of the water, and got some estimate of the wind. In doing this he left a good tail wind and lost about an hour.

Post-Gatty Round-the-World Flight, 1931.—On this flight Gatty used pilotage, dead reckoning, and celestial navigation. He carried a radio set, but made no practical use of it. Except for the fact that full use was not made of radio, the navigation on this flight might be considered the best to that date. He measured drift and ground speed on his own instrument designed for the flight. He constructed his own navigation charts. He used celestial navigation effectively, and claims to have been within 25 miles of his scheduled course at all times. Of particular interest is his feat of making a landfall at Blagoveschensk, Russia, after dark by means of the *Star Altitude Curves*. His best second-setting watch was out only 4 sec. in 10 days.

Lindbergh 1933 South Atlantic Flight.—In 1933, with Mrs. Lindbergh as co-pilot and navigator, Lindbergh flew 3,000 miles across the South Atlantic Ocean. This flight is the best example to date of efficient navigation, and a chart showing the route serves as the frontispiece of this book. There was perfect teamwork between Colonel and Mrs. Lindbergh. Normally he piloted while she operated the radio, observed the ground speed and drift on the Gatty instrument, and kept the log. Lindbergh accomplished the celestial navigation while Mrs. Lindbergh piloted the plane. This is clearly the best combination, since each person may at times have short periods of relaxation. Mrs. Lindbergh was in communication with South America within an hour after the take-off from Dakar, near Bathurst, Africa. She obtained three wireless bearings on the S.S. *Westfalen*, and directed the course to her. Later Lindbergh set a new course to the island of Fernando Noronha, and from there to Natal, Brazil. In other words, they showed the ability to make any desired contacts at sea or on islands by celestial navigation, radio, dead reckoning, and air pilotage—thus making full use of all methods for the safe navigation of aircraft.

NAVIGATION ON SCHEDULED TRANSOCEANIC PLANES

The navigation of scheduled transoceanic aircraft is accomplished with the assurance and accuracy approaching that of ocean liners. The large clipper planes have roomy and fully equipped navigation compartments and full use is made of all available methods for safe navigation. Many of the skilled navigators were formerly licensed marine navigators and are permitted to use their own preferred methods and equipment.

With the two-fold purpose of giving a valuable technical description of the navigation as accomplished on a clipper plane, and also as a tribute

to the author is published with the knowledge of Pan American Airways:

I hope you will pardon this long delay in acknowledging your congratulatory and greatly appreciated letter of April 1st. Preparatory work prior to the flight to Hawaii, and subsequent arrangement and study of data gathered during the flight, has so occupied my time that I am afraid all my friends consider me an extremely poor correspondent.

For reasons which I am certain you will understand, we are not permitted to discuss the particulars of the flight for dissemination among the general public. However, there can be no objection to an informal discussion that will not pass beyond the second party. Having long considered you the foremost authority on the subject of aerial navigation, and appreciating the interest you naturally would have in the Hawaiian flight of the "Pan American Clipper," I am exercising that privilege.

Due to the spacious chart room and large chart table aboard the Clipper, the navigation equipment need not be so severely limited as in smaller planes, hence the choice of equipment may be governed entirely by the individual's personal preference or the Company's desires in the matter. To date the Company has not decided upon any standard equipment, and therefore I chose the equipment used on the subject flight. My choice was not necessarily based upon a conviction that the particular type of any instrument chosen was superior to any other type. As a matter of fact, several factors influenced the selection. Preeminent among them was the fact that most of the instruments had been used extensively by the writer and had proven satisfactory; in some instances a choice was governed entirely by the nature of the work involved—as for instance, parallel rulers versus protractors—and I suspect that plain prejudice, which actuates so many of us, carried some weight.

A set of marine charts, general, coastwise, and harbor, was carried; also aviation strip charts of the California coast. The actual chart work was carried out on VP-3 and 4 Aircraft Plotting Sheets. By working along the track from Alameda to the left-hand border of the chart, then transferring that termination of the track back to the right-hand border in the same latitude, and continuing in this manner, two sheets sufficed for the entire crossing.

Time pieces carried were a Longines Civil Time chronometer, and a Longines second-setting watch. The latter was set to correct G.C.T. at all times by checking with the chronometer. This watch was of the arm type, but the strap was removed, and the watch clips on the octant were adjusted to accommodate the beckets on each side of the watch. I prefer such arrangement to carrying the watch on the arm.

Two sextants were carried—a Pioneer bubble octant, and a mariner's sextant. The former was used for all sights; the latter carried as a "preventer."

Originally a Pioneer Universal protractor was installed on the chart table but experience convinced me that parallel rulers, where room permits their use, are more satisfactory for rapid plotting of long-range D.F. bearings because of their greater scope. Protractors, such as yours, are more convenient for plotting

lessens confusion, so I decided upon the rulers only. Those carried were of the Captain Fields Improved type—graduated in degrees—and consequently the greatest objection to their use in aircraft; namely, creeping, when referring to compass roses, was removed.

I also carried a Dalton Mark VII Aircraft Navigational Computer, which I find a great convenience.

The actual navigation was comparable with such as would be practiced afloat—fixes were determined entirely by stellar observations at night. These fixes were more reliable than would be possible by crossing a line of position with a D.F. bearing, due to the amount of error which would be introduced by even a small angular error in the long-range D.F. bearings. By day, having only the single heavenly body for determination of lines of position, we did cross the bearings. However, during daylight hours we were nearer the radio stations and consequently the error introduced was generally considerably reduced.

The accuracy of fixes was very gratifying. By that, an accuracy of approximately ten miles is implied. My experience is that such a degree of accuracy is about the average one may expect in aerial navigation. A comparison of our expected time of arrival over Kaneohe Bay, Oahu, where our D.F. station is located, and the time of our actual landfall affords a good indication of the reliability of our sights. At 0457 L.C.T., while still above a solid cumulus bank, our fix by ★ Polaris and ★ Deneb was latitude 24°04′ N., longitude 153°14′ W. That was our last observation, and on the strength of it we advised our station we would pass over at 0700. We were then cruising at reduced speed so as to arrive at Pearl Harbor not earlier than 0800. Going below the clouds shortly after establishing the fix, we encountered light mist and scattered showers. The visibility varied between two to twelve miles, which prevented us sighting Molakai, as we would have done with normal visibility. At 0653 we sighted Makapuu Point slightly on our port bow, with Kaneohe Bay directly ahead. At 0700 we were directly off the radio station. This accuracy was due to smooth flying conditions at the time of sight, and of course it could not be cited as an example of accuracy consistently possible.

The greatest difficulty is, of course, the determination of drift angle. We carried smoke bombs and water flares for this purpose. The latter are of an improved pattern and are unusually effective when the surface of the water is visible. However, during both flights—westbound and eastbound—we were above solid cumulus banks approximately 90 per cent of the time. The smoke bombs are not entirely satisfactory. Although a special pattern has been developed, we find that the smoke blends too closely with the water color to afford a good reference mark.

Consequently, the difference between "no wind" positions and fixes established by observations were utilized entirely for determination of drift angle, and, of course, wind direction and velocity for laying new courses. This method proved to have been quite accurate, as indicated by the very nearly direct track we made for the entire westbound flight. However, it would not be so desirable in a region where sudden wind shifts could be expected. Then reliance would necessarily have to be placed on D.F. bearings despite their lack of extreme accuracy.

In addition to the actual navigation, I maintained a very detailed log during both flights. In addition to recording courses, variation, deviation, track made good, indicated and true air speeds, ground speed, etc., a complete meteorological record was kept. As you may imagine, each hour represented sixty very busy minutes.

I consider the development of the Greenwich hour-angle idea the greatest contribution to the science of navigation since Sumner, and have used it exclusively since first published in the Air Almanac. The second-setting watch runs it a close second as a time saver and an aid tending to minimize errors. Navigators owe you a debt of gratitude for those contributions to the science.

I suppose you wonder what method I use for computation of observations. I use Dreisonstok exclusively. Probably another prejudice, but I have used it since it first became available in 1927 or 1928, and still prefer it.

I would appreciate further communication with you upon any navigational matters which might be of mutual interest.

Thanking you very much for your letter, which really was greatly appreciated despite my tardiness in replying, I am

Very truly yours,
FREDERICK J. NOONAN