The Technique of

AIRCRAFT BUBBLE OCTANT OBSERVATIONS in FLIGHT

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● It is generally understood that the bubble in the bubble chamber of an aircraft octant represents the sensible horizon. The sensible horizon is a plane tangent to the surface of the earth having the observer's position on the earth as the point of tangency. The bubble actually represents an air horizon parallel to the sensible horizon but at a height above the sensible horizon corresponding to the altitude of the aircraft. For all practical air navigational purposes this height is disregarded. Therefore, we can say that the bubble represents the sensible horizon when the bubble unit is stationary and not in flight and is in correct adjustment and also when influenced only by the force of gravity acting on the fluid in the bubble chamber.

Unfortunately, additional forces influence the bubble when in flight. The first to be considered is the resultant of turn and acceleration errors. Before proceeding let us define centripetal force.

Centrifugal force is explained as follows: Because of their inertia, bodies set in motion tend to continue moving in a straight line; thus a body to be compelled to move in a circle must have a force acting toward the center of the arc of its travel. This force is called centripetal force. The equal and opposite reaction is centrifugal force. In a sense, centripetal force is not a definite force, but a reaction due to inertia.

Turn Error

An aircraft in flight is imparting centripetal force on the bubble of the octant. The automatic pilot is constantly correcting for turn, thereby causing turn error of the bubble. If, when you are observing a celestial body ahead of the aircraft, the aircraft starts a turn to the left, the fluid in the bubble chamber is forced to the right and consequently the bubble is forced to the left. In this case, provided the period of the turn is small, the resulting error of the bubble will be small. But let us assume the observation is being taken near the beam. Then the turn force is affecting the bubble in a manner to cause the greatest error in the observed altitude because the bubble is being forced toward the front or rear of the

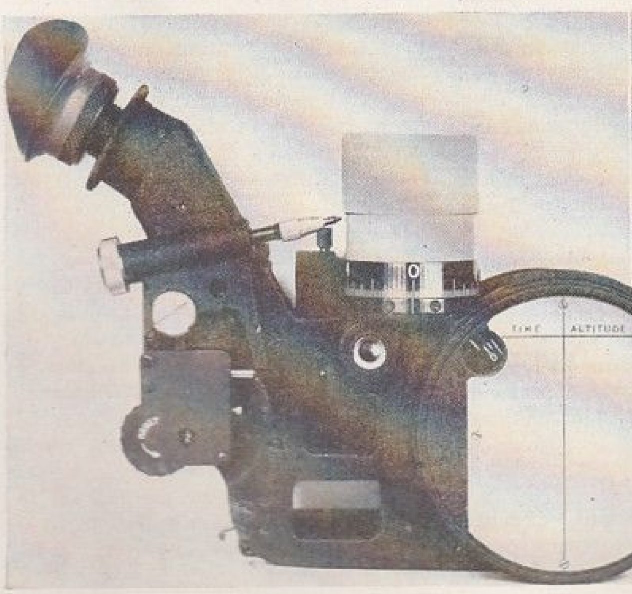

Fig. 1—Pioneer Octant (A-7) Rapid Shooting Recording Type

Fig. 2—Pioneer Octant (Mark IV) Continuous Recording Type

bubble chamber in conjunction with the direction of the turn toward or away from the body being observed.

Acceleration Error

Every aircraft in flight has some degree of acceleration. The airspeed meter may be registering 130 knots, but if the aircraft slows to 129 knots in 5 sec and then increases to 131 knots in the next 10 sec and then slows to 130 knots in the next 5 sec, it has completed one acceleration period. If, during this 20-sec period, a celestial body is being observed directly ahead, throughout the 5 sec that the aircraft slowed to 129 knots, the fluid in the bubble chamber was forced toward the front and consequently, the bubble was forced toward the rear; then during the increase to 131 knots, the fluid was forced toward the rear and consequently, the bubble was forced to the front.

On observations made directly ahead or astern the acceleration error is greatest and lessens as the direction of observation approaches the beam of the aircraft.

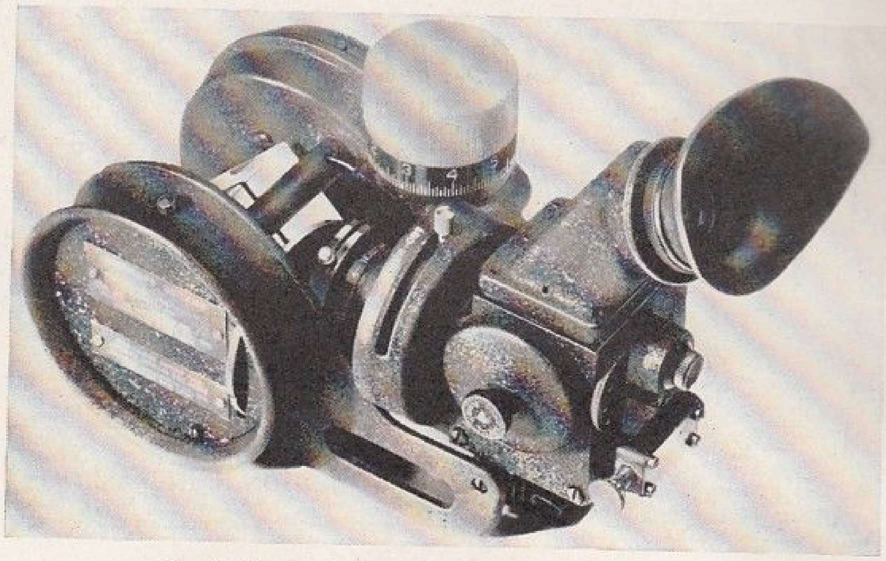

Fig. 3—Pioneer Octant, Type 1067 (No recording device)

Conclusions

From the foregoing, it is noticed that turn errors are greatest where acceleration errors are least and *vice versa;* therefore, the resultant should be a fairly accurate sine curve. This is the case in certain types of aircraft in certain flying conditions, but it cannot be used as an infallible rule. The periods of the turn error are quite constant when under automatic pilot control, but the periods of acceleration are not constant, so to accurately diagram the result of these two errors, one would have a longer period sine curve representing the turn with a shorter period secondary curve, representing acceleration, crossing and recrossing the turn curve at somewhat irregular intervals.

The best observations are obtained during good pilot supervision: *i.e.,* ask the pilot to help the automatic pilot by overriding the controls. There is a certain technique to this operation but most of the pilots with whom the author has flown, have acquired this technique quite easily.

Next, we will consider the type of aircraft octant with which it is necessary to write down each sight on the octant pad. (Fig. 3) With this type of octant the following technique has been found to give satisfactory results:

(a)—Shoot at regular intervals over a longer period of time.

(b)—Slow shooting over a long period gives more accurate results than fast shooting over a short period.

(c)—In concurrence with (a) and (b), the mathematical average of 10 shots is found to be 4 times as accurate as that of 5 shots, while the average of 20 shots was found to be about 2½ times as accurate as that of 10 shots. These figures were obtained using a Pioneer (No. 1067 type) octant and taking several series of shots over land in light turbulent air.

Presently, we have continuous recording octants, which complete a graph showing a record of continuous observation throughout a period of two minutes. (Fig. 2) The average time and altitude is found by the median method. Any well designed aircraft will undergo two or more periods in two minutes. Very good results are obtained with this type of octant.

However, practice shows that a rapid shooting recording octant gives results just as accurate as a continuous recording octant and requires less effort to use at high altitude, plus the fact that there are fewer intricate mechanical parts that might fail. (Fig. 1)

With regard to the rapid shooting recorder type of octant, it may be well to repeat:

(a)—Shoot rather rapidly at regular intervals.

(b)—For best accuracy, shoot over a long period of time (40 shots in 2 min is suggested).

(c)—Do not be misled by "steady" periods.

It is important to note that steady periods are deceptive and the so called "wild shots" are usually due to the fact that steadiness occurs at the peaks of the sine curve of a series of observations.

The Coriolis Law

Gustave Gaspard Coriolis, (France 1792-1843) in addition to many other achievements in natural science, became interested in the antics (*English*) of a billiard ball, and solved the vectoral forces of spinning spheres. Coriolis' law says:

"If a particle moves on a path as the path rotates, the acceleration of the particle is the geometric, or vectoral sum of: (1)—the acceleration the particle would have if the path were fixed and the particle moved along the path with velocity; (2)—the acceleration the particle would have if it were fixed on the path and the path rotated with angular velocity, and (3)—the Coriolis component, or the compound supplementary acceleration."

Determining the Position

To visualize the application of the Coriolis correction, the particle (aircraft) is accelerating along a path (track) that is space turning to the left in North Latitudes and to the right in South Latitudes. Therefore, reverting to the paragraph dealing with the turn error for demonstration purposes, it is obvious that all positions determined by aircraft octant observations in flight are to the left of the actual track in North Latitudes and to the right in South Latitudes until corrected for Coriolis error.

It is also apparent that the vectoral sum of the forces increases as we depart from the equator due to a space turn of smaller radius, and also as the velocity of the aircraft increases.

The following Coriolis correction is given for Latitude 50° and 150 knots.

In North Latitude correct celestial fixes 3 miles to the right of the track. In South Latitude correct celestial fixes 3 miles to the left of the track. In lower latitudes at lower speeds the correction is not enough to warrant practical application.