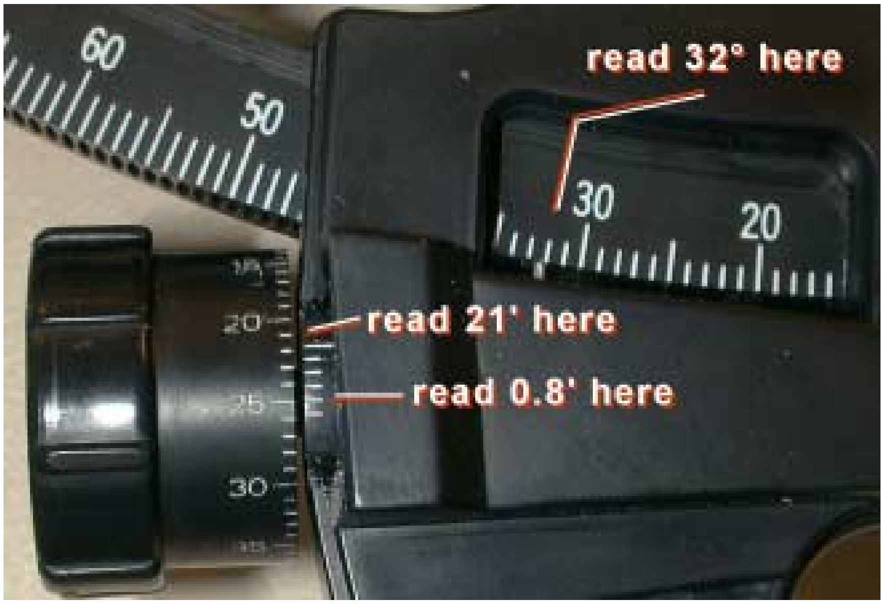
Celestial Sights with Plastic Sextants

Plastic sextants are often disparaged for lack of inherent accuracy and vulnerability to the effects of the sun. But while it is true that they are not as accurate as metal sextants and they are indeed more sensitive to the sun than metal sextants are — thermal expansion coefficients of plastic are some 10 to 30 times higher than for metals — plastic sextants can with special care still be used quite successfully for practical navigation at sea and do provide a less-expensive alternative for new navigators to get their feet wet with sights of their own. Indeed, plastic sextants are in practice easier to use than metal sextants for the actual sight taking because they are so light weight, but this ease of handling is rather outweighed by the extra care required in procedures and analysis. The task at hand here is to explain the issues and then propose a way to compensate for these limitations by presenting a systematic method for taking sights with plastic sextants.

In the authors opinion, the question of thermal effects of the sun have never been a real issue, since we have no reason to leave them for extended periods in the sun, just as we would not leave a thousand-dollar metal sextant in the sun. Whether or not they might thermally change during a particular sight session in the bright sun is not clear, we have one set of sights that might be explained by that, but it is not at all conclusive. [1]

To understand the limitations and issues at hand we need to look briefly at how sextants work. Most sextants have a series of notches cut precisely 1° apart into the outside edge of the *arc* of the instrument. The notches are labeled in degrees along the side of the arc. A *worm gear* at the base of the *index arm* presses into these notches as it moves along the arc. Large changes in *sextant angle* are made by squeezing two levers that disengage the worm gear and allow the index arm to slide along the arc. Releasing the levers, engages the worm gear once again, but sometimes a slight twist of the *micrometer drum* is needed to seat the gear properly. The degrees part of the new sextant angle is read from a reference mark on the index arm



against the degrees scale printed or engraved into the side of the arc.

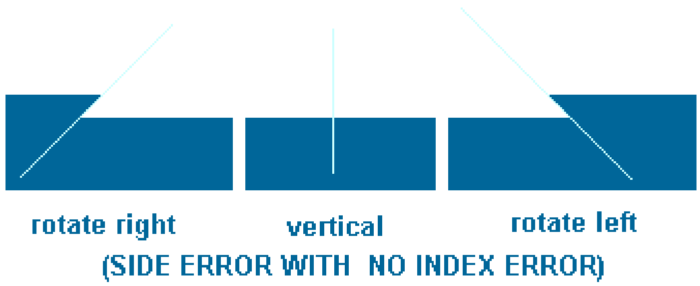
Angle settings in between whole degrees are made by rotating the micrometer drum. This rotation changes the angle continuously from one degree to the next. The drum settings can typically be read to a precision of 0.1’ of arc making use of a *vernier scale* printed along the edge of the drum. Hence if a sextant were set to an angle of 32° 21.8’, we would read the 32° from the scale on the arc, the 21’ from the micrometer drum, and the 0.8’ from the vernier scale. (see How to Read a Vernier Scale.)

An ideal sextant has a very positive action of the micrometer drum, meaning no slack in the gears. Turn it to the right by 1’ and immediately the angle increases by 1’. Stop and turn it to the left and it immediately starts to go down. A good metal sextant in good condition will behave properly in this regard. Plastic sextants, on the other hand, tend to have a bit of slack in this mechanism, consequently we get slightly different results when turning to the right to achieve alignment as opposed to turning to the left to achieve the same alignment. This is a well known issue with plastic sextants and it is mentioned in the manuals for the Davis Mark 15 and Mark 25 plastic sextants (it does not apply to the more basic Mark 3 model which does not have a micrometer drum).[2]

But there is more to this story. We cannot investigate slack in the gears without some means of observing the effects of our rotation of the drum. In other words, we have to decide what is or is not in alignment once we rotate the drum. An obvious time to study this effect is during the index correction (IC) measurement, which is typically done with the sextant set to 0° 0.0’ while viewing a distant sea horizon. (Note that there are other, probably even more accurate, means of measuring the IC — and gear slack — but for now we discuss only the more common IC method of using the horizon.)

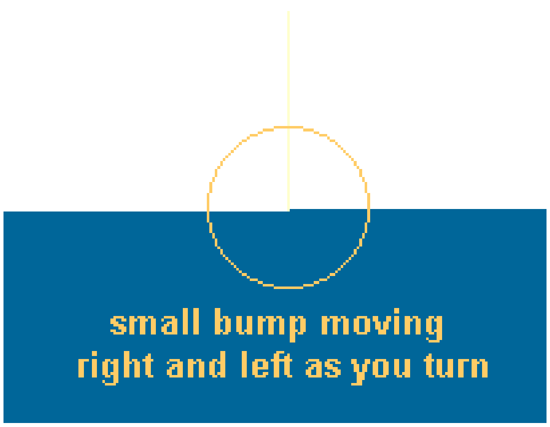
The sea horizon is the most convenient and most commonly used method, but for precision work it has the limitation of not often presenting a perfectly sharp line between sky color and sea color. Look very carefully at the best horizon and you often see — or at least appear to see — a very narrow line of some other color right at the horizon, or some other slight disruption of a perfect line. Consequently, even when we have a perfect sextant with no gear slack at all, we can still get the appearance of a slight gear slack because the imprecision of the reference line leads to some variance from sight to sight in what the observer might call “perfectly aligned.” The amount of this variance will depend on the nature of the horizon, the skill of the observer, the power of the telescope, and with the sextant model. A 6- or 7-power scope is better for IC checks than the 4-power scopes which are standard on most sextants, and this effect is naturally larger when viewed in the 2-power scopes on plastic sextants.

Here is a procedure for investigating this effect:



First remove the side error of the sextant by adjusting the horizon mirror until you can rock (roll) the sextant set at 0°0’ and not detect any splitting of the horizon. Many texts (and Bowditch, of course) explain the procedure. This may also require some collateral adjustment of the index mirror. With plastic sextants we have found that it is often useful to give each mirror housing (not the mirror itself) a bit of a flick with the finger to help the seating of the mirrors before and after the adjustments. If the flick changes things, you have to keep working on it. (Don’t flick it any harder than you would flick your own nose!)

Then with the sextant set to 0° 0.0’, view the horizon and turn the drum “toward” you (clockwise, angle decreasing) to clearly separate the two horizons viewed directly and by reflection. Then slowly turn the drum “away” from you (counterclockwise, angle increasing) until the horizons just first appear as a smooth straight line, which is what we call in alignment. Be sure to sneak up on this very slowly so you do not overshoot the alignment. We want the reading just as they first become aligned.



Confirm that you are aligned by panning (yawing) the sextant right and left a bit to verify that there is no motion along the horizon. This is a more accurate method than just looking straight at it and concluding it is aligned. If you are just very slightly unaligned, you will notice a slight bump moving right and left at the intersection of the two views, direct and reflected. Once confirmed, record the IC reading to the nearest 0.1’ and label this IC measurement with an “A” to note that you were turning the drum in that direction and a “touch” to note that this was the setting for the first touch of the two horizon views in alignment. If you have overshot the alignment, start all over again.

Now to continue, first double check your notes to confirm which way you are turning and think through the motion, then *very slowly and carefully* continue turning in the away direction until you can first detect that you are no longer aligned. Again, this is best done by doing a slight rotation then panning the horizon, then another and another pan, until you can detect some motion along the horizon which indicates that you are no longer aligned. Then read and record the new IC and label it with “A” and “leave,” meaning this was the value when you left the alignment.

Repeat this 5 or 6 times in the away direction and then do the same in the toward direction. This type of measurement will show what we are up against. You have effectively measured the angular width of “perfect alignment.” With a metal sextant and a sharp horizon, the touch and leave values will typically differ by only a few tenths, which reflects our limits on locating the horizon precisely. Put another way, if we just randomly set the sextant to alignment on a series of sights, we could fairly expect to get at least this level of spread in the values we measured, since anywhere between “touch” and “leave” gives the same appearance of alignment.

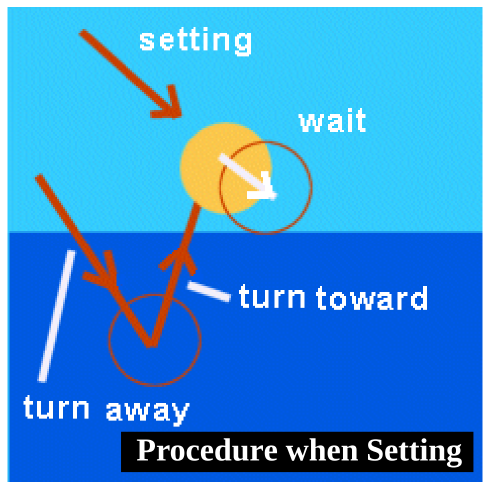
More to the point at hand, however, is that with a metal sextant, the spread in the touch and leave values will show little if any difference when measured in the toward or away direction. With a typical plastic sextant this is not the case. Not only will you detect larger spreads in the touch and leave values, you will most often note a significant difference in the IC values measured in the toward and away directions, which is a measure of the slack in the gears — or, if not that, at least some measure of the general behavior of the device (the actual worm gear in the plastic sextants is metal, but it seats into notches in plastic).

These IC differences in plastic sextants can also vary from day to day and from the beginning to the end of a given sight session — even if the temperature of the device has not changed at all during the session. Sometimes the toward and away differences might be zero and other times on the same device (without having adjusted the mirrors) be as large as 4' or 5'. We must stress here, however, that we are describing operational behavior, and not necessarily a limit on the ultimate accuracy obtainable with the sextants. The exercise is intended to show how users might verify for themselves why special care must be taken when doing celestial sights with plastic sextants. Next we show procedures that will to a large extent compensate for these limitations.

Suggested procedures for taking sights with plastic sextants…

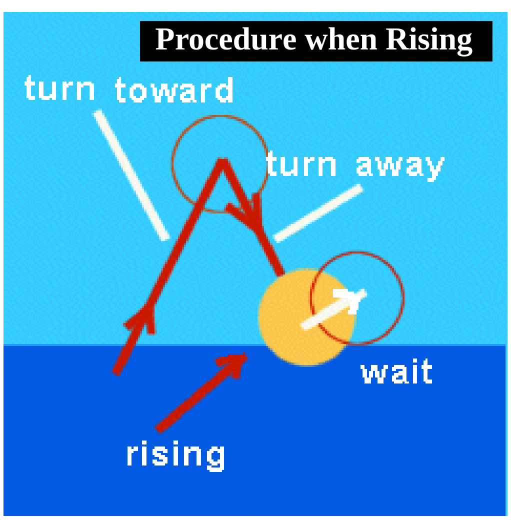
(1) Measure the IC values as explained above. The sextant should be in thermal equilibrium with the ambient temperature. See Sample IC data 1 and Solar IC data and forms.

(2) Use the "Set and Wait" procedure for taking the sights themselves, described below..



Procedure when Setting

Set and Wait Method. For objects that are setting (i.e. bearing to the west of south) get object and horizon in view, then turn the drum in the away direction till the object is well below the horizon. Then slowly and smoothly turn the drum in the toward direction until the body is about one-eighth of a sun diameter above the horizon (some 4' or so). When using the sun or moon, so that the lower limb is just very clearly above the horizon. The goal is to get to this point by only turning in the toward direction and then stopping with no backlash on the drum. Then do not touch the drum any longer but just wait for the sun to set onto the horizon as you continually rock the sextant back and forth to insure a perpendicular measurement. When the lower limb touches the horizon, note the time, and read the dial. Note the reading and that it was a toward sight.



Procedure when Rising

When the body is rising, do the reverse. Turn toward till the body is above the horizon, then carefully and slowly use the away rotation to get the lower limb some 4' or so below the horizon and then wait for it to rise up to perfect alignment. [3]

(3) Do at least 4 or 5 sights of each body. Use the appropriate toward or away IC for correcting the data.

(4) Then analyze your data using the Fit Slope method to choose the best sight of the lot for your fix. There is no need to sight reduce all of them if you are doing it by hand, just the best fit or a representative one. The slope analysis will essentially pile all the statistics of the set into that one sight. (Remember, too, that when you compute the Hc values for the theoretical slope of the line over the time range of your sights that you must use the proper DR position for each computation if they are different. When moving at any significant speed, this means updating the DR used at each computation. Sailing south at 8 kts, for example, any two sights of the same body taken more or less to the south that are 30 minutes apart in time would be some 4' different in sextant height. We must account for this in the slope analysis.)

I would propose this Set and Wait method as "standard operating procedure" for taking sights with plastic sextants, but should add that this is a good way to do sights in general with any sextant if conditions are a bit rough. It is longer, but much easier, and creates much less internal stress. If you miss it, just start all over again. Trying to cut corners and guess what time it really was aligned is not reliable.

I would also propose — as a broad generalization — that using these procedures one should be able to obtain accuracy's of some 5 or 6 miles as a general rule with plastic sextants. Maybe better in some cases, maybe a bit worse in others. Naturally, one needs to follow good procedures to obtain good fixes, which means well selected bodies (3 near 120° apart) with careful correction for the motion of the vessel during the sight session. Celestial calculators like the Starpath StarPilot do all of the sight reduction and this latter bookkeeping for you automatically. This level of plastic sextant accuracy is to be compared with that obtainable from metal sextants — also requiring good procedures and analysis — of some 1 or 2 miles depending on conditions.

Attached here are a few examples of sights with metal and plastic sextants taken during and just after the recent Victoria to Maui Yacht Race. The results are not too bad, but I must admit that they could have been better if I had followed the above procedures! Though we have taught various forms of these methods for years, the actual formulation of the ideas as presented above were developed during these sights and subsequent analysis… and in large part motivated by our recent correspondence with Cruising World — a motivation which they further kindled by their thoughtful response to our comments and concerns. Hopefully the article they published and the response they generated from it will motivate more navigators to get involved with celestial navigation. It is an enjoyable and rewarding pastime.

Footnotes

[1] There has been a published study that showed a large temperature dependence of the index correction of plastic sextants, but it is not at all clear that that study is pertinent to practical navigation — nor that the authors actually did measure what they set out to. See: "Temperature Dependenceof Index Error," R. Egler, Navigation, Journal of the Institute of Navigation, 42, No.3, Fall 1995. That experiment should be repeated in more realistic circumstances before its conclusions can be extended to real navigation underway.

[2] This most fundamental issue of index correction measurement in plastic sextants is conspicuously missing from the above article which studied the subject.

[3] It may help to remember that turning Toward makes the reflected image rise in your view; turning Away makes it descend in the sextant view.