AROUND THE ATLANTIC WITH THE LINDBERGHS

by

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The scope and success of the flight made by the LINDBERGHS, and the mass of data collected, is of international interest. It should prove of value to others interested in similar flights as well as those interested in the charts, weather and other conditions encountered.

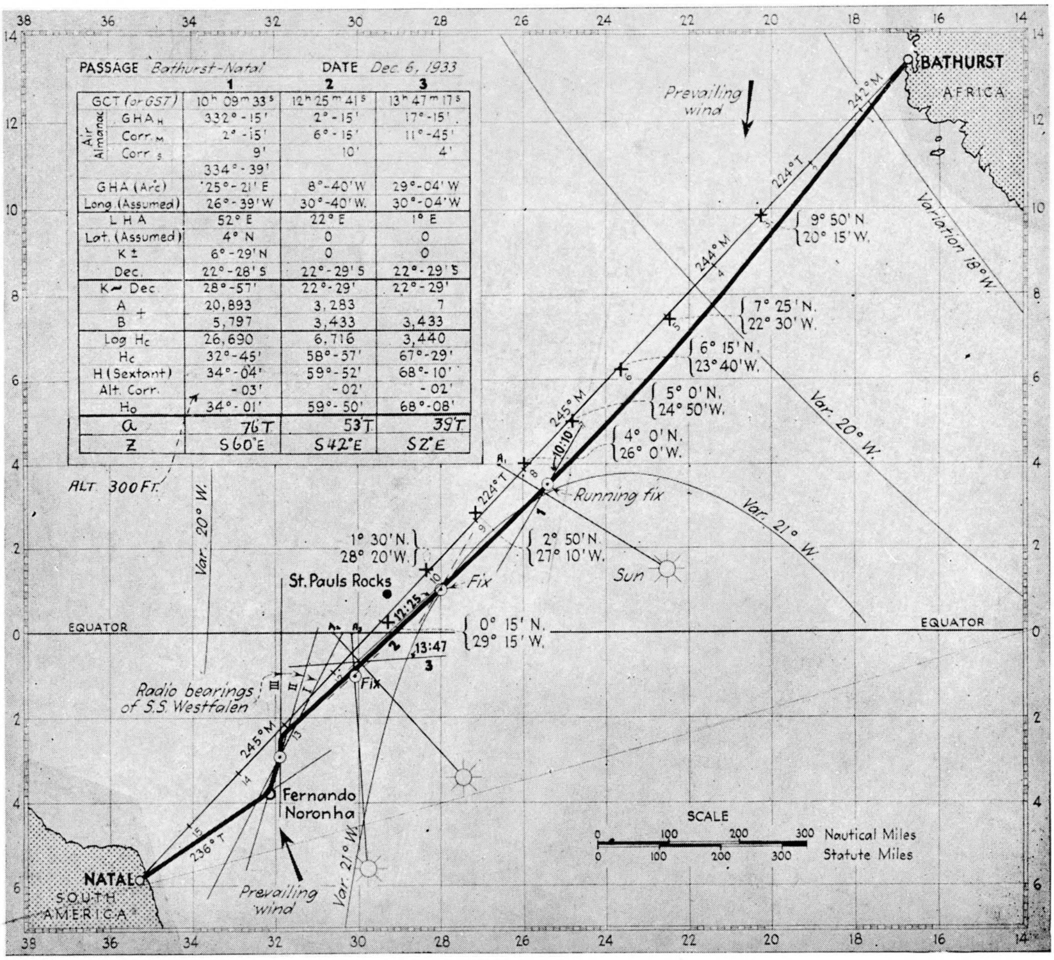
PURPOSE OF THE FLIGHT. — The flight was made primarily to learn as much as possible of the various routes which could be used for an air service between North America and Europe, in connection with Col. LINDBERGH's position as technical adviser to the PAN AMERICAN AIRWAYS. While in the Greenland-Iceland area steamship cooperation was furnished by the chartered Danish supply ship *Jellinge* employed by the PAN AMERICAN AIRWAYS.

CHARTS AND MAPS. — No central source of maps and charts existed. Hydrographic marine charts on the MERCATOR projection were preferred for all areas except in high latitudes when these were available. For navigation around Greenland, the Canadian Government conical orthomorphic projection map was excellent. On that map the great circle course appeared nearly as a straight line, while the scale furnished was accurate within 3 % for the area in which it was used. On the Bathurst-Natal flight (Fig. 1), British Admiralty charts Nos. 2202 B and 2060 A to the scale 1: 7,727,000 were used and found convenient. The heavy marine charts were folded to fit the lap and used without a board. Errors were noted in maps of Greenland, and to a less extent in other areas. This data will ultimately be made available to the mariner and aviator. The Government and civil authorities in each country visited cooperated in obtaining the best available charts and maps.

FLIGHT INSTRUMENTS. — The best available flight instruments were carried. These included the SPERRY gyro horizon and the SPERRY directional gyro for blind flying. The principal instruments included the air speed meter, rev. per min. indicator, dash-board magnetic compass, altimeter, climb indicator, turn indicator, thermometers, and the SPERRY blind flight instruments mentioned above. Nine of the principal instruments were mounted on an anti-vibration mount considered of vital importance for the delicate instruments.

An aperiodic magnetic compass mounted on the right side of the plane between the two seats, and visible from both, was used as the standard compass. The plane was steered continuously by the directional gyro as it was found to give more accurate results, especially in high latitudes, and over water or snow. The magnetic compass tends to swing back and forth over an arc and at a period depending on the conditions. If flying over land where there are ranges, the pilot automatically holds the plane on the course while letting the compass swing off to each side. When, however, the plane is over water or snow there are no ranges and when steering by magnetic compass the pilot follows the compass as it swings off the course and the compass period is increased when the plane is swung off course to follow it. This sets up a bad condition which results in the plane following a series of curved courses. This condition is further emphasized when the plane is near the magnetic pole where there is little magnetic directive force at best. In these adverse conditions any considerable maneuvering of the plane might make the magnetic compass absolutely unreliable; in fact, the compass has been known to turn round and round under such conditions.

On the other hand, the directional gyro is independent of the earth's magnetic force, and once set correctly may be used as a positive means for steering the proper course till mechanical and other errors cause it gradually to leave the meridian to which it is set. LINDBERGH set the directional gyro at intervals of from 20 minutes to 2 hours, though he usually checked it without setting it every ten or fifteen minutes. The



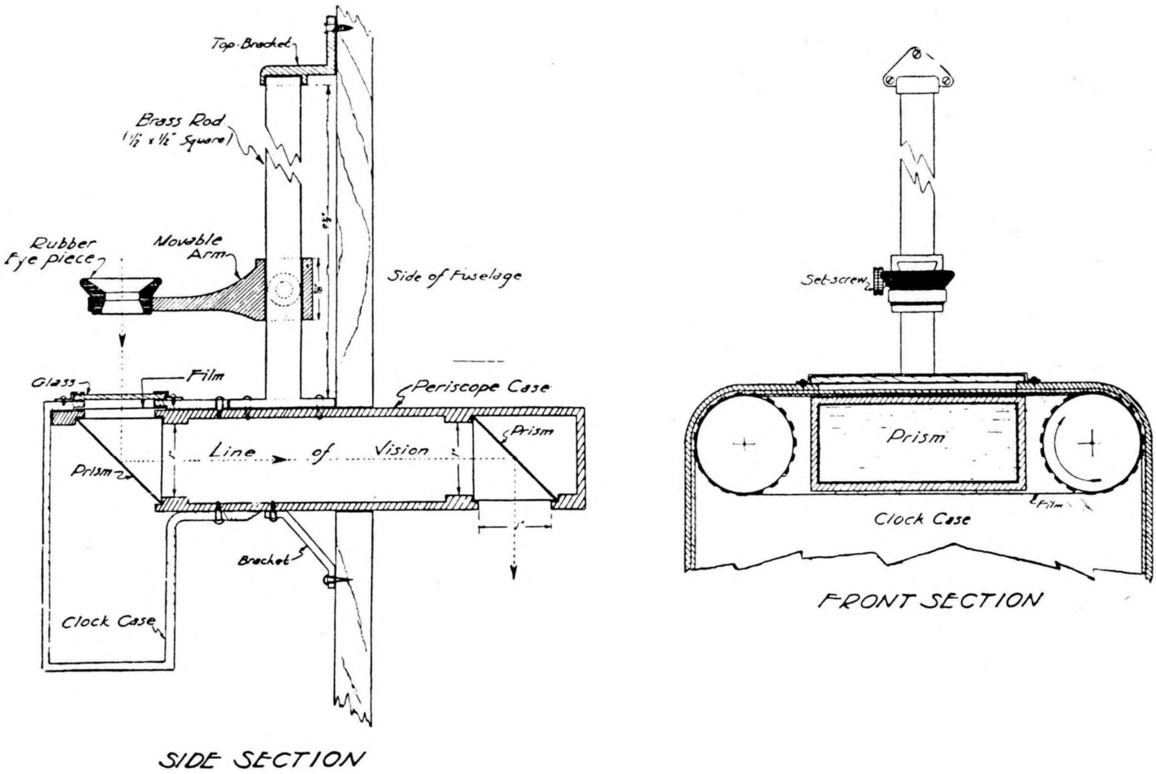
PASSAGE *Bathurst-Natal* DATE *Dec. 6, 1933*

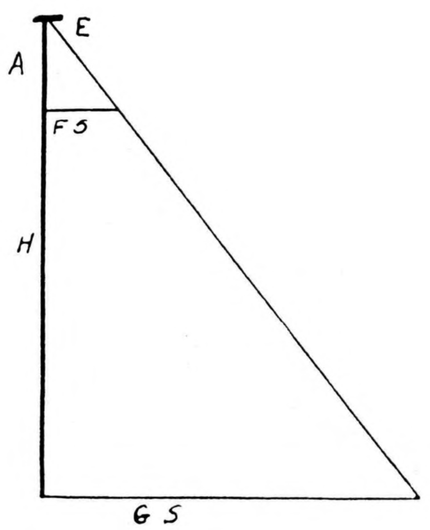
	1	2	3
GCT (or GST)	10h 09m 33s	12h 25m 41s	13h 47m 17s
Air Almanac GHA H	332° - 15'	2° - 15'	17° - 15'
Air Almanac Corr. M	2° - 15'	6° - 15'	11° - 45'
Air Almanac Corr. S	9'	10'	4'
	334° - 39'		
GHA (Arc)	25° - 21' E	8° - 40' W	29° - 04' W
Long. (Assumed)	26° - 39' W	30° - 40' W.	30° - 04' W
L H A	52° E	22° E	1° E
Lat. (Assumed)	4° N	0	0
K ±	6° - 29' N	0	0
Dec.	22° - 28' S	22° - 29' S	22° - 29' S
K ~ Dec.	28° - 57'	22° - 29'	22° - 29'
A +	20,893	3,283	7
B	5,797	3,433	3,433
Log Hc	26,690	6,716	3,440
Hc	32° - 45'	58° - 57'	67° - 29'
H (Sextant)	34° - 04'	59° - 52'	68° - 10'
Alt. Corr.	- 03'	- 02'	- 02'
Ho	34° - 01'	59° - 50'	68° - 08'
a	76 T	53 T	39 T
Z	S 60° E	S 42° E	S 2° E

FIG. 1.

Some details of the Bathurst-Natal flight, including computations for sample sights.

Schéma du parcours Bathurst-Natal avec exemple de calcul d'observations.





GS — *Ground speed — Vitesse au sol.*

FS — *Film speed — Vitesse de la pellicule.*

H — *Altitude.*

A — *Eyepiece scale — Échelle de l'oculaire.*

FIG. 2.

The Gatty Ground Speed and Drift Meter, showing details and principle of the device.

Indicateur de Vitesse au sol et de Dérive Gatty : détails et principe de l'appareil.

magnetic compass gave the best performance when the plane was steered by directional gyro and then gave an accurate check on the course steered. By thus using the aperiodic compass for setting the course and the directional gyro for holding it, an extremely accurate course could be followed. This was one of the secrets of the success in navigation on the flight.

THE *GATTY* GROUND SPEED AND DRIFT METER. — LINDBERGH considers the GATTY instrument the best means devised to date for measuring the ground speed and drift. This type of ground speed and drift meter is mounted inside the plane with a periscope giving a view of the earth's surface, and may consequently be used with comfort out of the wind stream. Figure 2 shows the principle on which the device is constructed, the solution given being that of similar triangle. The one difficult feature in making accurate observations is the fact that the accurate altitude above the observed object is required.

RADIO EQUIPMENT. — The highly successful radio equipment was developed by the PAN AMERICAN AIRWAYS for use on their far-flung air routes. Mrs. LINDBERGH operated the radio in code and obtained splendid results. On the South Atlantic crossing, she was in communication with stations on the South American coast shortly after leaving Bathurst. In addition to the regular radio set weighing 62 pounds, a portable emergency set weighing 44 pounds was carried.

THE DIRECTION FINDER consists of approximately 15 turns of insulated wire secured directly to the inner face of the fuselage thereby forming a fixed loop approximately 30 inches in diameter. A loop tuning unit is provided to go ahead of the regular receiver.

DETAILS OF AUXILIARY RADIO SET. — This auxiliary set was 3 ½ watt capacity, watertight, and as nearly as possible shock-proof. It consisted of both transmitter and receiver, was operated by battery on two frequencies, and was completely self-contained. This set was designed and built under the direction of Mr. Hugo LEUTERITZ, radio engineer of the PAN AMERICAN AIRWAYS. It measured about 18×18×18 inches and could have been taken from the plane for use in the rubber boat or carried with the sledge in case of a forced landing. This set has a range of 150 miles in the daytime and nearly 1200 miles at night. It was developed originally for use in the South American jungles in case of forced landings. For the further extension of its use, it was made water-proof and as nearly shock-proof as possible. In the course of rigid tests, it was dropped 18 feet on concrete and then operated at a range of 300 miles ; it was submerged in water for 24 hours, then hoisted out and found to be in working condition.

The portable radio set may be dropped by parachute to a party in the jungle, or in a boat. In this way relief may be provided when it is not possible to land a plane to render assistance. A party carrying this set may thus be guided through unknown jungles to safety.

CELESTIAL NAVIGATION EQUIPMENT. — In addition to serving as a factor of safety, celestial navigation was effectively used on the long over-water flights. The details of the navigation accomplished on the longest leg of the flight, that from Bathurst to Natal of 1800 miles, will be given in some detail. Fig. 1 shows the route taken, the courses steered and the directions of the prevailing winds, as well as sample solutions of celestial navigation observations.

Two high grade navigation watches kept time to within a fraction of a second, a truly remarkable performance considering the wide range of temperatures, and other unusual conditions to which they were subjected. One of these watches had the second setting feature and was rated to Greenwich civil time. The second navigation watch, in addition to the second setting feature had LINDBERGH's own invention of the arc-reading feature which made it possible to set the equation of time on the watch and then read the Greenwich hour angle in arc (or its supplement) direct from the watch face. However, the use of the *Air Almanac* which tabulates the Greenwich hour angle against Greenwich civil time makes the arc reading features unnecessary as LINDBERGH himself observed. A third watch with 24-hour dial and 8-day feature was also carried to insure against making a mistake in the date in high latitudes. Although it was wound only to the 24-hour mark and permitted to run only to the 96-hour mark, in an effort to get an even tension on the spring, the rate was poor.

LINDBERGH is most complimentary of the *Air Almanac* for 1933 published by the U. S. Naval Observatory, saying it is a great improvement over the *Nautical Almanac* previously available to aviators. Unfortunately, this publication has been discontinued although some of its features have been added to the *Nautical Almanac* for 1934.

For reducing celestial observations to lines of position, LINDBERGH used the Line of Position Book which is based on Dr. OGURA's well arranged and accurate tables. This flight demonstrates the advantage of short simple tables using an assumed position to the nearest degree. An attempt to use a more exact position for the assumed position would not be helpful, but would add to the size of the tables, now only 27 pages.

The weather was generally good on the Bathurst-Natal flight and all sun observations were made from the natural horizon while flying at an altitude of about 300 feet above sea level.

It has been customary, especially when using the bubble for the horizon, to take a series of about ten observations and then to use the average of these for working a line of position. Finding the average of a string of observations is a tedious operation made more difficult by the sexagesimal units used. LINDBERGH avoided this operation by continuing the observations till he got a string of three successive altitudes with consistent increments when using time intervals of about one minute. He figured that when this condition was met it was not an accident, and that either of the three chosen sights would be reasonably accurate. One of the three sights was then worked out and the resultant line of position plotted. As a check another of the three sights was then worked out independently but not plotted. All of this iequired only five or ten minutes, and the results were uniformly good.

The lines of position were plotted directly on the heavy marine charts folded to fit the lap without using a chart board. LINDBERGH makes the definite statement, "I consider celestial navigation necessary to future aviation." He further states that he would not have undertaken the Lisbon-Azores flight or the South Atlantic crossing without a sextant.

The total weight of the celestial navigation equipment was only ten pounds.

It was observed that more accurate sextant altitudes could be taken when the plane was being steered by the directional gyro than when being steered by the magnetic compass; the plane was much steadier when steered by the former.

ACCURACY OF THE DEAD RECKONING. — The accuracy with which the dead reckoning courses were originally set and then followed is both impressive and gratifying. The LINDBERGHS made it a practice to first set the course by making an estimate from all the available data. Later, drift and ground speed observations, as well as celestial observations were made as a check on the navigation. Also, radio bearings were taken when available, and weather and other reports obtained by radio. It was found unnecessary to make any changes of course due to navigation checks obtained, as in each case the original dead reckoning course, or the course set by estimate in flight when a change of wind was observed, was found to be sufficiently accurate. In fact, LINDBERGH thinks that a trained water pilot can estimate the wind drift in low wind velocities nearly as accurately as it can be measured. It must be remembered that usually the wind varies considerably from moment to moment with the result that a series of drift observations are needed to get the average drift. However, LINDBERGH hastens to stress the need of all available means for the safe navigation of aircraft. In any case it is reassuring to have frequent checks on the navigation, and under adverse conditions, it is vital. As LINDBERGH put it, "the pilot should expect to reach the destination by dead reckoning, but should use celestial navigation and radio as a check on the work and as a factor of safety."