TWO NEW NAVIGATION INSTRUMENTS.

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In using an ordinary sextant for the measurement of altitudes of the sun or stars it is necessary to see a good natural horizon in the telescope, the image of the sun being brought to tangency with it. Where a natural horizon cannot be seen a liquid surface is used from which light is reflected to give a second image which is brought to tangency with the first one.

When one is high above the surface, as in the case of an aviator, the horizon becomes more and more distant and less and less distinct and if the visibility is not of the best, is lost altogether, especially in a telescope. The same result is found if there is much smoke, haze or fog even if the observer is on the surface.

It has become desirable therefore to have an instrument which will measure altitudes accurately and in which one need not see the horizon at all, and need not use a liquid surface to get the second image.

A number of such instruments have been produced, in some a horizontal position being indicated by a level bubble, an image of which is reflected into the field of view of the telescope. In others a rotating gyroscopic mirror is used which either assumes a horizontal position or has a small precessional motion about such position. In either one it is necessary for the observer to watch two images and bring them together at a certain point in the field. One image changes its position with any slight change of the observer, or with any change in his motion, and the other with any movement of the index of the instrument, all of which is undesirable and makes for inaccuracy and loss of time.

In the instrument here described this is not true, both images being reflected from the same mirror and moving the same way at the same time. The mirror is a rotating gyroscope top, driven by the observer blowing through a small rubber tube, the air striking the rim of the mirror horizontally at diametrically opposite points. The rest of the instrument consists of two tubes, an index and a graduated scale. The telescope tube is mounted so that it moves with the index and always points into the mirror. The second tube is mounted on the opposite side of the mirror and moves about the same center as the telescope and exactly the same amount, but in an opposite direction. This tube is of smaller size than the telescope and has a lens at the lower end. The upper end is half covered and is at the focus of the lens. The light from the half covered end will then emerge from the lens in a parallel beam, fall on the mirror and if the instrument is held about horizontal, will enter the telescope, the observer seeing a field that is half light and half dark exactly as the natural horizon is seen. This will be true whether the angle of elevation of the tube is great or small.

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The telescope lens being larger, will not be entirely obstructed by the horizon tube and light coming from any object in the same direction that the horizon tube points will be reflected from the mirror exactly as the first beam and an image of such object will be formed in the field of the telescope. Any deviation of the mirror from level will change the position of both objects equally and if one object be the sun and it is placed tangent to the horizon line, it will remain so. If the instrument is held approximately level and the index moved to about the altitude of the sun, the telescope then assumes an equal angle to the plane of the mirror (horizontal), the horizon tube assumes the same angle on the other side of the mirror and the observer sees both his horizon mark and the sun in the field, a slight change in the index bringing the solar image into tangency with the horizon, the index reading the altitude directly.

With a small amount of light reflected into the horizon tube at night, the horizon is as easily visible as in the daytime and altitudes of stars can be obtained with great ease. This is a great advantage as stars in different directions can be observed one after another rapidly, each one giving rise to a line of position on the earth's surface and all intersecting at the position of the observer. In the daytime it is necessary to wait till the direction of the sun has changed enough to give two lines that will intersect at a favorable angle, two or three hours at least.

At the present time observations of stars cannot be made at sea except occasionally, the night horizon not being plainly enough seen, nor can observations of the sun be made when the air is smoky or foggy, even though the sun may be distinctly visible. This instrument would allow altitudes to be secured at any time the air was clear enough to see the celestial body. There is never any correction for dip of the horizon, on land, sea or in the air.

In the determination of latitude and longitude by the sextant, the usual procedure is to measure the altitude of the sun or star at a certain time. This time gives us the hour angle of the sun. Using this as one known quantity we can assume a latitude and longitude which we believe to be approximately correct and from these quantities solve the spherical triangle whose vertics are the pole, the zenith and the object observed, the quantity sought being its altitude, which is then compared with the altitude just measured, the difference giving a correction to the assumed latitude and longitude.

In the solution of this triangle it is necessary to use a table of log cosines and one of log haversines and natural haversines. The actual computation consists of finding the log cos of the latitude, the log cos of the declination of the body observed, the log hav of the hour angle, and adding the three together. The natural hav corresponding to this number is then looked up in the table, and to it is added the nat. hav of the quantity, (latitude minus declination). The angle corresponding to this function is then found from the table and subtracted from 90°, the result being the altitude sought. The azimuth must be obtained from an azimuth table before the resulting line of position can be plotted on a map.

For the application of navigation methods to aviation it is important that the observations be reduced as quickly as possible. Going at 100 m. per hr. or more, and taking 30 minutes to find the result may give a man a position where he was at the time of the observation but hardly where he is. It is also important that the reduction be made with as little as possible in the way of books and tables.

In order to get more speed in the reduction and to get rid of all logarithmic computation I have devised a mechanical way of making the solution.

The instrument consists of a disk of brass about 14 inches in diameter having the edges graduated in time on the outer edge and in degrees on a circle about an inch inside the edge. Pivoted at the center of this disk is an arm with a vernier on one end by which either of the graduations may be read and having a slot running through the other half, in which a marker slides. This marker consists of a small plate of transparent celluloid with a fine black dot in the center. Upon the surface of the brass plate there is scribed a circle having a diameter exactly one-half the graduated circle on the edge, and passing through the center. There is also a straight edge which slides horizontally across the brass plate having a hinge by which it may be raised out of the way when not in use.

The whole solution depends on the fact that any great circle on a sphere may be made to project into a straight line, and arcs so projected may be measured by a cosine scale along such straight lines.

For an observer outside the celestial sphere in the direction of the north pole, the sphere would be bounded by a great circle, the equator, the pole being a point at the center, and the hour circles being radial lines. When the sun is in the equator it would appear on the boundary of the sphere—at any other time it would appear toward the center, its distance from this point being the cosine of its declination. This point may be determined from the smaller circle scribed on the surface, it having this property: If the pivoted pointer is set at any angle, and the dot in the marker is set on the smaller circle, the dot will be a distance away from the center equal to the cosine of the sun's distance from the equator. The dot will then represent the sun and may be set at the proper hour angle by means of the graduation and vernier.

If now the whole celestial sphere be viewed from any other position in the meridian than the pole, the only change in the apparent position of the sun (dot) is along a vertical line. We therefore set the sliding straight-edge over the dot, knowing that from whatever meridian position we view the sphere the sun will be somewhere in the line. We then set the pointer to the azimuth of the sun as found from an azimuth table. We may now consider that we are looking at the sphere from a point above the zenith, the center being the zenith, the radial lines being vertical circles and the bounding circle the horizon. The sun is in our straight-edge line and is also in the center line of the pointer when it is set for the azimuth. We therefore move the dot till it comes under the straight-edge, move the pointer till the dot comes on the cosine circle, the reading on the vernier being the required altitude. This altitude is then compared with the altitude measured at the time for which the computation is made, the difference being the amount the observer is away from his assumed position.

This is illustrated in the diagrams, where a latitude of 40° is assumed, a longitude such that the sun has an hour angle of three hours, the declination of the sun being 20°.

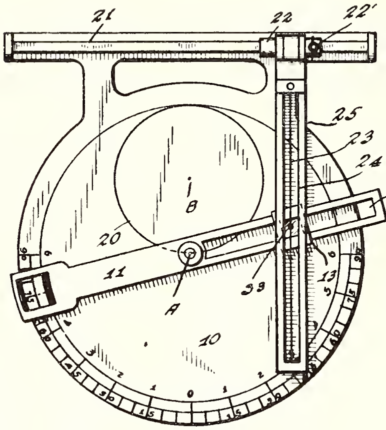

Fig. 1.

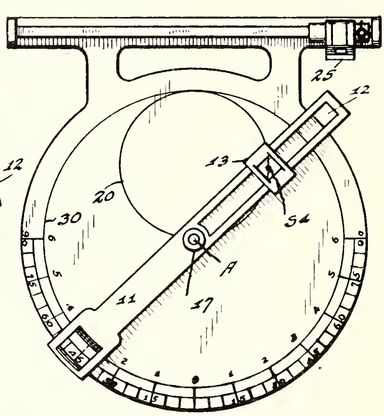

Fig. 2.

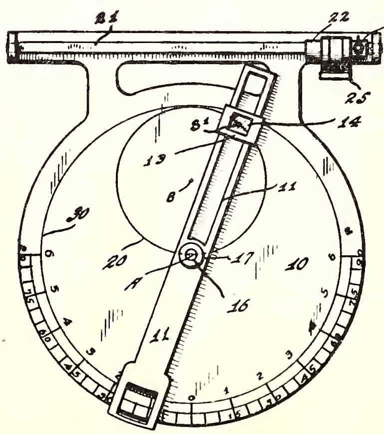

Fig. 3.

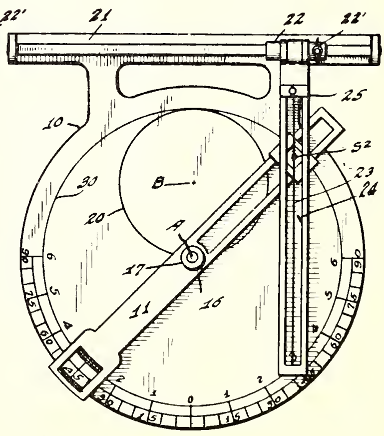

Fig. 4.

Figs. 1-4—Successive stages in the manipulation of a navigation instrument for determining altitudes of celestial bodies, as described in text.

In figure 1, the vernier is set at 20° and the dot is placed on the circle at S. Next the vernier is set at three hours (or 45°) and the straight-edge placed over the dot (fig. 2). The azimuth of the sun is next set off on the vernier and the dot placed under the wire (fig. 3). The straight-edge may now be moved out of the way and the dot brought over the cosine circle, the vernier reading the corresponding altitude of the sun (fig. 4).

Practically, the larger part of the data can be prepared in advance of the observation. When the time of the observation becomes known the solution need not take over 30 seconds, an azimuth table and ephemeris of the sun being the only tables required. Obviously stars may be used as well as the sun as long as the declinations are not over about 80°. The design of the instrument may be varied somewhat to give greater stability to the straight-edge, make it easier to use in a poor light and to make it possible to find the azimuth without a table.