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THE "NAVIGRAPH."

By Ives Le Prieur.

From "L'Illustration," April 4, 1925.

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THE "NAVIGRAPH."*

By Ives Le Prieur.

Commander Le Prieur, whose flight experiences in a low-speed seaplane we related in our number of September 27, 1924, invented, four years ago, an instrument destined to render very great service to aviators, namely, the "navigraph," designed to correct errors of orientation due to the effect of the winds during flight. Commander Le Prieur accompanied the Goys expedition to Gao in order to test his navigraph on a long journey and over regions devoid of points of reference. On the return of the participants in this expedition, we requested Mr. Le Prieur to explain, for our readers, the principle of his instrument, whose efficacy was demonstrated on the long monotonous voyage over the Sahara.

The Editor.

Colonel Goys' expedition had, among its objects, that of testing aerial navigation methods on a long journey. It was under this head that I obtained the installation, on the "Roland Garros" and the "Jean Casale," of a small instrument, the "navigraph," which I invented four years ago with the idea of preventing the repetition of such accidents as the tragic loss, in the Sahara, of Colonel Leboeuf and his pilot, Lieutenant Chatenay,

*From "L'Illustration," April 4, 1925, pp. 317-319.

and of General Laperrine, still fresh in all our memories.

I wished to improve the opportunity to subject my navigraph to the severest test in traversing a desert where landmarks are rare and sometimes lacking altogether for more than 400 km (249 miles).

It was under such conditions that I departed from Buc on January 18, 1925, delighted to participate in such an attractive voyage, with a crew consisting of such men as Colonels Goys and Vuillemin and Captains Pelletier Doisy and Dagneaux.

The reader should first know something about the special difficulties to be overcome by the navigator during the voyage. If there were no wind, the pilots could trust to their compasses alone; but the errors due to the lateral force of the wind, if ignored or poorly calculated, could attain a hundred kilometers (over 60 miles) in a few hours flight. Any one can judge of the effect of the wind, who has seen an airplane or airship flying "crab fashion" and can understand why the axis of the aircraft does not necessarily indicate the direction of flight.

Let us briefly consider this problem (Fig. 1). When an airplane, starting from the point A, steers in the direction AX, a lateral wind will cause it to deviate from this course AX. At the end of the time it would have taken, in still air, to arrive at B, it finds itself at C, having followed the route AZ. If we assume that the airplane requires just an hour to fly from A to B, in still air, the vector A B, in the triangle ABC, represents the hourly speed of the airplane in km/hr. with reference to the air; the vector BC will represent the direction of the wind and its velocity in km/hr.; and the vector AC will represent the resultant path actually traversed in one hour with reference to the ground and also the resultant hourly speed. The angle BAC is the drift or course error due to the wind.

The same airplane starting from a point A' situated at the same distance AB from B and steering in the direction A'B, would find itself, under the influence of the same wind, likewise at C, having followed the route AC. In the triangle A'BC the airspeed (speed of airplane with reference to the air) and the magnitude and direction of the wind have remained the same. Only the ground-speed (speed of airplane with reference to the ground) and the drift have changed.

An airplane starting from any point on the circumference AA' with a radius AB and steering toward B would follow a route passing through C. We can thus find a point A" such that the direction A"C is the direction to be steered by the airplane in order to arrive at its destination C.

The navigraph renders it possible to reproduce, on a small scale, the triangle with the three vectors AB, AC and BC. It affords the means for following the most direct route between any two points, whatever changes may occur in the direction and velocity of the wind and without its being necessary to identify the regions flown over. It renders it possible to fly from one point to another by the shortest route, without previously being acquainted with the region to be flown over.

It consists essentially of a small telescope connected with a pencil by a hinged parallelogram, which keeps them parallel (Fig. 4). The motions of the pencil and, consequently, of the telescope, are recorded on a strip of paper. Another piece of paper (this one circular) mounted on a graduated drum, serves for the graphic resolution of the triangle of velocities.

Any point that is sighted on the ground through the telescope is indicated by the pencil on the paper strip (Fig. 5). If the telescope follows this point in its apparent motion under the airplane, the pencil traces a line whose general direction is that followed by the airplane with reference to the ground and which consequently gives the angle of drift. This direction is recorded by the operator by drawing a line along the hinged ruler on the paper circle. This line is termed the "drift line." If the compass course of the airplane is then slightly changed and if the operator repeats the same operations by following a new point on the ground, he will obtain a second drift line. The paper circle having, during the change in the course, been turned by an angle equal to that through which the airplane has turned, the two lines intersect at a point C. The vector BC, which represents the wind in magnitude and direction, furnishes the key to the problem. A simple motion, in fact, enables the navigator to find, immediately and without calculation, the corrected course according to the wind. This course, followed by the compass, will keep the airplane in the precise direction of the goal.

This course remains correct only so long as the wind does not change. The wind generally does change, however, as shown, for example, by the accompanying graph of the winds encountered on the Paris-Gao voyage (Fig. 2). During the entire flight the navigator must, therefore, attentively watch for the slightest change in the wind. Hence he frequently puts his eye to the telescope of the navigraph, in order to discover the slightest change in the angle of drift.

In this connection, it is surprising to note, on the graph of the stage from Tessalit to Gao, that if the navigator had been content to follow the course as corrected on starting, the airplane would have been, at the end of the 450 km (280 miles) stage, 82 km (51 miles) off its course, instead of only 4 km (2.5 miles) due to frequent use of the navigraph.

On both the "Roland Garros" and the "Jean Casale," the instruments comprised:

A Vion compass (V) mounted in the axis of the airplane (Fig. 3);

A route compass (R) mounted in front of the pilot;

A Le Prieur navigraph (N);

A table (T), convenient for navigation maps.

The airplanes were particularly well adapted for the installation of the instruments, due to the comfortable and commodious room reserved for the navigation service in the front end of the cockpit.

The ground was easily observed through glass windows. The navigraph was mounted on a horizontal shelf between the windows and the cockpit. A suitable opening in this shelf rendered it possible to make vertical observations through the telescope.

From the navigation viewpoint, the route to be covered consisted of: stages where the course could be followed on the ground from details given on the map; one stage of 200 km (124 miles) over the sea; stages over the Sahara without possibility of identification. The stages of the first class were: Buc-Avora-Perpignan-Alcazares; Oran-Colomb Bechar-Beni Abbes; Ouallen-Tessalit. For these stages the method of navigation combined the use of the navigraph with the identification of the points flown over.

The navigraph enabled me to know at all times the direction and velocity of the wind and to deduce from them our speed with reference to the ground, the latter being naturally dispensed with during hours of flight over known landmarks.

This knowledge of the prevailing wind and of the corrected course constituted a guaranty for cases where all landmarks were temporarily obscured by clouds or fog.

Crossing the Mediterranean.- This stage of 200 km (124 miles) was flown entirely by navigraph. We chose the loxodromic course of 185°, corrected to 180° by reason of a known east wind of 15 km (9.3 mi.) per hour at the start and of 10 km (6.2 mi.) at the finish. This course brought the airplane to within 2 km

(1.24 mi.) of the goal, an error of only 1%.

Stages above the Sahara.- These stages, the most difficult from the navigation viewpoint, were as follows:

Beni Abbes-Adrar.- Distance 320 km (about 200 mi.); loxodromic course by compass, 156° (Fig. 6). It was decided, during this stage, to follow the direct course by leaving the customary trail on the left and at about 30 km (18.6 mi.). During this stage we encountered four different winds:

At 7.45 a.m., a wind of 120° at 10 km (6.2 mi.) per hr.
" 8.25 " " " " 120° " 25 " (15.5 mi.) " "
" 8.55 " " " " 60° " 25 " (15.5 mi.) " "
" 9.40 " " " " 100° " 45 " (28mi.) " "

At 8.50, on the order of the chief of the expedition, we made a 20° change of course, in order to approach the trail (due to uneasiness about the running of the engine).

At 9.20, without ground observation, we resumed the estimated and corrected direct course toward Adrar and landed at 10.05 with an error of less than 1 km (0.6 mi.). Had we followed the direct course by compass without wind corrections, the error would have been 65 km (40 mi.) to the right. If we had simply corrected for the known wind at the start (a case where we would have been supposed to make an aerological sounding), this error would have been 42 km (26 mi.) to the right.

Tessalit-Niger (Gao).- Distance, 450 km (280 mi.) without landmarks; loxodromic course by compass, 207° (Fig. 7). This course was adopted so as to reach a precise point on the Niger half-way between Bourem and Gao. The winds encountered on the route were:

At 7.09 a.m., a wind of 90° at 35 km (22 mi.) per hr.;
" 7.30 " " " " 215° " 15 " (9.3 mi.) " "
" 8.10 " no wind;
" 9.15 " a wind of 210° at 20 km (12.4 mi.)per hr.

We followed a rectilinear route and came within 4 km (2.5 mi.) of the desired point, an error of only 1% or 0.5°. Had we followed the direct course by compass, without wind correction, the error would have been 13 km (8 mi.) to the right. If we had simply corrected for the known wind at the start, the error would have been 82 km (51 mi.) to the left.

In short, this trip of 4200 km (2610 mi.) enabled me to demonstrate that large airplanes, like the 4-engine Bleriots, are really adapted for long trips and that, in particular, their navigation cabins leave nothing to be desired. The navigraph always gave me the wind very exactly and the navigation errors never exceeded 1 km in 100 km flown. The navigraph must therefore be included among the meteorological sounding instruments, since it determines the wind at the precise time and place where the course of the airplane needs to be corrected. Soundings with a pilot balloon or theodolite gives the wind at only one point and then with a delay that renders its value doubtful. It requires, in order to be of much value, a very extensive organization in materiel and personnel.

Accessibility of Engines During Flight.

I cannot refrain from thinking of how much these great ships of the air would be improved by rendering their engines easily accessible during flight. It is impossible to guarantee the uninterrupted functioning of an engine, however good it may be, if it remains inaccessible during flight. If we are to make long non-stop flights (which is the true reason for the existence of aviation), it will be necessary to rely absolutely on the continuous functioning of the engines. In the very great majority of cases, engine stalling is due to some trivial cause, like the breaking of a fuel pipe, the encrusting of a spark-plug or the burning of a magneto. With easy access to the engine, any mechanic could repair such troubles in a few minutes and start the engine again. Due to the presence of other engines, such a brief arrest of one engine would not prevent the airplane from continuing to fly without loss of altitude, as I witnessed for ten minutes on the departure from Adrar of the airplane piloted by Colonel Vuillemin. The great problem (and I venture to say the chief one), for the French air service to solve as quickly as possible, is to create an airplane of the type now in use, but with easy accessibility to the engines during flight. Such an airplane is technically possible and several of our foremost constructors have contemplated building one. They have hesitated, however, on account of the great expense it would entail.

Such an airplane would mean the real success of aviation, by making the engines capable of guaranteeing long non-stop flights, such as from Paris to Algiers, Paris to Buenos Aires by Dakar and Pernambuco, and Paris to New York. The successful crossing of the Atlantic by Alcock in 1919, on a single-engine airplane was a bold undertaking, but of no use for aviation in the long run.

It would seem foolhardy at the present time to attempt to cross the Atlantic, even with our multi-engine airplanes which, sooner or later, would be compelled by engine trouble to descend to the water and to almost certain disaster, and still more foolhardy with only one engine, however excellent it might be.

On the contrary, multi-engine airplanes provided with navigation cabins and cabins for the engines, will have no reason to envy the giant airships. They will be the acme of safety in aviation and the real "masters of the air."

The French air service has the opportunity to take the step which I almost venture to call decisive. Let us not allow this opportunity to escape.

Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics.

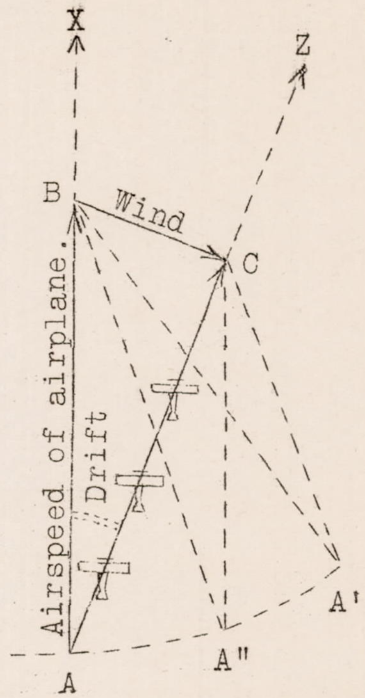


Fig.1 Triangle of composition of the air speed AB with the wind velocity BC giving the resultant speed AC and the drift BAC.

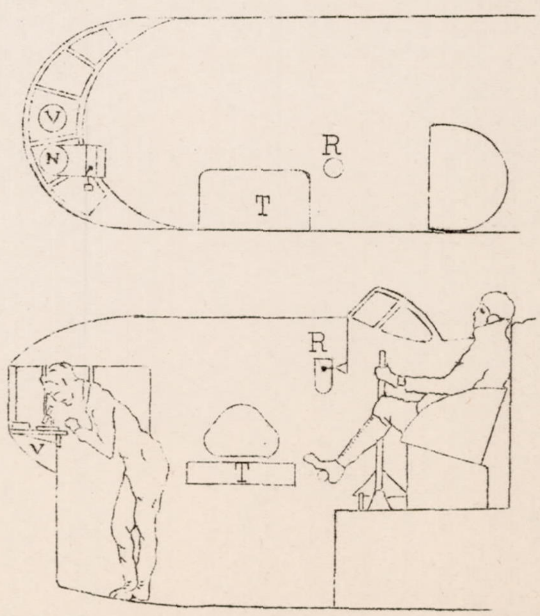


Fig.3 Diagram of navigation cabin. V, Vion compass. R, route compass. N, LePrieur Navigraph. T, map table.

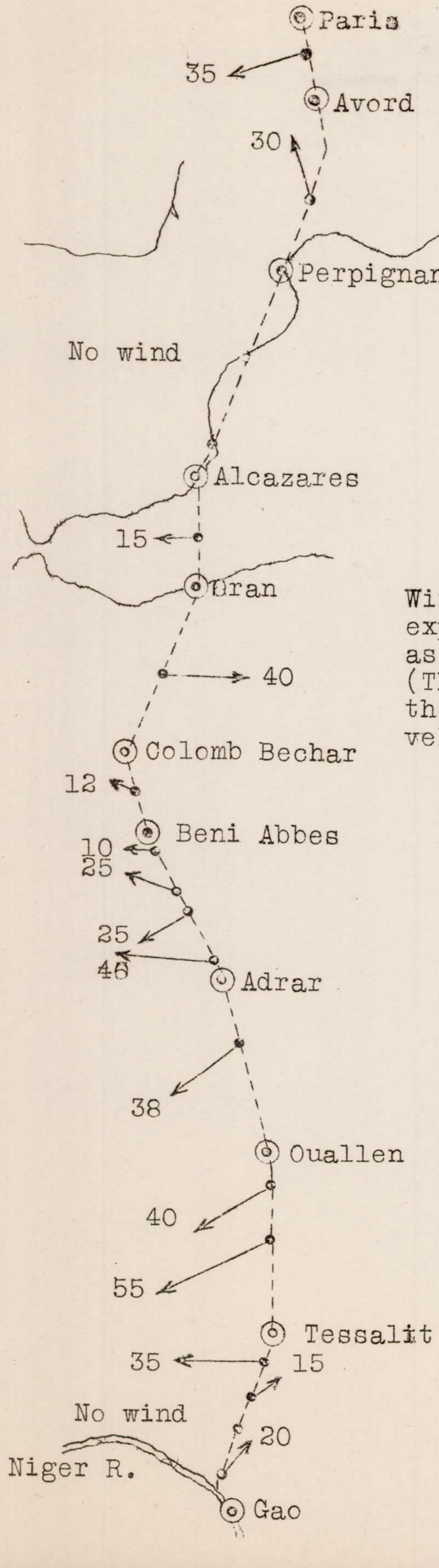


Fig.2
Winds encountered by the Goys expedition on the route Paris-Gao as determind by the navigraph. (The arrows show the direction of the wind and the figures give its velocity in km/hr.)

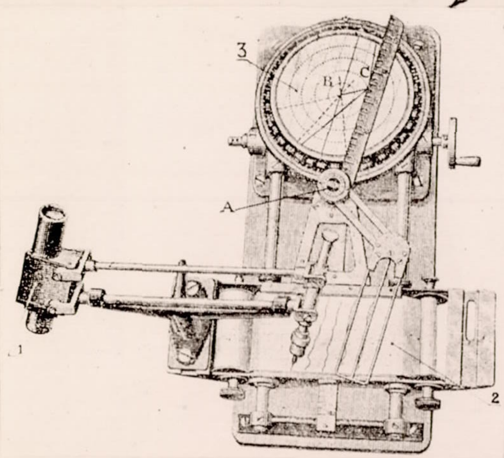


Fig.4 The Le Prieur navigraph. Telescope(1), for viewing points on the ground, connected, by means of hinged arms, with a pencil for tracing on a paper strip(2) the lines of drift. Dial(3) provided with a paper circle for inscribing the triangle of velocities (speed of airplane AB, wind velocity BC ground-speed AC). The ruler AC renders it possible to trace the drift lines on the paper circle.

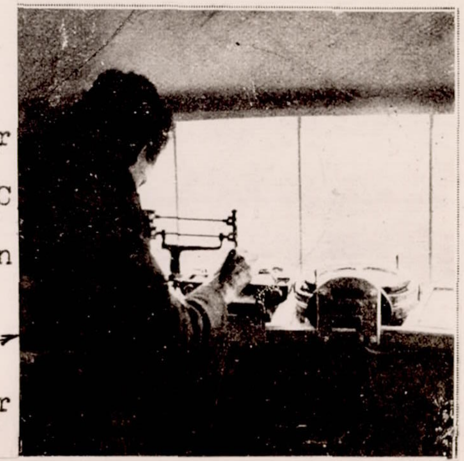
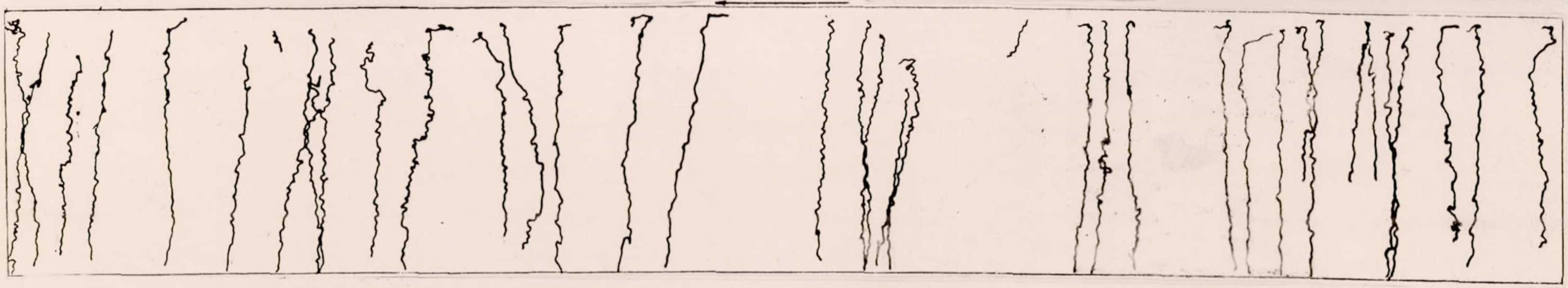
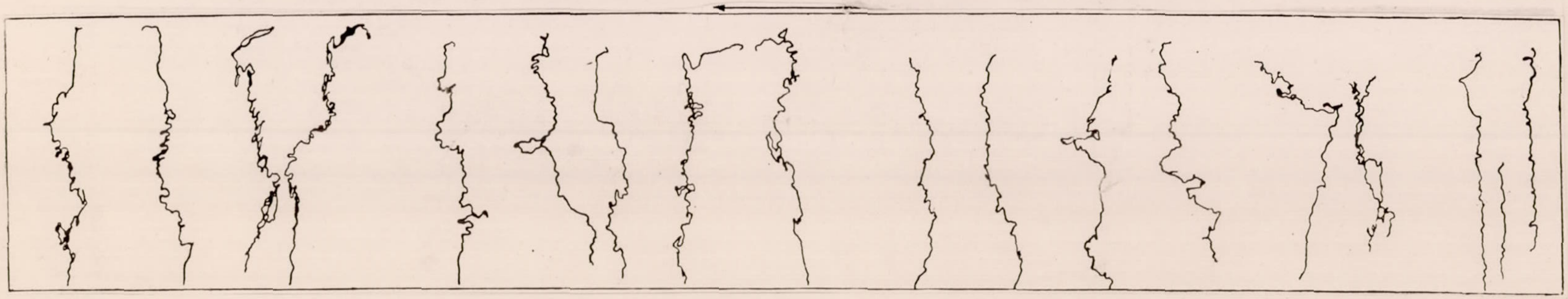


Fig.5 Cabin of the "Roland Garros". The navigraph, to the left of the compass, is being operated by Commander Le Prieur.



Obtained Jan.23, over sea, between Tarragone and Alicante, by sighting crests of waves.



Obtained Jan.25, between Oran and Colomb Bechar in a very agitated atomosphere.

Fig.8 Facsmiles of drift diagrams recorded by the Le Prieur Navigraph on the "Roland Garros".

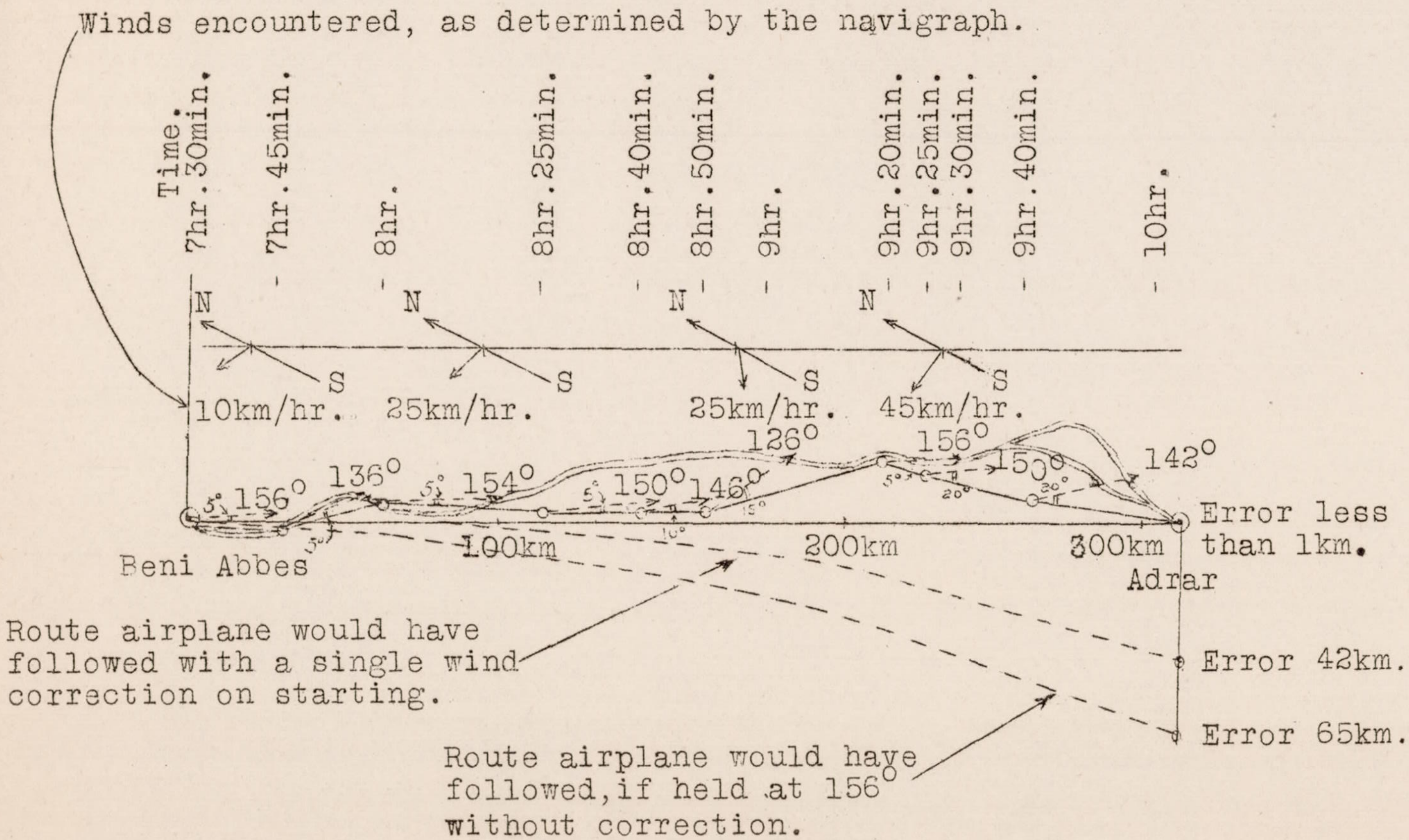


Fig.6 Itinerary of the Roland Garros between Beni Abbes and Adrar.

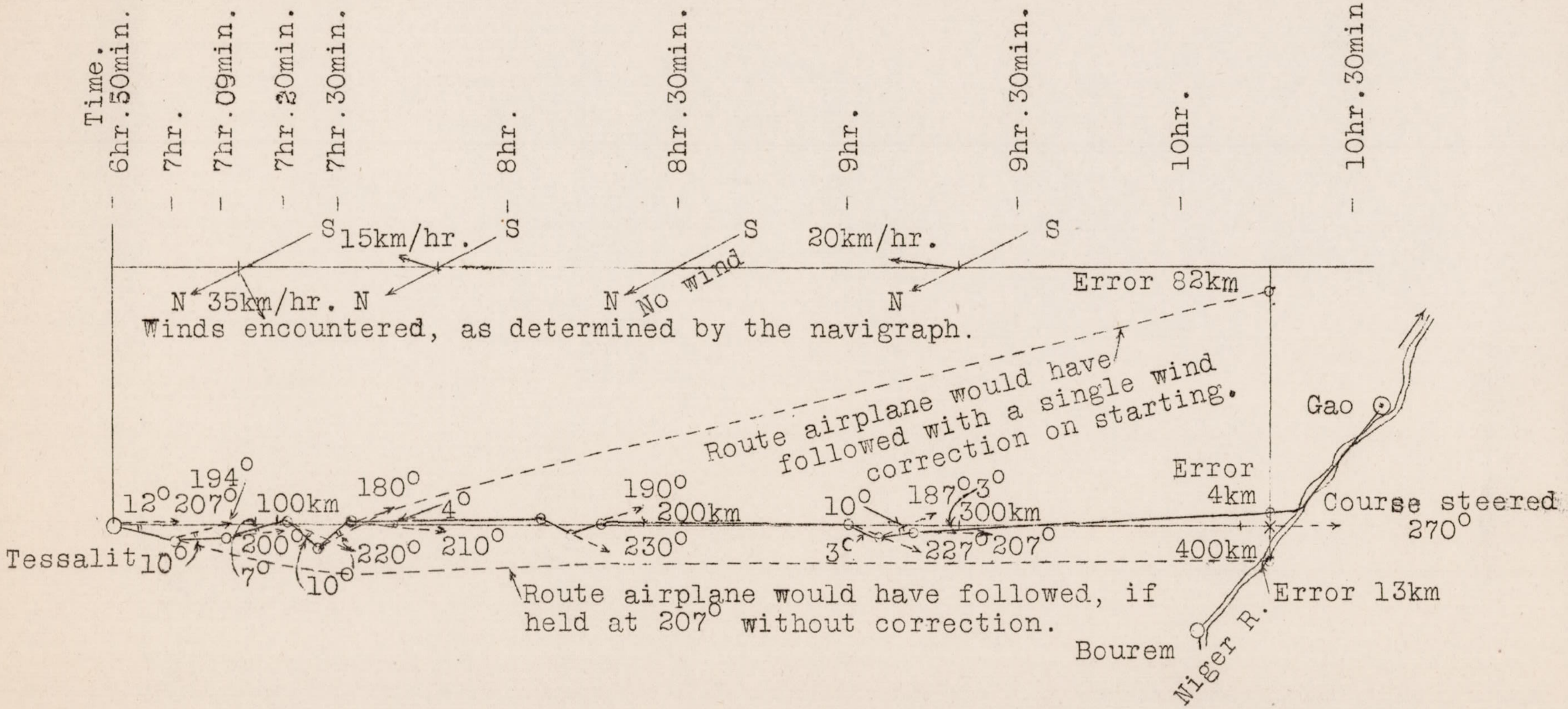


Fig.7 Itinerary of the Roland Garros between Tessalit and Gao, rectified during flight with the aid of the navigraph.