AERIAL PHOTOGRAPHIC FLIGHT LINE FLYING

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THE purpose of this paper is to analyze the more common methods employed in flight line flying, to describe a method, and some mechanical aids that have been developed to make it easier for the average pilot to do good flight line flying, to suggest improvements in these mechanical aids, and to suggest additional equipment which would further improve flight line flying.

In the past the normal procedure for flying flight lines can be divided into two parts, namely, determining the line to be flown, and then navigating the line chosen.

In determining the line to be flown the pilot has generally used either one of, or various combinations of the following procedures:

A. Identify each line on the ground from points on the flight map that are recognizable on the ground.
B. Identify one line on the ground from information furnished on the flight maps and "window block" each additional strip, i.e., sight through the window along points on the airplane that he has found by experience will give him the center line of the adjacent strip.
C. Assume the position of the first line from information given and estimate the position of each succeeding line.

It can be readily seen that only the first method is very accurate and dependable, and that that is true only when the flight maps are sufficiently accurate. The last two methods, or combinations of them, have to be used at times and can be used with surprising results if all the other conditions of flying the lines have been simplified, and the pilot has the necessary mechanical aids to fly whatever line he decides is the one to be flown.

After the pilot determines the line on the ground he intends to fly, he puts the airplane on the line at the proper altitude and assumes a heading, with or without drift, which he thinks will carry him down the line. He keeps the line on the ground lined up with two points on the nose of the airplane. If he sees he is drifting to either side he estimates a correction to the heading of the airplane, picks new points on the nose of the airplane in line with the flight line, and flies until he sees that he is drifting off again. He then makes another correction in the same manner.

The above procedure sounds easy, but in reality it is very difficult. It is like "shooting from the hip." There are lots of people in the movies but only a few in real life who can shoot a pistol accurately "from the hip." Furthermore to acquire this skill took years of practice. There are a few pilots who can fly as described above, but they too acquired such skill only through years of practice.

There are two main difficulties with the above procedure. The first is determining the heading, including the drift if any, to keep the airplane always aligned by points on the airplane with points on the ground. If the pilot uses one point on the airplane then he must keep his eye absolutely in one place. If he uses two points on the airplane, one in front of the other, then his eye must be in line with these two points at the time he is sighting. In either case he must sight with one eye. If he closes the other eye it becomes very tiresome. If he holds it open he becomes very confused. Furthermore, if he looks away, which he has to do quite frequently to check his instruments, particularly the altimeter, and to check his maps, he loses sight of his alignment, and it takes time to regain it, or he has to figure a new alignment. The second difficulty is determining what is directly beneath the airplane, i.e., whether the airplane is directly over the line or point in question. You can not see straight down by looking out the side windows of the airplane. Lining up with the flight line and imagining where the line projected under the airplane comes is very difficult because it will vary depending on the amount and direction of the drift, and on which side of the airplane the pilot is sitting. If the pilot looks through the window which is in the floor between the pilot and co-pilot seats, he cannot tell what is directly beneath the plane unless he places his eye directly above the window. Even then the area on the ground that can be seen is very limited and he may have to look several times before he sees a point on the line. Furthermore, every time he moves his eye over far enough to look down through the window he loses his alignment ahead, he loses his sense of the vertical, and the airplane will bank a little, the line of sight through the window ceases to be vertical and he still does not know what point he is directly above.

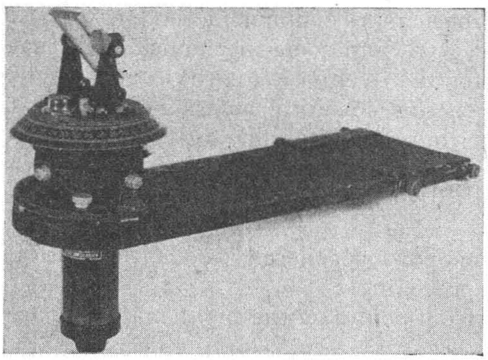

FIG. 1. General view of Pelorus and mount.

Only a few people have ever learned to "shoot from the hip" but millions have learned to shoot very well by use of proper sights. From the experience gained over the last eighteen years, both as a pilot and an aerial photographer, on production work, and as an instructor, the writer believes that any pilot who is willing can be trained in a very short time on the sighting equipment described below to do acceptable flight line flying.

To alleviate the difficulty of sighting ahead, it was decided that some kind of vertical line collimating sight with an azimuth circle on which the drift angle could be set would best solve the problem. After trying several different types of collimating sights, such as the gun sight, and discussing with Dr. I. C. Gardner of the Bureau of Standards the optics of such a sight, it was found that the Pelorus navigational instrument, although not the ultimate desired, did satisfy the basic requirement very well. Figure 1 shows a general view of the Pelorus. Figure 2 shows the instrument installed on the pilot's side of a Beachcraft photoplane. This type of sight gives the eye a considerable amount of freedom of movement without changing the alignment. As long

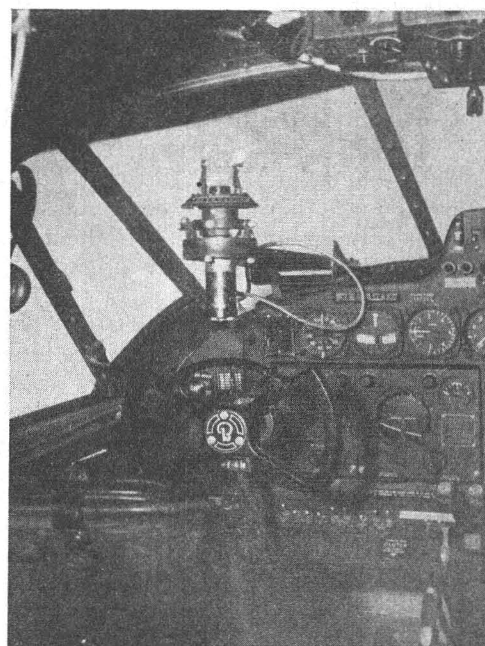

FIG. 2. Pelorus mounted in plane.

as the eye can see the vertical line in the sight the alignment is correct. Although the line of sight can be seen by only one eye at a time, the light coming from the collimating sight is parallel and appears to be far out in front of the airplane. Consequently the pilot can keep both eyes open without fatigue or confusion. When the drift angle is set on the azimuth circle, i.e., the line of sight is set off from the center line of the airplane by the actual amount of the drift, all the pilot has to do is keep the line of sight on the flight line ahead and the airplane will stay on the flight line. It is like putting a long handle on the airplane and letting it slide down the flight line. Although the winds are fairly constant on a photo day over the length of flight lines generally flown, they do vary and it is difficult to get the drift angle exact. However this difficulty can be overcome very easily by making slight corrections in the drift setting if the airplane appears to be drifting off the line. Furthermore by use of the collimating line of sight, the pilot can detect whether or not he is drifting off the flight line quicker than without it. Therefore he can make small corrections in the drift setting and stay much closer on the line.

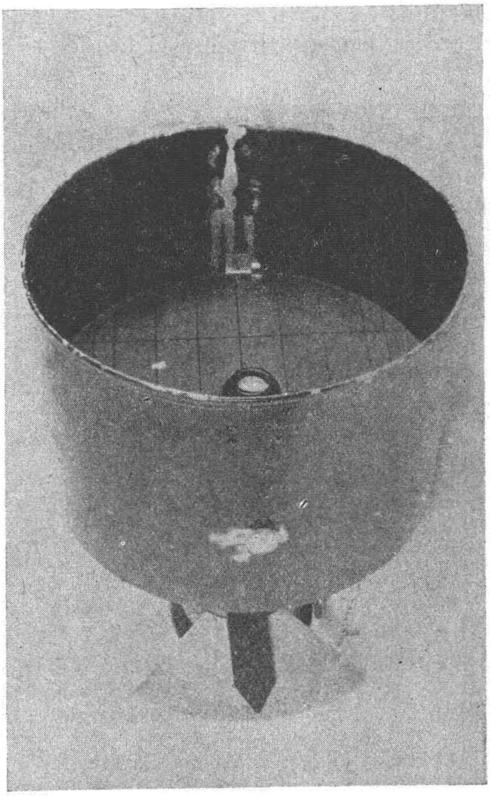

FIG. 3. General view of Modified Pilot view finder.

There are two main ways of determining drift which are readily adaptable to this type of flying. One is with the pilot view finder which will be described later, and the other is by use of the collimating sight. The pilot puts the airplane on the line, sets off an assumed drift angle in the sight, and then holds the line of sight on the flight line, which may be a section line or even two or more points on the line. If the assumed drift angle was correct, and the collimating sight line is kept vertical, the sight line will continue to follow down the section line or stay in line with the two points. However if the drift angle was not correct, the sight line will begin to make an angle with the line on the ground, i.e., if the sight line is held in coincidence with distant points on the flight line the sight line will appear to move either to the right or left of near points. He then makes a correction in the drift angle and tries flying the line again. He keeps making corrections until he finds a drift angle that will keep him on the flight line. A satisfactory drift angle can usually be obtained in this manner in less than five minutes. Furthermore the collimating sight makes it much simpler to project a line on the ground between or beyond any two points on the ground. The sight line appears to lay on the ground and when it is lined up with any two points on the ground, it is a simple matter to pick up any number of additional points either between or beyond the two points in question. Consequently it is fairly easy to fly a flight line when only two points from the line on the map are visible on the ground.

To eliminate the difficulty of determining what is directly beneath the airplane it was decided that some sort of a view finder located so that it could easily be seen by the pilot would best solve this problem. A view finder mounted over the window in the floor of the airplane between the pilot and co-pilot's seats was tried. This view finder did not cover sufficient area on the ground, and the units on the drift scale were too large, being marked only to the nearest five degrees. Consequently it was decided to build a larger view finder. This was done by making a cone out of aluminum that would take a circular ground glass approximately twelve inches in diameter and fitting it to a ball and socket joint containing an eight and one-half inch lens. The drift scale was also enlarged to a diameter of approximately six inches. This permitted the drift angle to be divided into one degree units of approximately one-tenth of an inch each. Thus the drift could be read to the nearest one-half degree accurately. The ground glass (Fig. 3) was marked with two very heavy perpendicular black lines, one being parallel with the line of flight, and the other at right angles to the line of flight. These lines intersected at the center of the ground glass, and when the view finder was level, the intersection of the two lines indicated what was directly beneath the airplane. Additional finder block lines were marked on the ground glass parallel to the line of flight at such a distance apart that they represented ten per cent of the width of the picture.

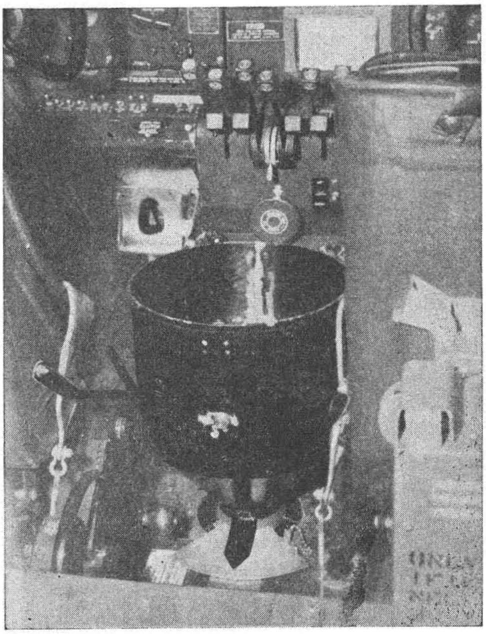

FIG. 4. Pilot view finder mounted in plane.

The ten per cent space on either side of the center line was divided in half by a yellow line. Thus the space between the center line and the yellow line on either side of it represented five per cent of the width of the picture. Two red lines were added perpendicular to the line of flight at a distance which represented forty per cent of the width of the picture. These were the interval lines for a sixty per cent overlap in the line of flight. Since the area covered on the ground by any camera is a function of the focal length of the camera, a separate ground glass had to be made for each different focal length camera to be used. Figure 3 shows a general view of the Pilot view finder. Figure 4 shows the Pilot view finder installed in the airplane.

With such a view finder, the pilot can easily determine what is directly beneath the airplane, i.e., whether he is over the flight line or not, and if not he can tell exactly what per cent he is off. Also by turning the view finder in the ball and socket until the travel of the image points is parallel with the fore and aft lines of the view finder he can determine the drift to the nearest one-half of a degree. This gives him a check against the drift determined by the Pelorus.

The drift obtained by the Pilot view finder checked against that obtained by the pelorus is far more accurate than that obtained by the photographer with the view finders now in general use. Thus the photographer working with the pilot will be able to set the crab on the camera much more accurately and prevent a great amount of reflying which has been caused in the past by excessive amounts of crab. Furthermore the pilot will be able to check with the photographer on the interval in line of flight, and prevent a considerable amount of reflying because of insufficient overlap in line of flight.

To augment the use of the Pelorus and the Pilot view finder, it has been found that, although not essential, it is very helpful to use the automatic pilot. By use of the automatic pilot the pilot has much more time to keep a constant check between the Pelorus and the Pilot view finder and to study his flight maps which is absolutely necessary on long flight lines. Precision flight line flying then becomes almost as simple as it sounds: check the flight map, check the view finder, and check the Pelorus, then adjust the view finder, adjust the Pelorus, and adjust the automatic pilot.

The above system of flying has definitely established its worth in precision flight line navigation. However the Pelorus could be improved as follows:

a. The cross hair or sight line should be brighter.
b. The sight line should be much longer.
c. There is too much parallax on the ends of the sight line. This could be corrected by using a bigger and more highly corrected projection lens.
d. The over all size of the instrument should be made smaller.
e. The instrument should be mounted on a better shock absorbing sytem.
f. The drift scale should be made larger so that the drift could be set to the nearest one-half of a degree and the scale need include only approximately thirty degrees in either direction.
g. Additional short vertical lines could be placed along the horizontal line of the reticule to facilitate bracketing the flight line with the sight line since it is practically impossible to hold the sight line on the flight line all the time.

The Pilot view finder could be improved as follows:

a. Increase the brightness of the image on the ground glass by using a faster lens, and a more translucent ground glass.
b. Develop a better sun shade for the ground glass.
c. Either build the view finder into the airplane or enlarge the window in the skin of the airplane so as to prevent any masking of the image on the ground glass.
d. Connect the drift mechanism in the view finder with that in the collimating sight so that when the drift is set in one instrument, it is automatically set in the other.

While the above studies were in progress the use of two other ideas to further increase the efficiency in precision flight line flying developed.

The first idea was the use of an Automatic Pilot which has a north seeking directional instrument. This would eliminate the precession in the present directional gyro, and would greatly facilitate the flying of flight lines on any given heading.

The second idea was the use of a collimating sight that could be adjusted for drift and for the lateral angle from the flight line the airplane is on to the adjacent flight lines, so that the pilot could take a back sight on the line just previously flown, and a fore sight on the next line to be flown, i.e., take the guess work out of "window blocking."