11.19 Artificial Horizons

How do I practice celestial when I am landlocked, far from the ocean? This is a question we often get. Our usual first answer is, do you have any lakes near by, and then how big are they? If you have access to a lake or any other body of water, even just a quarter of a mile across, then your best method of practice is to use the dip short techniques we cover in Section 11.6. Those methods are accurate when done right, and do indeed provide realistic practice with sextant sights. We would recommend dip short over the use of artificial horizons if you have the option—and if, indeed, your goal is practice, as opposed to specifically studying artificial horizons.

With no water nearby for practice, or if planning something like desert or arctic travel where you want a backup to the GPS, or if you just want to do celestial the way Lewis and Clark did it, not to mention countless other land-based explorers throughout history, then you are left with some form of artificial horizon for the job.

What is an Artificial Horizon?

An artificial horizon is just the name of some device that will reflect the sun or stars so that sextant sights can be taken without reference to a real sea or distant flat land horizon. In the desert or some conditions in the Arctic, the actual visible land horizon might sometimes do the job, but not often. The reflecting surfaces used historically in artificial horizons include a small tray of Mercury (not so wise a choice for health reasons as we have learned over the years), or a pan of water, oil, molasses, or simply a mirror.

The only commercial one we know of these days is from Davis Instruments, the makers of plastic sextants and other boating gear. It consists of a small plastic tray with a glass tent over it as shown in Figure 11.19-1. The tray is for the reflecting liquid (a dark oil or molasses might work better than water but for the sun alone, it does not matter much what liquid is used.) The tent of glass is to keep the wind off the water. Even the *slightest* breeze puts tiny capillary

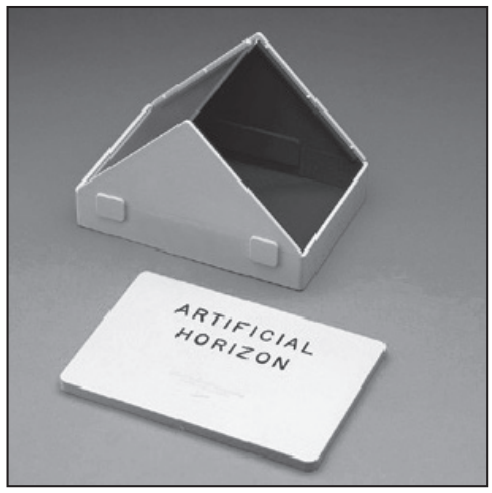

Figure 11.19-1 *Davis artificial horizon, about 4 inches wide, about $30.*

ripples on the surface that make sextant sights impossible. The Davis unit is designed to fold up into a small package when not in use and includes shades for use with the sun.

The glass covers on the Davis units (which is the same basic design used since before 1800) are in the form of a tent (two sides at 45°) for two reasons—I would guess. One is so any reflections from the glass itself are minimized and two, so that the light rays on to and off of the reflecting surface penetrate the glass at a near perpendicular angle. This is because the glass used is not high quality plate glass (which is much more expensive) and consequently the two surfaces of the glass pane may not be strictly parallel. A piece of glass with two sides not parallel is by definition a prism, and prisms bend light rays. If the light rays are bent at all, the measurement will be distorted. (If you have ever seen through glass in an authentically old house, you will see that things viewed through them are wavy and distorted to some extent.) The Davis units should work fine and are convenient for travel, but it is just as easy to build one yourself and you could end up with a better product for the job.

How to Make an Artificial Horizon

The simplest home solution using liquid, is just a pie pan filled with oil for calm nights, or covered with a quality piece of plate glass if there is a breeze. This should work well for the sun and bright planets, but will not be very useful for weaker bodies. It will certainly perform as good as any commercial device and perhaps better because the pie pan is bigger than the plastic tray.

It is best to arrange the device on a (very stable) post or table at about chest high so that you can comfortably look down onto it and be able to move around it to view different directions in the sky. You need to be able to look toward the surface of it from a small angle as well as from larger ones.

A liquid guarantees a flat surface but is some trouble to work with and it does not offer good reflection for stars. For stars we have found the best solution is to use a mirror. You will likely sacrifice some accuracy, but the sights will be much easier and this is about the only practical way to do stars, since the reflections from a liquid surface are weak. Use the same device to elevate the platform and then use a high quality machinist's level and shim the mirror to be level in all directions. For the last stages of shimming, we used business cards to make discrete controlled elevations. The mirror should be about a foot square or round and must be a quality plate glass mirror. We sacrifice some accuracy with the mirror because we cannot get it as level as a liquid surface.

For liquids, the containers and working areas should be all kept clean as any dust or dirt on the surface will interfere with the reflections, and sheltered from the wind to the extent possible. My favorite liquid is molasses; it will thicken after a few weeks, but a few drops of water and few seconds in the microwave and you are good as new. There are obvious (nutritional) advantages to this over dirty motor oil, which some navigators use. An example of molasses at work is in Figure 11.19-2

How to Take the Sights

First do the index correction using the sun or the stars themselves—we rule out the conventional method of using the horizon, but you may have distant hills or buildings that could be used. If using the sun, use the method described in Section 11.7 on Solar IC (this is the way Lewis and Clark did it). If using the stars at night, just set the sextant to 0° 0' and look to the star through the telescope. You will see two dots of light. The horizontal offset is the side error—not crucial if small—and the vertical offset is the index correction. Rotate the micrometer drum till the two dots line up vertically (or coincide if there is no side error) and then read the IC from the micrometer. As always, do it several times and average the results. Try it with bright stars and with fainter ones.

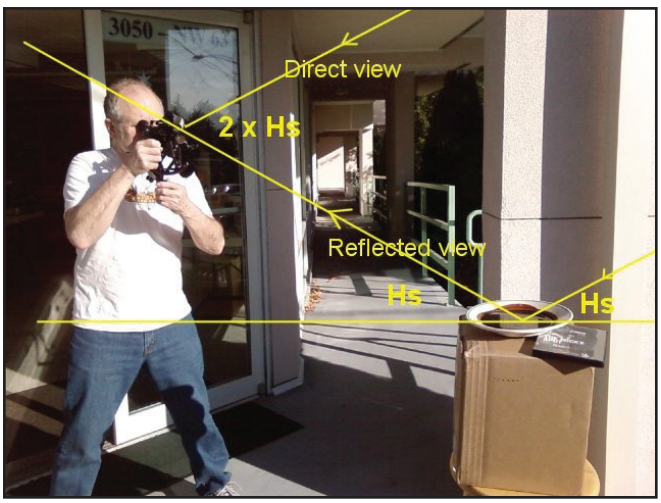

Figure 11.19-2 *Using a plate of molasses as an artificial horizon.*

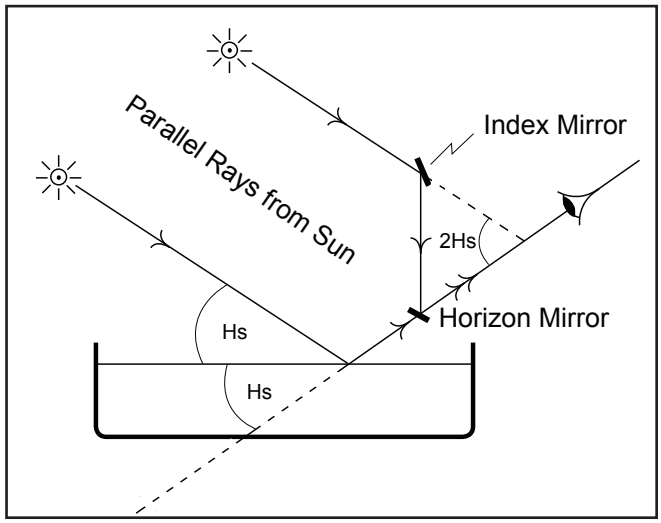

Figure 11.19-3 *Geometry for artificial Horizon, looking down toward the reflective surface.*

A fundamental issue with using a reflected image as a reference is that the angle you will end up measuring is twice the actual angular Hs of the body above the horizon (Figure 11.19-3). The geometry of a normal sight is shown in Figure 11.19-4. This fact has two effects on the process. One is once we measure the sextant height of the body we must divide the results by 2. If we measure Hs' = 36° 28.4' then we first convert this to Hs = 18° 14.2' and call this the measured height. The second practical consequence of this is we can only measure bodies that are about 55° to 60° high in the sky since most sextants only read to about 110°—some to as high as 150°, if this application was in mind at the time. In the old days, special artificial horizon sextants built on a fixed tripod oriented to the liquid surface usually had these higher arc ranges.

The first step in taking the sights is to precompute the altitude of the body you wish to shoot. Even for the sun this could save time, but for stars and planets it is essentially mandatory. Set the sextant to twice the precomputed value, and then orient yourself so that you can see the image you wish to shoot on the surface of the liquid through the direct (open glass) side of the horizon mirror. Since you are on firm land, it might be possible to jury-rig some arrangement for you to lean your arm on for the sights. Explorers often laid or sat on the ground and used their elbows onto knees or ground for support.

When looking to the image on the surface you should see the reflected image in the mirrored side of the sextant as well (if your DR and time used was close in the precompute). Then for stars or planets, just rotate the drum till the two images coincide, or are precisely beside each other (if you have a side error in effect). Then read the time and record the Hs.

For sun sights, you can do the same thing, that is overlap the images, and this is actually the easiest way to be sure you have what you want, although this is not the most precise way to do the sights. At least do it this way once or twice to get underway on the process. When touching limb to limb (the more precise alternative), it is easy to get confused as which limb is which. The sight reduction procedure in the following section explains this further. You will need some sun shades for the job, both on horizon and index mirrors or just use one over the roof, or just one over the front of the telescope. Generally you can get by with the shades on the sextant alone, as if you were doing sights from a glaring sea horizon.

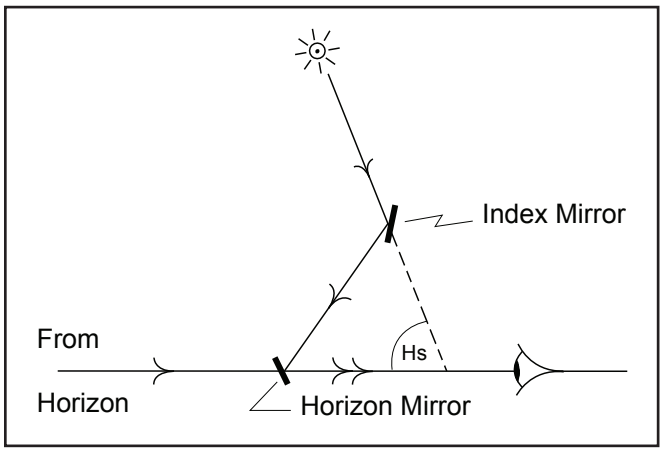

Figure 11.19-4 *Geometry of a normal sextant sight, looking toward the horizon.*

For doing limb-to-limb, use the lower limb of one image to just touch the upper limb of the other. Then after index correction, half the result will be the Ha of the upper or lower limb of the true sun according to the limb used as reference on the image reflected from the liquid surface.

It can be tricky to keep track of which limb is which, especially if you rotate one past the other. You have plenty of time, however, so these methods are learned with practice.

In any view or time of day, the two suns will be either coming together with time if you just watch them both in view, called *closing suns,* or they will be separating with time called *opening suns*. If you keep the suns from crossing over each other, this behavior will reverse from morning (closing suns) to afternoon (opening suns) as the sun changes from rising to setting. In the morning use the upper limb of the surface reflected sun as your reference. In the afternoon, the lower limb is used.

When the timed sight is recorded, note upper or lower limb as if it were done with a sea horizon, but use the definitions given earlier. If we do it wrong it will be apparent in the sight reduction.

For the most accurate sights when you must use a glass roof, you might want to try taking sights again with roof or cover glass turned over so you are looking at the other side of the glass, and then if the values are different, average them. To see if there is any effect from this you will need to take multiple sights and study the results. Just turn it over, do not turn and rotate. This is a rather long process for star-sight fixes or sun-moon fixes, because you need multiple sights from each side which you can plot; so you can choose an effective simultaneous time for each body (Section 11.24). This step would certainly not be required for practice sights or routine fixes, although since you will want to take multiple sights in any event, you might think ahead to turn over the glass on alternating sights of a sequence. If it is dead calm at the artificial horizon, you can leave off the roof and this is not an issue.

How to Reduce the Sights

For star or planet sights, first apply the index correction to the Hs you measured. Next divide the result by two and call this Ha, the apparent altitude (with artificial horizon sights there is no dip correction). Sight reduction of stars are otherwise done in the normal manner to obtain an LOP. That is, look up the altitude correction of the body and subtract it to get Ho and fill out the rest of the form in the normal manner to get Hc and Zn.

For sun sights taken by overlapping the images (as opposed to touching limbs), just do the same as a star, listed previously, being sure to use the Stars and Planets column to find the altitude correction. Do not use the sun corrections for anything when doing overlapped images. For this case there is no upper or lower limb corrections.

When using limb-to-limb, be sure you have identified the limb properly and then sight reduce using the proper upper or lower limb column of the sun's almanac altitude corrections. When doing this method, we always like to refer to the overlapped suns method to be sure we got the right limb. If you did it wrong, the answer will be off by some 32'.

If done carefully, artificial horizon sights can be just as accurate as or more so than those using a real sea horizon in typical conditions from a moving vessel. The only reason we don't promote the process more if you have a lake or other water around is that the overall process is sufficiently different from normal sights that it does not offer that much real practice in typical seagoing navigation. The process is, however, definitely a way to prove to yourself that celestial navigation really does work—but you could just take our word for that till you find a real horizon.