Determining a Meridian from the Sun

A Readily-Made Pasteboard Instrument

By John D. Adams

IN surveying the public lands, the U. S. General Land Office makes use of the usual surveyors' transit equipped with a solar attachment. This device makes it readily possible to determine a meridian with an accuracy of a minute or two in arc—a result, however, that necessitates very close adjustment of the several portions of the mechanism. In its most improved form the attachment is rather formidable in appearance, and in this doubtless lies the reason why so many engineers avoid it and are unfamiliar with its principle of operation.

The most interesting way of gaining a clear and practical understanding of some seeming obscurity is to provide, where such is possible, a working model reduced to mere essentials, the manipulation of which if it does not accomplish more than pages of written text will surely aid in elucidating them. It is accordingly the writer's purpose to present, in place of the telescope, mirror, latitude and declination arcs of the solar attachment, a simple and interesting device, consisting of two pieces of cardboard, with which an approximate meridian may be mechanically determined on precisely the same principle that lies hidden in the highly improved instruments used by the United States surveyors. By making such a device in a somewhat more dur-

LAYOUT OF THE DEVICE FOR DETERMINING A MERIDIAN FROM THE SUN

able form, a means will be provided whereby a meridian may be quickly determined within a degree—a result hardly to be expected with the magnetic needle with all the uncertainties of local attraction.

From the center point on one side of a piece of smooth, flat cardboard erect a perpendicular from four to six inches long. Using a point near the upper end of this line as a center, draw six radii on the right hand side of the perpendicular making the following angles therewith: $23^{\circ}27'$; $22^{\circ}30'$; $19^{\circ}53'$; $15^{\circ}47'$; $10^{\circ}37'$; and $5^{\circ}23'$. These will represent and certainly south declinations, and should be dated as indicated in Fig. 1. On the other side of the perpendicular draw

six similar radii for the north declinations at the following angles: $23^{\circ}27'$; $22^{\circ}41'$; $20^{\circ}20'$; $16^{\circ}38'$; $12^{\circ}00'$; $6^{\circ}27'$, which are also to be dated as shown.

Cut another piece of cardboard to the exact angle of the latitude of the place where the device is to be used, and then fasten the two pieces together with a thin cloth hinge. Through the central point of the radial lines tightly insert a piece of sewing needle just long enough to project about one-sixteenth of an inch on each side of the cardboard. At some convenient point where the sun's rays are available, place the lower edge of the lower piece of cardboard on a level surface,

HOW THE PASTEBOARD INSTRUMENT IS MOUNTED

SIMPLE DEVICE FOR "DIRECT SOLAR" OBSERVATIONS

holding the same as nearly vertical as possible with one hand. With the other manipulate the other piece of cardboard until the shadow of the piece of needle lengthens out as far as the hinge, when it will be evident that it is in the plane of the sun's rays. While maintaining this condition, move the whole about on the level surface until the shadow falls on the radius corresponding to the date of observation, when it will be found that the vertical piece of cardboard is in an exactly north and south position. A few trials will show that in no other position will these few simple conditions be met. To demonstrate this, simply set the latitude section in any posi-

MOUNTAIN SOLAR TRANSIT, SHOWING ENLARGED LATITUDE AND DECLINATION ARCS

tion but on the meridian, and it will at once be found that at no possible angle of the hinge will the sun's shadow lengthen out across the proper date line.

If it is desired to make the experiment in the afternoon, draw radial lines on the side shown in Fig. 1; if in the morning, the other side should be used, as in Fig. 2. In common with the modern solar attachment, the best results cannot be obtained within two or three hours of noon, a fact that is not due to any defect in principle, but to the smallness of one of the angles in the involved spherical triangle.

As our years are not all of the same length the sun's declination is not always the same on identical dates, in consequence of which more accurate results may be obtained by replacing the date lines with a declination arc on either side of the center line. By consulting the current ephemeris of the sun, the exact declination may be determined and then indicated on the arc by a light pencil mark, through which the sun's shadow may then be caused to pass. By means of a metal protractor having a projecting arm, it is a comparatively simple task for a draftsman to lay out the necessary scale to at least half degrees.

It should be understood that the accuracy of the results depends to a certain extent on having the horizontal surface quite level, a condition, fortunately, that is easy to attain with a piece of board and a small level. Though not so important a condition, the latitude sector should be held vertical, but those who wish to make use of the device for practical purposes would, of course, dispense with the cardboard entirely and construct a base of substantial width that would always stand vertically. The latitude sector could be made adjustable, the cloth hinge replaced by pivots, and other improvements would doubtless suggest themselves.

It is not the purpose of this article to go into the theory of the solar observation, as those who are interested can find it duly expounded in standard works, but it is hoped, after a little experimenting with the cardboard model, that what had previously appeared a very abstruse matter, necessitating a complicated mechanism and elaborate mathematical treatment, is essentially a very simple idea.

In this connection it may be well to refer to another form of solar observation, also used by the U. S. General Land Office, called the "direct solar." The sun is observed through the main telescope of the transit, and its altitude in a vertical plane measured. Its azimuth is then calculated by means of the following formula:

$$\cos \text{Azimuth} = \frac{\sin \text{Declination} - \tan \text{Latitude} \times \tan \text{Altitude}}{\cos \text{Latitude} \times \cos \text{Altitude}}$$

For south declinations the sun's declination is considered negative. If the algebraic sign of the result is positive, the azimuth is referred to the north point; if negative, to the south point.

In this form of observation the involved spherical triangle is solved mathematically, whereas with the solar attachment the solution is effected mechanically. By means of logarithms the above formula is reduced very quickly, and in taking a set of several readings it will be noted that all but the two terms involving the altitude may be considered constant.

PRECISE TRANSIT WITH TELESCOPIC SOLAR ATTACHMENT

An interesting and simple means of experimenting with this form of observation for meridian is illustrated in Fig. 3, and although only paper and wood enter into the construction it is readily possible to determine thereby a north and south line with an error of less than thirty minutes. A well seasoned block about five inches square and an inch and a half thick should be procured from the mill, where facilities are always available for securing a high degree of accuracy in sawing. On one surface only a paper protractor, reading to thirty minutes, is to be attached by means of glue—the glue being applied to several small spots rather than to the entire surface to prevent warping. In placing the protractor, set the block on a perfectly flat surface, and line up the 90° mark with a steel square, which may also be used to determine whether the surface of the protractor stands at right angles with the horizontal surface. This condition is important, and any slight adjustment that may be necessary may be made by pasting on a narrow strip of paper along the proper edge

of the base. Prepare a small radial arm of the form illustrated, and in the upper projection drill a hole about the size of a pin, so that the sun's rays may pass through and illuminate a small spot on the lower projection. This arm is attached to the block by means of a pin or small nail near the upper end put in at the exact center of the protractor. Set the arm at 90° , and with the steel square resting on the same horizontal surface as the block, make a small dot on the lower projection of the arm to indicate where the sun's image should fall.

To determine a meridian, carefully level up any convenient flat surface, on which the block should be moved about until the surface of the protractor is in the plane of the sun. Adjust the angle of the arm until the image falls on the small indicating dot, then record the sun's direction by drawing a line with a sharp pencil on the horizontal surface using the lower edge of the block as a ruler, after which read the altitude. The above formula will then give the relation of the sun to the meridian, which may be laid off with a protractor set on the line previously drawn.

By consulting an ephemeris it will be seen that for practical purposes the exact time is not a matter of great importance. To avoid the necessity of interpolating with the eye in reading the altitude, one may follow the sun for a minute or two until the reading is an exact division on the arc, when the mark may then be made on the horizontal surface. This may be repeated several times in a few minutes, and the mean of all the results taken.

A very convenient ephemeris of the sun and Polaris may be had from the Superintendent of Documents, Government Printing Office, Washington, for five cents.

AN IMPROVED TOWING SPAR WHICH CAN BE USED AS A NAVIGATIONAL INSTRUMENT.

By LIEUT. COMMANDER S. F. HEIM, U. S. Navy.

In these days of radio compasses and gyro controlled artificial horizons, it might be considered rather late to offer a scheme for taking sights by bringing the heavenly body down to a spar towed by the ship. The writer has read in the U. S. Naval Institute Proceedings of sights being taken on the waterline of another ship, on a boat sent out by the ship and even on a chip log astern of the ship, but spar which would seem to be the logical method because it can be let out from the ship without stopping or altering speed and its distance from the ship can be controlled accurately by marks on the tow line.

The scheme seemed so simple and plausible that the writer wondered why it had not been done before and he inquired of experienced officers and searched the files of the Naval Institute but failed to find where it had ever been tried. To test his theory he went out in the bay off Greenbury Point on a submarine chaser and steamer both day and night and took sights, using an ordinary towing spar with only 350 feet of line. A small waterproof storage battery light was attached to the spar at night. The results of these trials were accurate far beyond expectations. These results in altitude difference by Marcq Saint-Hilaire method were accurate within 1 minute of arc.

Of course it is realized that conditions here were ideal, with no wave movement of either the spar or the ship; but it is proposed to eliminate these errors as far as practicable at sea by use of the improved towing spar which will remain afloat with 500 or 600 yards of line out from the ship. The longer the length of line the more accurate will be the results. The maximum possible error due to rising and falling of spar in sea will be the angle with tangent equal to maximum rise divided by length of tow line. Thus with a 3-foot rise and fall of spar with 600 yards of line the maximum error would be 5 minutes in altitude.

The three views of the towing spar are self-explanatory and a description is unnecessary. This spar was developed and used by the commanding officer of the "U. S. S. Charleston"

while engaged in convoy duty during the war. The old navy towing spars and special sheet metal tank spars supplied to ships were useless for this work because they would tow under at the distances at which they were desired to be used. The towing under was caused by two things: their shape and the towing line. The improved spar shown in sketch was towed by a small wire rope of about the diameter of a lead pencil. This wire line was wound on a small reel secured just forward of the quarterdeck winch. The spar was hauled in by means of the deck winch. It was found that manila line was unsatisfactory for towing logging and friction tend to pull the spar under. It will be noted that a strong keel or centerboard is attached to the spar. This is an important feature which causes it to tow during turns and prevents capsizing.

TOWING SPAR USED ON THE U. S. S. "CHARLESTON"

By having at hand a table of "dips" to use for different speeds and lengths of tow line, the operation of taking a sight would be comparatively simple. He could take the bearing of the heavenly body to be observed and then head the ship directly away from the body and with spar out take a series of sights. The average of the series should be taken to counteract the errors due to wave heights of the spar. By practice in fair weather when the "dip corrections" are computed he could determine the limits of accuracy and how much confidence to place in it when occasion for its use arrives. We have all experienced the occasion when a sight was highly desirable or even necessary with the sun out or stars shining but no horizon visible.—Copyrighted by the U. S. Naval Institute. Reprinted by permission, from the *Proceedings* of the Institute, March, 1920.

CONCRETE PONTOONS FOR SHIP SALVAGE.

A set of reinforced concrete floats have been built by Messrs. Christiani and Nielsen says *Le Génie Civil* (Feb. 21, 1920) for the salvage of ships. The floats are cylindrical and measure 21 meters long and 3.60 meters in diameter. Each float has a bearing capacity of 100 tons and is designed to lift 200 tons. It can withstand an external pressure 2 kg. per cm^2 and in exceptional cases 4 kg. per cm^2 so that it may be used at depths of 40 meters.