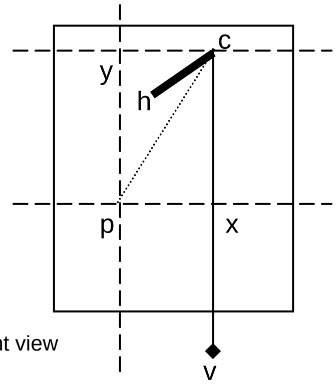
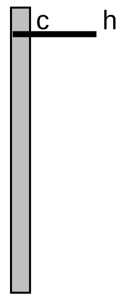
TRUE NORTH BY COMPARING ACTUAL~CALCULATED SOLAR AZIMUTHS



front view



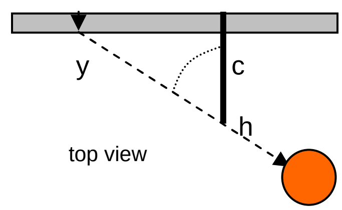
side view

A flat board has a nail inserted perpendicularly into it at point "c" and its length from board surface to tip is "ch".

A vertical line "cx" is drawn and a perpendicular "cy" is drawn, and a plumb line "cv" attached to the nail so that the plate when attached to a wall can be set so that "cy" is horizontal.

The standard time is noted, and the tip of the shadow "p" is drawn.

Distance xp is measured, this happens to equal distance yc. And since angle hcy is a right angle, and since the sun's azimuth from the wall's perpendicular (ch) is angle chy, then the azimuth from the wall's perpendicular at the time must be:



azimuth at the noted time = atan (yc / ch)

When a wall's perpendicular is true south, i.e. ch points true south then life is simple, however few walls are so aligned.

If we have the standard time, we can convert it to local apparent time (L.A.T.) using the formula:

standard time = L.A.T. + EOT + long.corr + summer.time thus

L.A.T. = standard.time – (+ EOT + long.corr + summer.time)

NOTE: When empirically marking a dial, the hour line's time has the EOT added to it. For example to mark the 11:00 am line, with an EOT of +10, the line would be marked at 11:10, because when the shadow is on the 11:00 hour line, it would be 11:10, there is no sign reversal. In this case however, we are reversing the signs of the EOT, longitude correction, and summer time since we are now going the other way. **HINT**: forget summer time, use standard time.

Then, given the L.A.T. and the date, we can calculate the sun's azimuth from true south (formula A8.4 in the appendices). First, the L.A.T. must be converted to a local hour angle (LHA)(table A2.2 or 1 degrees per 4 minutes), the latitude must be known, and finally the sun's declination (formula A8.2a or A8.2b or table A2.11)

suns azimuth = ATAN(SIN(lha) /
[as calculated] ((SIN(lat) * COS(lha)) – (COS(lat) * TAN(decl)))

Once we have the sun's azimuth from true south calculated, and the sun's azimuth from the wall's perpendicular measured, the difference in azimuth's will be the wall's declination from true south.

There are a number of steps, and the spreadsheet **illustrating-shadows.xls** has a worksheet dedicated to facilitating this reverse azimuth process. The steps are: (1) measure an actual azimuth at (2) a legal standard time, then (3) calculate the L.A.T. or local apparent time and (4) calculate the azimuth for that L.A.T. and date, and (5) the difference in azimuths is the wall declination. Multiple readings increase the final accuracy. The spreadsheet makes this so simple.

Some readings and basic data are collected and saved in "illustrating-shadows.xls", this sheet uses latitude, longitude, and Julian day and derives the day's corrections.

E O T correction		4/4/2007			94				Julian date and EOT come from the			
changes daily				mm.mm	3.12	hh.hh	0.05		table of contents index page:			
				EOT m	3	EOT ss	7					
LONGITUDE correction				latitude	32.75				Wall location from index page:			
fixed by location				longitude	108.20							
				ref long	105							
				corr m.mm	12.80							
				cor m	12	cor ss	48					
Today's sun declination (n-/s+ of the equator)									Today total correction mm.mm			15.92
5.395	DECL	noon altitude:		62.65					mins	15	secs	55.00
Perpendicular gnomon length:					3				Perpendicular pole length from index page			
Readings at legal standard time					measured	L.A.T. local apparent time						
hour	min	horizontal	vertical	hh.hh	azimuth	hh.hh	hh	mm	calc azi	delta	abs.delta	avg
9	7	9.20	7.90	9.12	71.94	8.85	8	51	68.58	3.36	3.36	3.36
9	50	6.20	8.00	9.83	64.18	9.57	9	34	59.12	5.06	5.06	4.21
10	25	4.00	7.00	10.42	53.13	10.15	10	9	49.36	3.77	3.77	4.42
10	47	3.10	6.70	10.78	45.94	10.52	10	31	41.92	4.02	4.02	3.90
11	6	2.30	6.60	11.10	37.48	10.83	10	50	34.53	2.95	2.95	3.48

The rod perpendicular to the wall or measuring board was 3 cm. The longitude correction was 12 minutes and 48 seconds, the date was April 4 giving an EOT of +3 minutes 7 seconds. However, the spreadsheet does all the work.

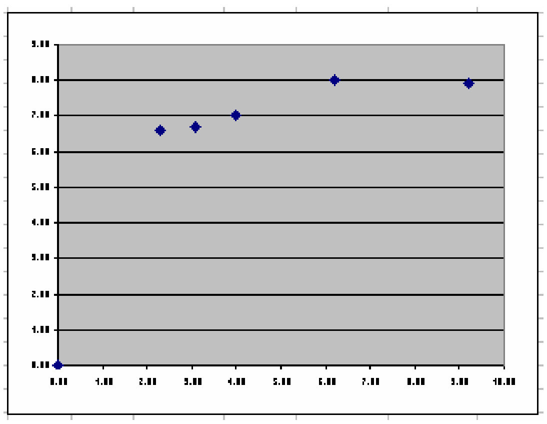
Measurements were made at legal winter time MST (not daylight savings which was in effect) of 0907, 0950. 1025, 1047, and 1106, with respective vertical and horizontal values from the base of the perpendicular rod of (9.2, 7.9), (6.2, 8.0) cm, and so on. This provided azimuths of 71.94, 64.18, 53.13 and etc degrees, and altitudes which are not essential.

measured azimuth [proof in appendix 7] = atan (horizontal / rod length)
measured altitude [proof in appendix 7] = atan (sin(azimuth) * vertical / horizontal)

Having gathered raw data, all that is left is to calculate the azimuth for the local apparent time, the difference between the measured azimuth and the calculated azimuth is the wall's declination.

Local apparent time or L.A.T.: = standard – (+ EOT + long.corr + summer.time)

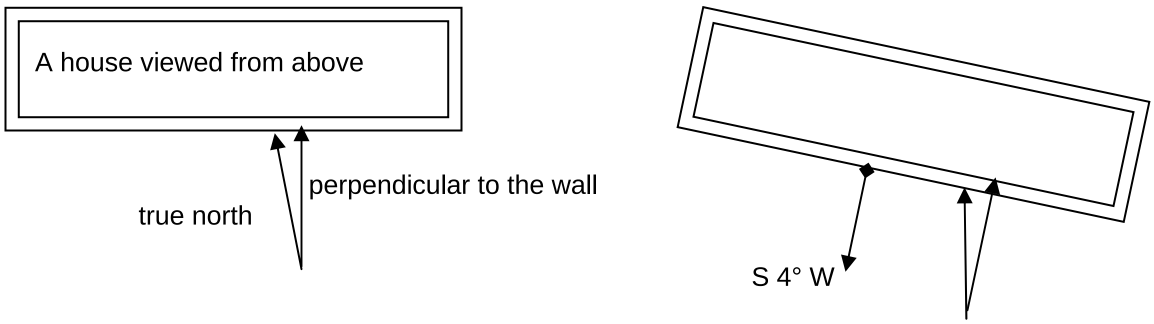
The spread sheet does all the hard work, and even plots the "x,y" points of the shadow which it graphically portrays as a double check. That is the only reason for the "y" vertical measurements. The graph visually suggests that the first reading may be out of tolerances, so that could be ignored, and the last also seems erroneous. The average of the middle figures would probably be accurate, and doing that by hand offers 4.28 degrees. The above was checked with the astro compass which offered 4 degrees, and with three orthogonal compass readings which also showed 4 degrees.



SOME THINGS TO CONSIDER

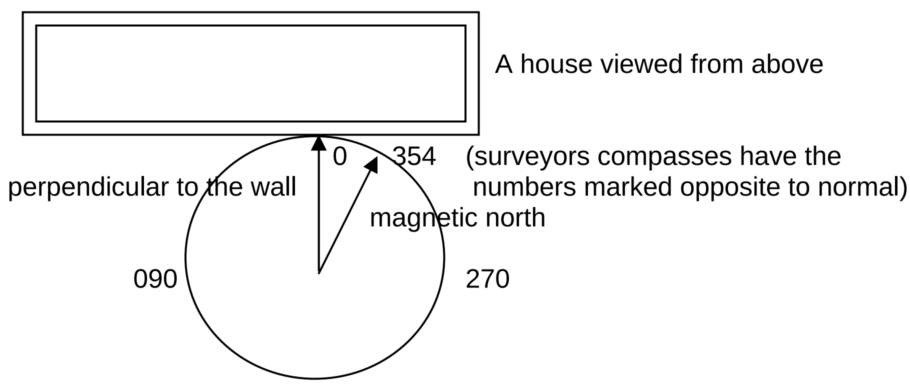
ASTRO COMPASS USAGE

The astrocompass method consists of placing the astro compass on a board whose edge is against the wall in question. For a wall S 4° W, the astro compass will be rotated left when correctly set up.

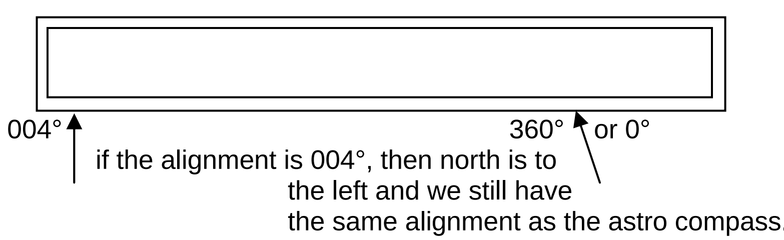


SURVEYOR COMPASS USAGE

The compass points to magnetic north, and the true north is found by considering the magnetic declination (or variation as navigators and pilots call it).



With the compass aligned perpendicular to the wall, the same house would show the compass needle deflected to the right reading 354 magnetic with 10° easterly variation. This translates to a 364° true bearing, or 4°. This might seem to be contrary to the astro compass, however it is not.



It is easy to become disoriented in the heat of field measurements. Work out the rough alignment first with any compass, then estimate some astro compass or wall declination by azimuth figures next, then perform the actual final measurements.

When using a magnetic compass, consider taking three readings, one east, one west, and one south of the wall, several readings from different places will reduce errors due to rebar or minerals.

PROOF OF ALTITUDE AND AZIMUTH ON A VERTICAL PLATE

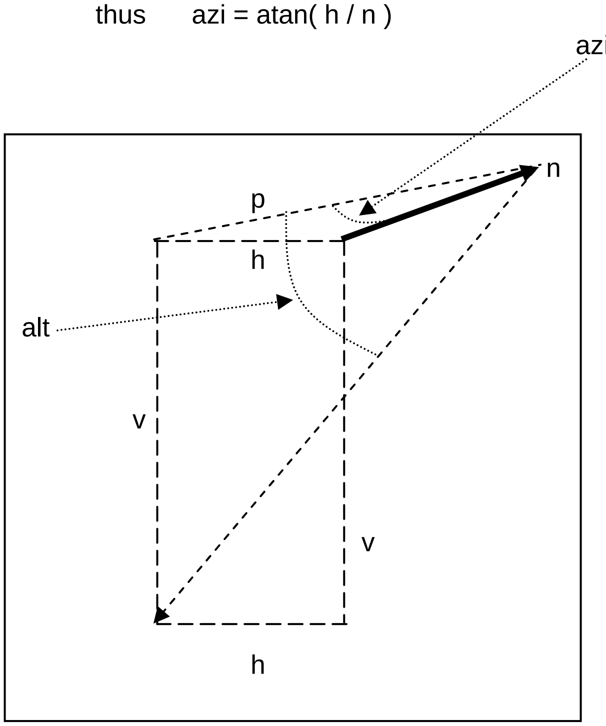
This is the proof of the formulae for the azimuth-at-any-time method of deriving a wall's declination from true north or south. In essence actual azimuths are noted, and for their times, they are calculated also, and the difference between actual and calculated azimuths is the wall's declination.

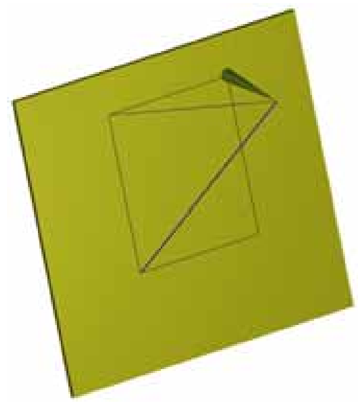
Lines v and h are vertical and horizontal coordinates of a shadow on a plane that is affixed to a wall whose declination is to be measured.

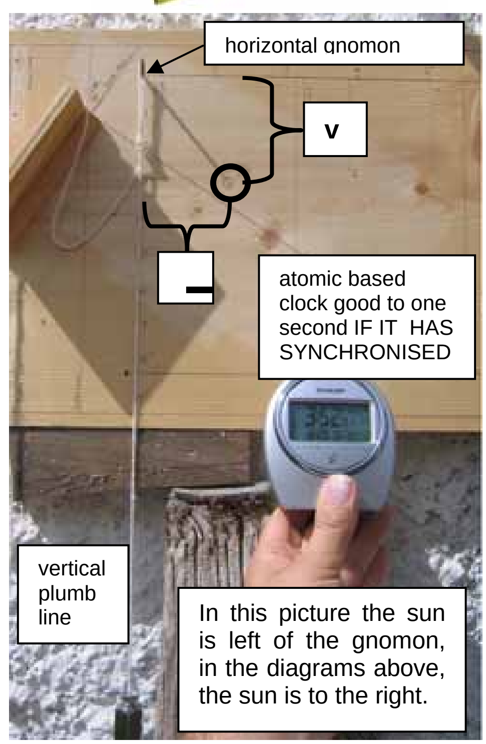
Length n is the length of a rod perpendicular to the plane affixed to the wall whose shadow is cast on the plane generating coordinates v and h from where the rod meets the plane.

AZIMUTH

tan(azi) = h / n
thus   azi = atan(h / n)







ALTITUDE

tan(alt) = v / p
and we already have   tan(azi) = h / n
and   sin(azi) = h / p

thus   p = h / sin(azi)

thus   tan(alt) = v / p = v * sin(azi) / h