMENT

DAY 5: The alignment of the cube must be measured. There are several techniques. One takes all day and measures the intersection of the sun's shadow on some circles. Another measures the sun's azimuth several times and uses an accurate clock. Another uses the astrocompass. And many people use a magnetic compass. Because there was no rebar, a Brunton surveyor's compass was used. The method used was to position oneself south of the cube, and aligned such that the east face was just no longer visible, then a bearing taken of the east edge of the south facing surface of the cube. It measured 355°. The process was repeated for the east and the west alignments, they were 265° and 085° so they agreed. This was not done for the north facing surface as a car would have upset the magnetic field. Since three of the faces all agreed and the observer was a distance of about 20 feet from the dial, this reading would probably be accurate.

South facing surface: 355° magnetic
from the south

with a 10.6° E mag
declination

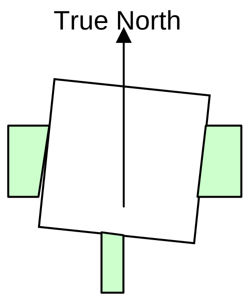


0° magnetic is	10.6 true
355° magnetic is	365.6 true
which is also	5.6 true

location lat:	108.2° W
location long:	32.75° N
magnetic declination: (variation)	10.6° E

SOUTH FACING DIAL PLATE

DAY 6: We have determined that the south facing surface is south 5.6° west. This is a declining vertical dial, and the formulae give us hour lines, a style distance and a style height. Style distance is the distance the gnomon is rotated from the vertical, and style height is the angle the style of the gnomon makes with the vertical.



gnomon for the west facing dial, and dial center is south

gnomon for the east facing dial, and dial center is north

Drawing pictures of what is logical will help avoid mistakes and will make sense of the numbers you calculate for SH, SH, and hour line angles

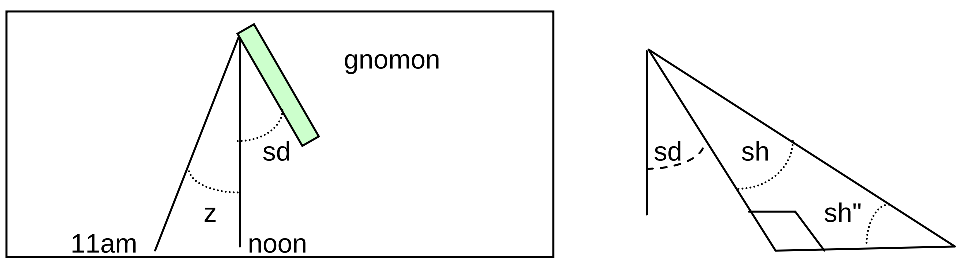
The formulae for south decliners are:-

The hour line angles are based on: z = atan(cos(lat)/(cos(dec) cot(ha) + sin(dec) sin(lat))

Gnomon rotation or slewing is optional and if used employs the following formula:-

Gnomon offset from vertical is: **sd** = atan(sin(dec) / tan(lat)) **Style Distance**

Style and sub style angle is: **sh** = asin(cos(lat) * cos(dec)) **Style Height**



However, the reference-spreadsheets.xls file allows us to calculate these results.

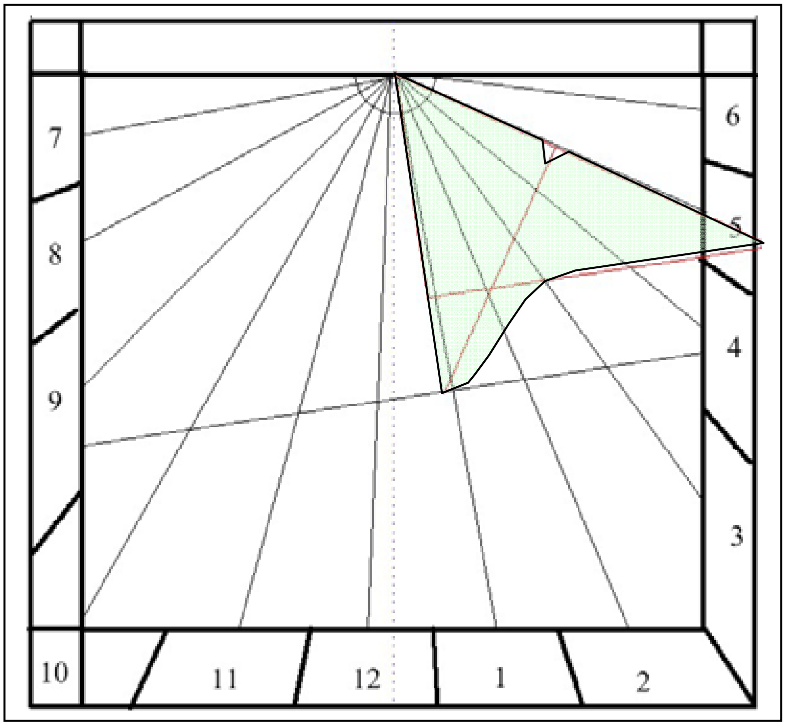
The spreadsheet needs to consider longitude differences between the location and the legal meridian. While horizontal dials tend to be portable, a vertical declining dial is obviously tailored, this the final dial plate should also be tailored.

Note that while the angles of hour lines change when the longitude is considered, the style distance (SD) does not.

The hour line angles can be readily checked against the SHADOWS software, and the style distance SD, similarly. The style height in SHADOWS requires a conversion from linear dimensions to trigonometric to angular. They were within less than a degree. When using SHADOWS software remember to display the dial data with the longitude correction.

Hour line angles from vertical.

TIME	DEC SxxW
hh.mm	5.6
6.00	82.9
7.00	-79.3
8.00	-61.6
9.00	-44.9
10.00	-29.6
11.00	-15.6
12.00	-2.5
13.00	10.1
14.00	22.7
15.00	36.0
16.00	50.3
17.00	65.9
18.00	82.9
STYLE:SD	8.6
STYLE:SH	56.8



The dial plate was made from cardboard first and checked throughout the day.

Two sets of hours lines are seen. One is the hour lines assuming no longitude correction, the other took longitude into account.

An equinox line was drawn where it would look appropriate, and where it would be helpful holding the gnomon, the gnomon would be a copper sheet, the dial plate would be opalescent glass that would show a good shadow.

It being accurate, the final dial plate was then made from permanent materials, in this case, glass and copper.

This dial could add calendar lines, and Italian lines to effect, however, it was decided to have a larger gnomon, with a nodus notch for the equinox, and leave it there. Other dials in the series would provide calendar information.

DAY 7: The actual glass plate is constructed.

An iridescent white glass was used for the dial plate, it showed a good shadow, and the shadow reflection was tested at many angles.

Only one hour line was identified, noon.

The segments were assembled with 1/4 inch copper foiled, soldered, and copper plated. The border was 1/4 inch copper tube.

The dial plate was affixed using an adhesive suitable for tile and concrete block.

One piece of glass was not cut as well as I normally cut them. No excuse for it, but since this was a textured iridescent glass, a new piece would have upset the look. The technique was to add a brass dragonfly to distract the eye from the hour line being slightly offset. It can be seen on the 10 am hour line just above the equatorial line.

The lead lines on the file cannot be a thick as is often done because they themselves can cause shadows.

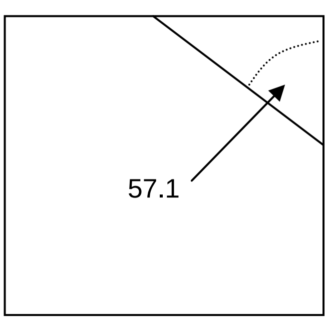
Another distracter for the eye was added on the lower right corner, a glass jewel. Similarly a glass jewel was added where the hour lines converge. Care must be taken that such a jewel does not confuse the hour line shadow.

DAY 8: EAST FACING DIAL PLATE

Just as the south facing plate was a decliner, so also is the east and the west facing plate, in this case it is a great decliner. Again, no calendar lines would be designed in since the object is to emulate a cube dial from ones youth.

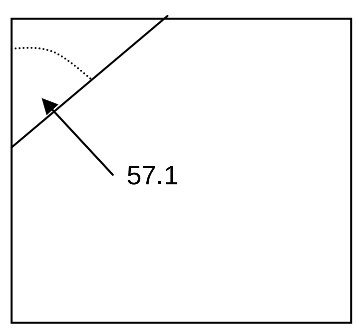
Since the south dial was S 5.6 W, the west facing dial would be S 95.6 W, which is more than 90 degrees. It is also North 84.4 West. It uses the same spreadsheet as would be used for S 84.4 E.

Using S 84.4 E in the reference-spreadsheets, and using the S...E column, the style distance (SD) is found to be –57.1 degrees.



West facing ←

East facing →



And as a double check for reasonableness, the angle from horizontal should be close to latitude for a great decliner such as this. And 90-57.1 is 32.9, so the SD seems reasonable.

Longitude corrected

Legal hh.hh	LAT hh.hh	-DEC S84,4E
		-84.4
6.00	5.8	-57.6
7.00	6.8	-56.4
8.00	7.8	-55.0
9.00	8.8	-53.3
10.00	9.8	-50.7
11.00	10.8	-45.1
12.00	11.8	-19.3
13.00	12.8	-84.6
14.00	13.8	-67.6
15.00	14.8	-62.9
16.00	15.8	-60.5
17.00	16.8	-58.9
18.00	17.8	-57.6
	SD	-57.1
	SH	4.7

The style height is 4.7 degrees, so the style will look something like...

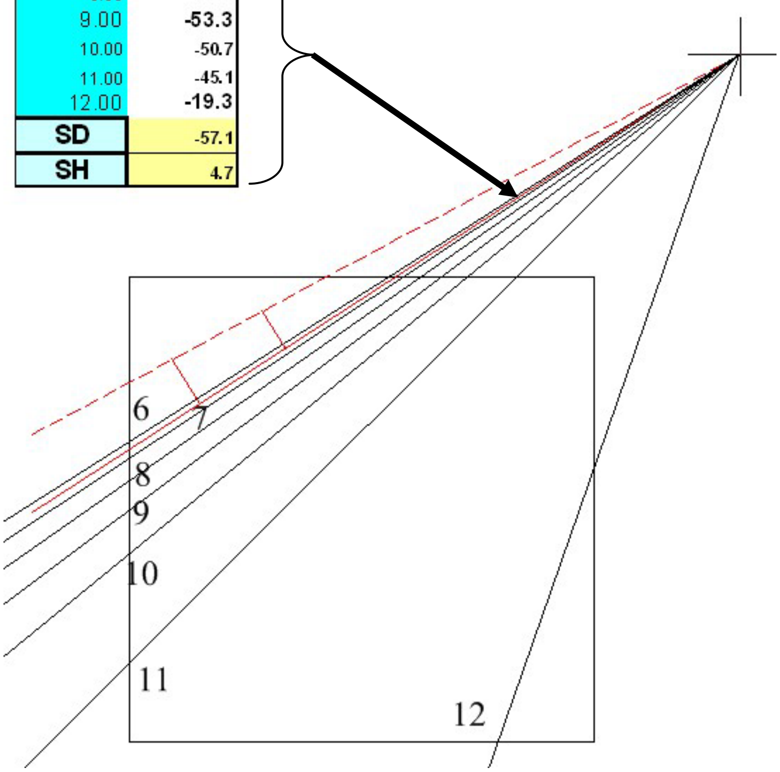
east facing   west facing

And a reasonableness check for a great decliner such as this would be that this should be close to the dial's declination from south. And 4.7 degrees is close to the 5.6 declination, so this looks reasonable.

The SD and SH reasonableness checks are for great decliners just a bit off from the cardinal points.

When the SOUTH FACING DIAL was shown from above, the orientation of the gnomons was drawn. This helps orient which gnomon goes where, and, where the dial centers are for the east and west dials are. The dial center is where the extended style of the gnomon eventually meets the extended dial plate.

TIME hh.mm	-DEC SxxE
	-84.4
6.00	-57.6
7.00	-56.4
8.00	-55.0
9.00	-53.3
10.00	-50.7
11.00	-45.1
12.00	-19.3
SD	-57.1
SH	4.7



The third step is to derive the hour lines themselves. Since this is a great decliner, the hour lines will be angled with a convergence point some distance from the dial itself. Pure east and west dials have hour lines that are parallel.

TurboCAD was used to draw the hour lines, and a square around a usable area, and even the style was drawn by projecting it, i.e. rotating it by 90 degrees so it was flat on the dial plate. The biggest problem is figuring out how to tell TurboCAD OPTIONS, ANGLE to work.

DAY 9: WEST FACING DIAL PLATE

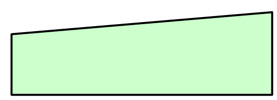
The west facing dial uses the S 84.4 E figures except for the lower column, covering noon to 6pm.

Longitude corrected

Legal hh.hh	LAT hh.hh	-DEC S84,4E -84.4
6.00	5.8	-57.6
7.00	6.8	-56.4
8.00	7.8	-55.0
9.00	8.8	-53.3
10.00	9.8	-50.7
11.00	10.8	-45.1
12.00	11.8	-19.3
13.00	12.8	-84.6
14.00	13.8	-67.6
15.00	14.8	-62.9
16.00	15.8	-60.5
17.00	16.8	-58.9
18.00	17.8	-57.6
	SD	-57.1
	SH	4.7

The –19.3 means "the other side of horizontal " compared to the other hour line angles.

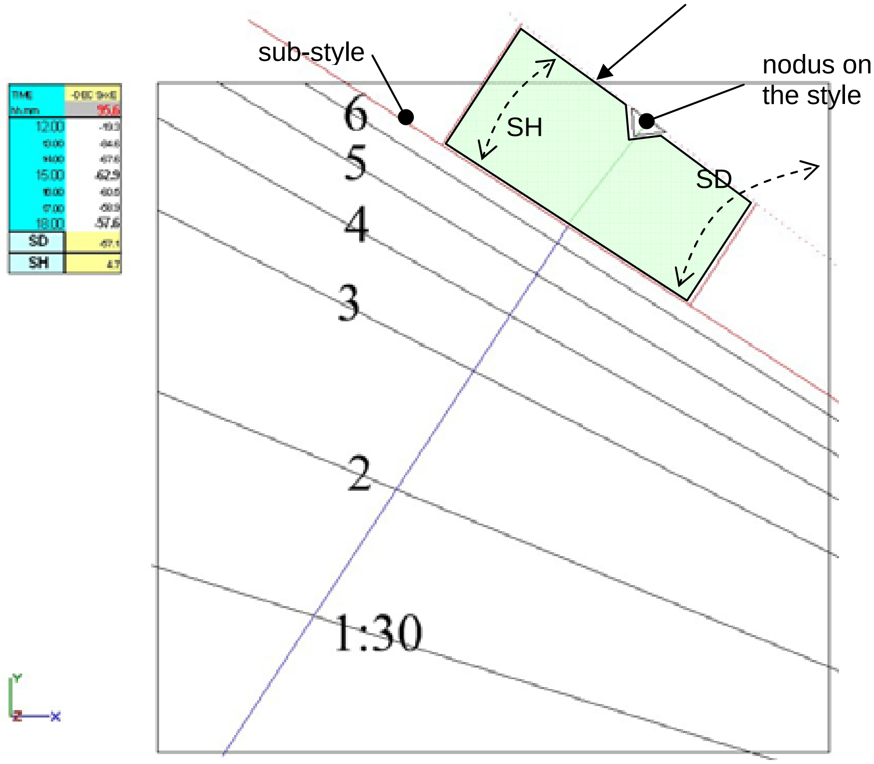
The style height is 4.7 degrees, so the style will look something like...



west facing

Again, the spreadsheet hour angles become angled lines on a sheet of paper.

The style is easily drawn as a rotated projection of a style.

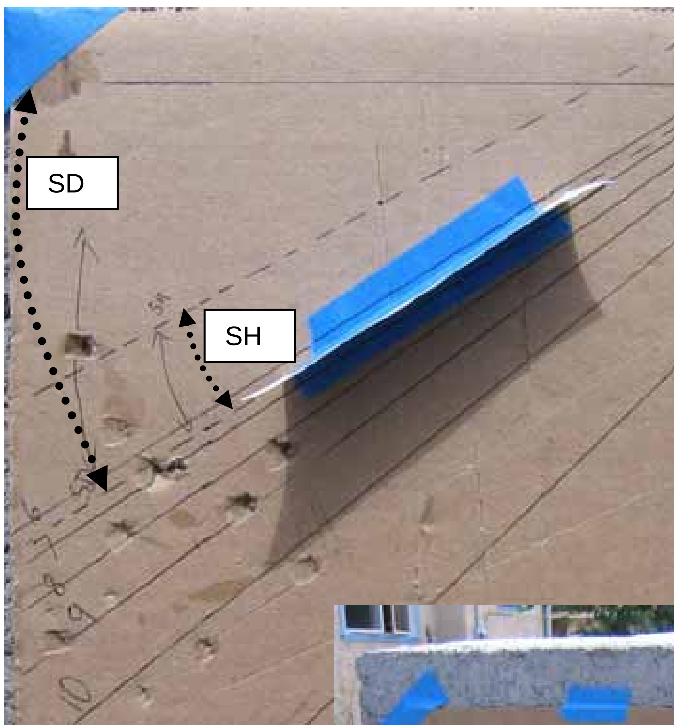


Having drafted the lines for the hours, and the style distance (SD) and style height (SH), they are printed out. While TurboCAD was used, any low cost drafting package could have been used.

After the lines were drafted, then a surrounding box was placed where the dial plate looked more satisfying.

Then, the print out is placed on a cardboard mockup, in the middle of it, and every line drawn to extend over the cardboard, remembering to use a different color for the SD and SH, Of course a leveling line should be included.

Then the cardboard dial plates are placed on the dial vertical surfaces.



The east facing cardboard dial plate tacked on the actual dial, and how the gnomon was built is easily shown.

The west facing cardboard dial plate is tacked up and ready for testing.

When the cardboard dial plates are validated, then they will be converted to the final materials, namely glass and copper.

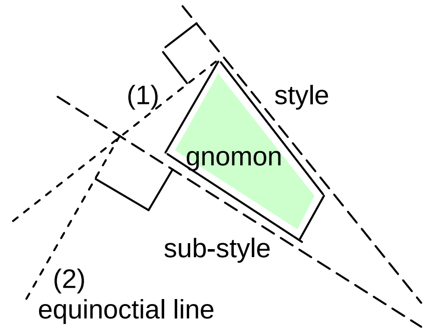
A large flower pot or other similar impediment to walking too close to the gnomons is a good idea. This protects the gnomons as well as the arms of itinerant passers by.

While these dial plates are not made to display calendar lines, there is some benefit to the equinoctial line. If desired, the equinoctial line can be drawn easily. It is perpendicular to the sub-style line, which was drawn using SD. It's distance from the selected nodus is determined by projection and geometry, or by simple trigonometry.

An exaggerated view of the gnomon is shown to the right.

The equinox range of movement of the sun is on a disk perpendicular to the style. A line is drawn perpendicular from the style until it intercepts the sub-style, see (1).

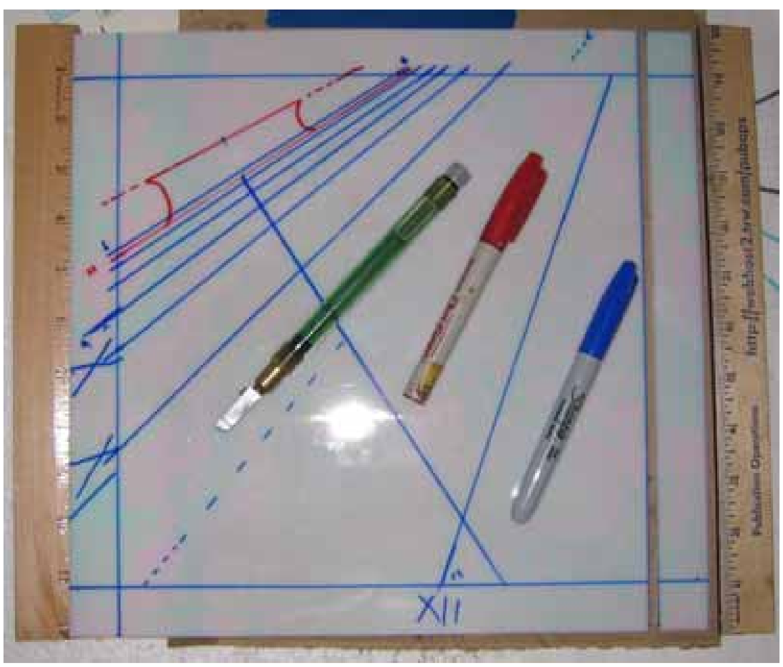
Then, perpendicular to the sub-style (2) from that point of intersection, is drawn the equinoctial line.



With glass and copper dial plates, that equinoctial line can be helpful as an additional anchor for the gnomon. When equinoctial lines exist, then obviously there must be a nodus. While for a predominantly east or west dial, one edge of the gnomon can be used, for a south facing dial plate, in order to have a long shadow, the style may be considerably longer than normal, thus the style might need a nodus somewhere along the style. If an equinoctial line is drawn first, at a place that is aesthetically pleasing, reversing the above process will locate the required nous.

DAY 10: FINAL DIAL PLATE CONSTRUCTION

As before, an iridescent glass that shows the shadows clearly would be used, 1/4 inch copper foil, and the final plate would be affixed with a tile adhesive.



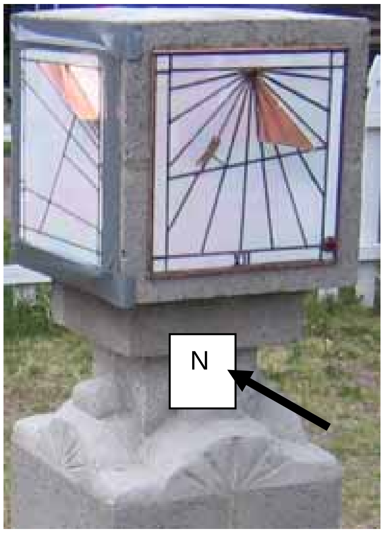
And for the final dial plate, the print out is placed on the glass plate, in the middle of it, and every line drawn to extend over the cardboard, remembering to use a different color for the SD and SH, Of course a leveling line should be included.

The glass was cut and foiled. Because some glass pieces were rather small, 7/32 and 3/16 foil was also used.

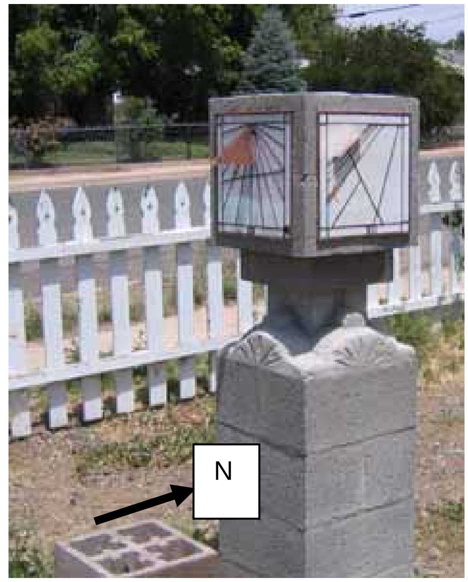
Always pick glass that will show the shadow from usable angles, some glasses may not be suitable.

Some rules of thumb: these gnomons are offset from an hour line and are not rectangular. The way to tell if they are correctly aligned (not necessarily correctly set) is to rotate the dial plate and see if the style parallels each hour line. This ensures correct alignment, however as stated, it does not protect from lateral and vertical gnomon errors, only rotational errors.

DAY 11: COMPLETION OF FINAL DIAL PLATES AND CLEAN UP



The west dial has tape holding it in place until the adhesive has set.



The east facing dial shows 11 am standard time, or 12 noon summer time. The south facing dial shows the same time, which was a relief.

The east and west dial gnomons had a nodus notch in the center of their styles.

The south dial gnomon had a nodus cut appropriately for the equinoctial line. Additionally, the south dial's gnomon was rounded to minimize injuries.

These dials were all calculated for the latitude of the town, their noon time lines are offset because the dials were also corrected for the longitude difference between the location and the legal time reference longitude.

The east and south dials have legal standard time marked at noon, the west facing dial is marked for noon and 1 pm standard time, as well as 1 pm and 2 pm summer time.

The equation of time is required. To that end, a small plaque was made for passers by.

This sundial has three faces, one for morning hours, one for middle of the day, and one for afternoon hours. It was designed for Silver City, NM latitude 32,75 N and longitude 108.2 W. Added to that the streets are 5.6 degrees east of true north. These dials are corrected to show standard time, so add one hour if daylight savings time is in effect. Also, pocket watches do a good job of showing 24 hours, but not of the daily rotation of the earth. To force the universe to comply with artificial pocket watches, a table of corrections is used, called the equation of time or EOT, see the figure of 8 chart to the right.

For information about sundials please go to:

www.illustratingshadows.com