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THE APPLICATION OF THE AUTOMATIC RADIO DIRECTION FINDER TO AERIAL NAVIGATION

BY

H. BUSIGNIES*

Delivered before the Radio Club of America
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Introduction

Ten years ago intitial efforts were made to develop a radio compass system, then called "Hertzian compass" in which the angles indicating the position of a radio transmitter with respect to the axis of the plane, appeared automatically on a graduated scale, similar to the scale of a gyro-compass indicator or repeater.

Two years ago the device was put in commercial production and, particularly for the French air force, had a great many applications.

An automatic and unbroken visual indication of the direction of a radio station has numerous advantages in navigation. By eliminating manual operation, navigation is made simpler and the chances of error, due to non-automatic and thereby intermittent indication, are reduced.

Under normal conditions, natural landmarks, villages, houses, or other prominent indications are often sufficient for navigation, the necessary information being transmitted to the human eyes by light waves. The automatic radio compass with its continuous visual indication of the position of a distant and unseen radio transmitter in effect increases in a simple way this visible horizon of the pilot.

We find in nature a similar extension of the horizon. Naturalists think that carrier pigeons and migrating birds navigate by using waves of a nature and in a manner unknown to us.

So far as is known, radio compasses usually indicate merely the deviation of the airplane from its proper direction: if the plane be headed towards the right, the needle indicates "right"; if the plane be headed towards the left, the needle indicates "left," but no indication is given to the pilot as to how many degrees the plane has turned.

We think that the words "homing devices" must be preferred for such systems and "radio compass" kept for instruments of the class of the one to be described, in which the direction of chosen transmitters, situated all around the plane, may be indicated. More varied applications are thus possible than in the case of an instrument showing only the direction to the left or to the right of the axis of the airplane.

Principles

A receiving loop aerial turning regularly around a vertical axis permits maximum reception every time that the plane of the loop passes in the direction of the transmitter. If the loop turns regularly at a certain speed, a certain number of maxima and minima of receptions per second can therefore be observed in a receiver tuned on a transmitter.

A rotating speed of five revolutions per second has been chosen. Maxima and minima of receptions, therefore, take place at the rate of ten a second.

The phase of these maxima and minima, i.e., the moment at which they occur in connection with a given origin, depends on the direction of the transmitter in relation to the axis taken as origin. If the loop turns regularly, these maxima always appear when the plane of the loop points in the direction of the transmitter. If the location of the transmitter changes in relation to the radio-compass, the minima and maxima phases also change. This changing of phases is utilized in the apparatus to obtain the automatic indication. (See Figure 1).

The high frequency waves received in the loop pass through amplifier, detector, and low frequency amplifier stages in the receiver. In the output stage a variable current, representing the maxima and minima of reception, with phases identical to the phases of the wave received, is thus obtained. To obtain the measurement of phase in the indicating instrument, it is necessary to adopt a known origin as point of reference. This origin is obtained by placing on the rotating axis of the loop a two phase current generator, the phase of which is constant in relation to the revolutions of the rotating loop.

The variable current obtained at the output stage of the receiver, representing the maxima and minima of reception caused by the rotation of the loop, and the two phase currents from the generator are fed into a special

* Radio Engineer, Les Laboratories, L. M. T., Paris.

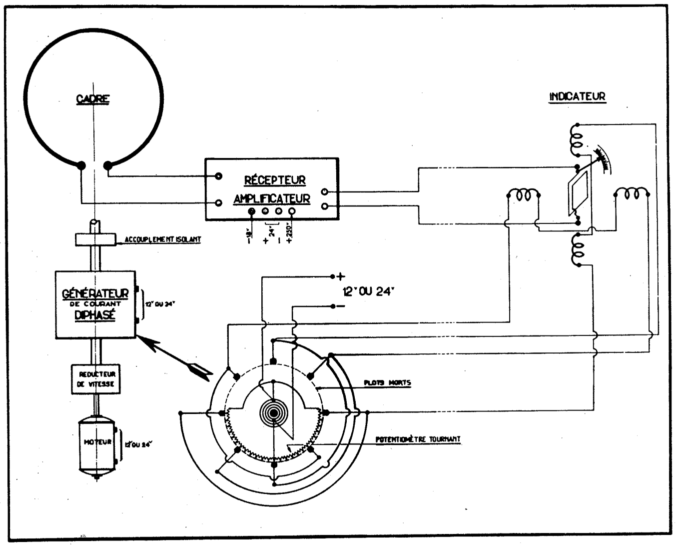


FIGURE 1
SCHEMATIC LAYOUT OF EQUIPMENT

improved phasemeter. The two phase current creates a rotating field in a magnetic stator, comparable to the stator of a synchronous motor. This field rotates at a speed double the speed of the loop. The variable current from the receiver actuates an armature carrying a pointer associated with a dial. In this armature, therefore, an alternating current is produced by the rotation of the receiving loop and, in the stator, a fixed phase rotating field exists due to the two phase current generator. Thus the magnetic reactions of one flux on the other give a definite position to the armature, which sets itself perpendicular to the flux when the current going through it is maximum, thereby indicating the desired phase relationship and, as will be evident later, the direction of the transmitter.

General Layout

As seen in Figure 2, the two phase current generator consists of a revolving potentiometer, fed by d-c. current, rotating regularly between fixed brushes. These brushes represent alternately opposite points of maximum positive or negative potential, and pass through all intermediate values in such a way that the result is the production on these brushes of an angular potential waveform which is rendered sinusoidal by the inductance of the stator of the indicating apparatus. Accordingly, an indication can be obtained at any distance, as only one simple electric link between the indicator and the other parts of the equipment is employed.

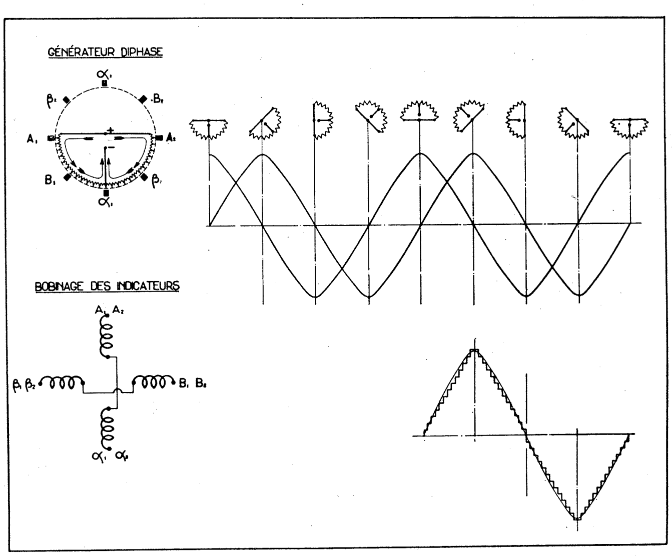


FIGURE 2

The potentiometer consists only of half a circumference since there are two maxima and two minima for each revolution of the receiving aerial, i.e., two periods of the variable current at the output-stage of the receiver for each one revolution of the loop. In order to synchronize the two phase currents with the variable current at the output-stage of the receiver, it is necessary that they should have the same frequency as the variable current. It is, therefore, necessary to double the rotation speed of the rotating magnetic field by doubling the frequency of the two phase currents relative to the rotating frequency of the loop.

The origin of indication is simply the setting which exists between the two phase generator and the receiving loop: by modifying this setting by mechanical means, the

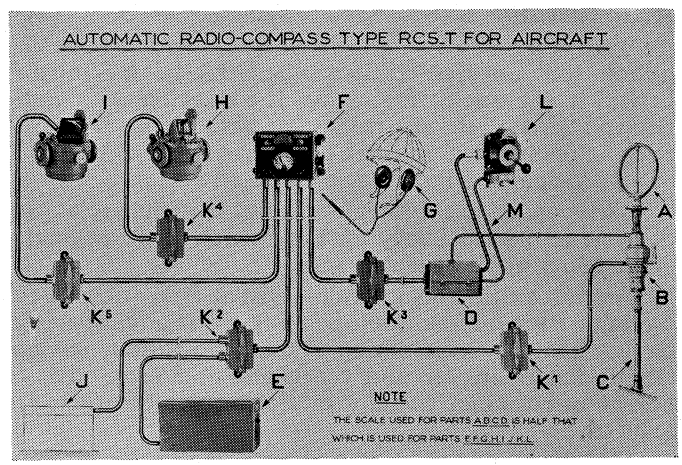


FIGURE 3
AIRPLANE AUTOMATIC RADIO-COMPASS TYPE R. C. 5

origin can be modified as desired to have the indicators show zero angle when the airplane is heading towards the transmitter.

The indicators not only utilize the current maxima to show the direction, but they also entirely integrate the variable current due to the signal. Therefore, the sensitivity is very high and the stabilising of the indicators is proportional to sin α (α being the angle through which the armature might be artificially pulled out of position).

Description

Figure 3 gives a general view of the equipment. The indicating apparatus and the control units are shown on a scale double that of the loop. "A" represents the receiving loop. Beneath it, the high frequency collector, which gathers the currents generated in the loop and, also, the high frequency transmission line leading to the receiver are mounted. "B" represents the small generator, the reducing gear, and the motor operating the receiving loop.

The receiver D and the rotating loop A are entirely remote-controlled by a small control unit, comprising simply the mechanical remote tuning of the receiver, a volume control to adjust the signal intensity, and a main "on" and "off" switch which, in a third position, starts the rotation of the loop.

Two indicators are utilized. One is called "navigator's indicator" and the other, "pilot's indicator." In the first, the indication is read on a movable dial graduated in 360° and moving in connection with a fixed pointer. In the second, the indication is limited to plus or minus 15°. The first is called "navigator's indicator" because it allows any of the crew of the airplane taking bearings to determine the position of the plane in relation to any given transmitter located around the plane.

The second is specially limited and designed for flying toward any given transmitter, and especially concerns the pilot. It represents an important advantage over the so-called "homing" systems, and permits correction for drift.

By means of this indicator the pilot can modify the reference axis by $\pm 15°$ in such a way that by altering his pointer the same number of degrees as the angle of drift he can steer with his indicator on zero and thus fly a great circle course directly to the transmitting station. This would not be possible with a so-called "homing" device. In fact, for this facility, it is necessary that the indicating apparatus indicate angles and that it be not limited to indicating a movement to the left or to the right.

In Figure 3, E represents the converter for the anode high tension; this converter is fed by the storage battery J.

The junction boxes K_1, K_2, etc., allow very rapid replacement of any part of the apparatus by a standard, identical part.

The receiver is shock-proof mounted; the wave-length range covered in two steps is 200-2000 meters (1500-150 kcs.). The radio compass is entirely supplied by the airplane's battery, 24 or 12 volts, and will operate correctly with a current variation of $\pm 15\%$.

When piloting, it is difficult to maintain an indicating graduated dial on a predetermined value and pilots prefer to keep a needle in one position without figures, even if they have to do the setting by other means. It is this principle which is used here.

The radio compass does not itself indicate the "sense" of direction. It will be shown later that there are several ways of eliminating this 180° ambiguity.

A few months ago, a relative distance-meter was incorporated in the equipment. This is a milliammeter in the automatic volume control circuit which indicates the relative strength of the signal. With this distance-meter, the approach of the station can be seen continuously and the attention of the pilot called when he is near the station.

The total weight of the apparatus without the wiring is 48 pounds. Depending on the size and type of the airplane, a few pounds must be added for wiring.

Installation on Planes and Quadrantal Deviation

Installation on board airplanes gives rise to a certain number of problems.

The first is the deviation of the waves due to the metal parts of the airplane or to the closed circuits formed by them. These deviations are constant and cause errors in bearings which may be as much as $\pm 10°$ or 15°. Nevertheless, by choosing the proper location for the loop it is possible to reduce these deviations to a small figure, sometimes even to zero.

Another problem is to satisfy, at the same time: the condition of location of the loop and other parts, and the condition of the possibility of mounting the parts inside the plane.

From this last point of view the reliability of the equipment is very important and it is pointed out, that all the parts of the equipment are independent and can be installed in any location on board; the transmission line between the loop and the receiver can be any length up to a maximum of 10 meters.

Figure 4, which is an example of installation, shows the receiver installed near the loop; this receiver could also be installed near the radio operator or the pilot.

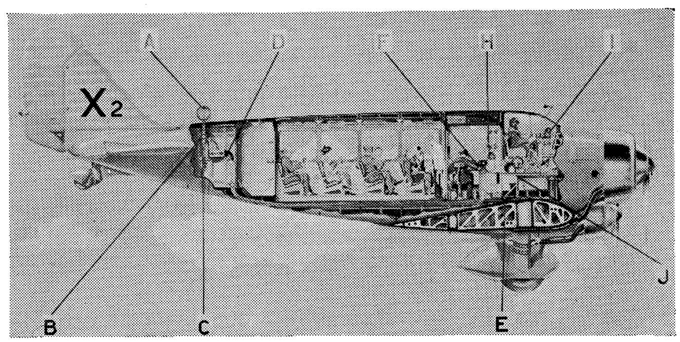


FIGURE 4
TYPICAL INSTALLATION OF R. C. 5 RADIO-COMPASS

We have made an extensive study of the deviations called "quadrantal deviations" and we know, for the usual "shapes" of planes, the best loop location to minimize the deviation.

However, due to the fact that it is sometimes difficult to put the loop in the best position from the radio point of view, we have developed two useful processes to avoid the necessity of consulting a correcting table after checking bearings.

The drag due to the small loop stopped in any position is about 7 pounds at 110 miles per hour and increases only 15% when rotating.

This increase is constant for any greater or smaller speed. The effect of rotation is very small because the speed of the sides of the loop is small in relation to the speed of the air stream.

However, to reduce the drag in very high speed planes, we have tested loops partially recessed in the fuselage and covered with a stream-lined housing.

Figure 5 shows the attenuation of the signal strength in relation to the high H of the loop outside the fuselage. When the loop is half recessed, the attenuation is of 4.5 decibels, which is an acceptable figure.

Figure 6 shows the loop half recessed in a fuselage without the stream-lined housing. The circuits located on each side of the loop are adjusted to compensate the quadrantal deviation due to the fuselage and reduces this deviation from $\pm 12°$ to $\pm 2°$ as shown on Figure 7.

When this process of compensation is not utilized, it is possible to avoid the use of correcting curve by means of a small instrument called the "Radio-navimeter"

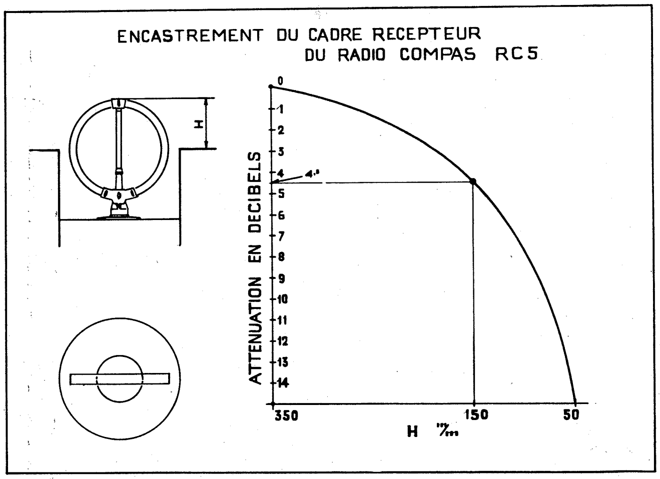


FIGURE 5
RECESSED LOOP; ATTENUATION OF THE SIGNAL

which, by adding the true geographic course of the plane with the angle of bearing of the radio station relative to the plane, directly gives the true bearing of the station in relation to the North.

It is only required to put two pointers on the angular values found, and a cam, adjusted according to the deviation curve automatically operates these corrections, and then assumes true readings.

To adjust the cam, it is simply necessary to draw the quadrantal deviation curve on it, as on a graph, and to cut it out along the curve.

It should be noted that in "homing," this instrument is not required, the reference to the North not being used and the deviations for angles near zero degree being negligible. Figure 8 shows two views of the "Radio-navimeter," front and rear, and between them the cam before adjustment.

Accuracy

The guaranteed accuracy of the apparatus is $\pm 2°$ for a distance of about 500 km. from a 300 watt transmitter.

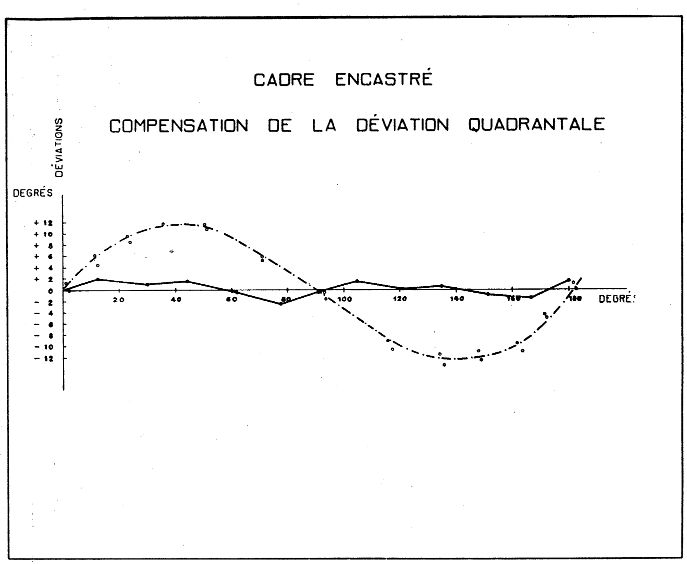


FIGURE 7
REDUCTION OF THE QUADRANTAL DEVIATION BY COMPENSATING CIRCUITS

Figure 9 shows how, by the adjustment of polar pieces in the indicators during the development, the error curve of the indicators has passed from curve 1 to curve 4 by curve 2 and 3; the tolerance in manufacture is $\pm 1°$. This error is the only one in the radio compass. The receiver is very sensitive and, in most cases, this sensitivity is not fully employed.

The range of powerful broadcasting stations is, of course, much greater than that indicated for the small power stations. Through a station like Radio-Paris (60 kw.), it is possible to work the R.C. 5 radio compass as far as 2,000 km., and even more, at sea. Naturally ranges at sea are much greater for a given power than on land.

In fact, from the point of view of accuracy, it is difficult in an airplane to navigate within 1° or 2° and, therefore, this figure is fully satisfactory for aerial navigation.

Due to the well-known inertia of the magnetic compasses, it is difficult to keep an airplane on a steady course

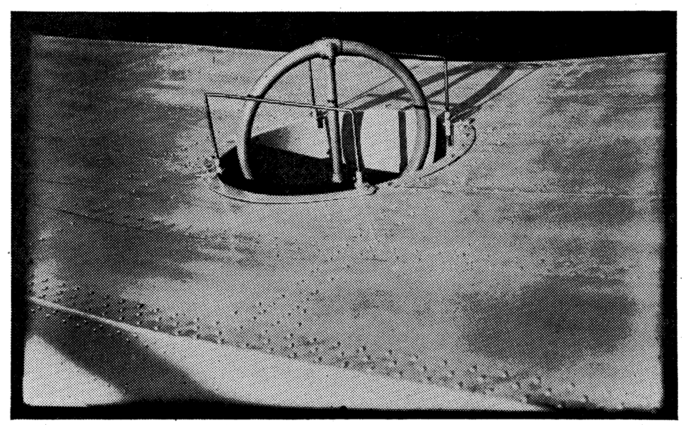


FIGURE 6
PARTIALLY RECESSED LOOP, AND COMPENSATING CIRCUITS QUADRANTAL DEVIATION

by means of a magnetic compass alone. The great stability of the R. C. 5 indicators, therefore, considerably facilitates the keeping of a correct course. In this connection it should be noted that the direction finders allow for a plane, an inclination of about 30° without producing a fault greater than 1°.

The above reference is not meant to be a criticism of the utilization of the magnetic compass which, so far, is an indispensable apparatus, even a gyro is present on board, but it is desired to show the advantages offered by navigating directly with the indications of the radio compass. Furthermore, the utilization of the magnetic compass or gyro can always be combined with that of the radio compass.

Interference.

As indications are given automatically, an important point is the question of interfering transmitters. When using the equipment on broadcast transmitters and radio-beacons, interference is not to be feared, due to allocation of wave-lengths. However, the use of broadcasting stations operating on common wavelength is recommended only when near the station used (50 miles).

Very exhaustive experiments have been made on the question of interference. Two stations of the same power, at the same distance, were used, situated 90° one from the other, which is the worst case as regards interference: the frequency of one station was varied in order to note when it would start and when it would stop interfering with reception of the station having a fixed frequency.

A difference of 1 kc. between the frequencies of the transmitters is sufficient to give a correct indication on the fixed frequency transmitter. However, interference, if any, can both be seen and heard, and thus the operator is warned against the use of such indications.

Night Effect

Like all radio direction finders, the apparatus can be affected by the "night effect" produced by the fact that at night the radio direction finder receives two or more waves; the direct wave following the curvature of the earth, and the indirect waves being reflected by the ionosphere. On land this error starts at about 70 to 100

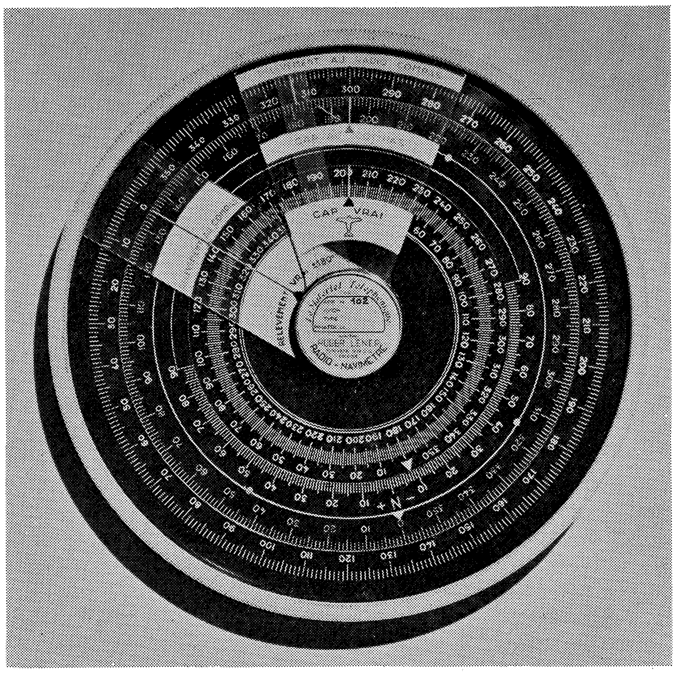


FIGURE 8A,
RADIO-NAVIMETER, FRONT AND REAR VIEWS. CAM CORRECTING QUADRANTAL DEVIATION BEFORE ADJUSTMENT

km. from transmitters employing ordinary antennae; at sea, the error starts at greater distances: 200 or 300 km.

In order to reduce this error on land, numerous means of transmission can be employed. Transmitters utilizing an aerial strictly vertical or an "anti-fading" antenna, considerably reduce these errors and the operating range increases by 200 km., which is sufficient in most cases where the radio compass is utilized. It is possible to navigate by utilizing stations situated one after the other without having to take, when starting, the most distant station. The antenna-type radio-beacons used extensively in the U. S. A. give a good range without night effect.

Stations Available for Direction Finding

The question is often asked as to which stations can be utilized:

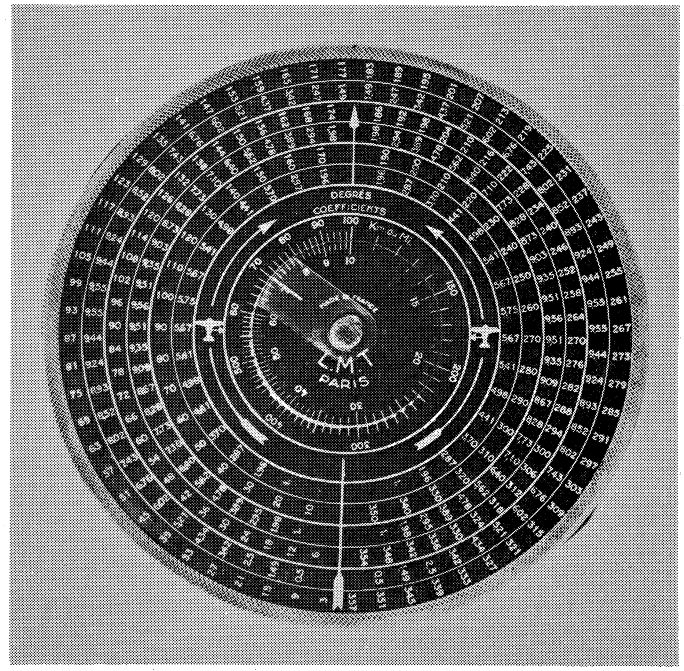


FIGURE 8B

First, the numerous broadcasting stations which, situated near big cities, form a net of Hertzian beacons for navigation over great distances.

Second, all radio beacons of any transmission system, directive or not, for air or sea navigation. The radio compass will indicate their direction, the same as in the case of an ordinary transmitter.

Airport stations can also be utilized. On receiving a call from an airplane, they can transmit for some ten seconds at regular periods to direct the plane towards the

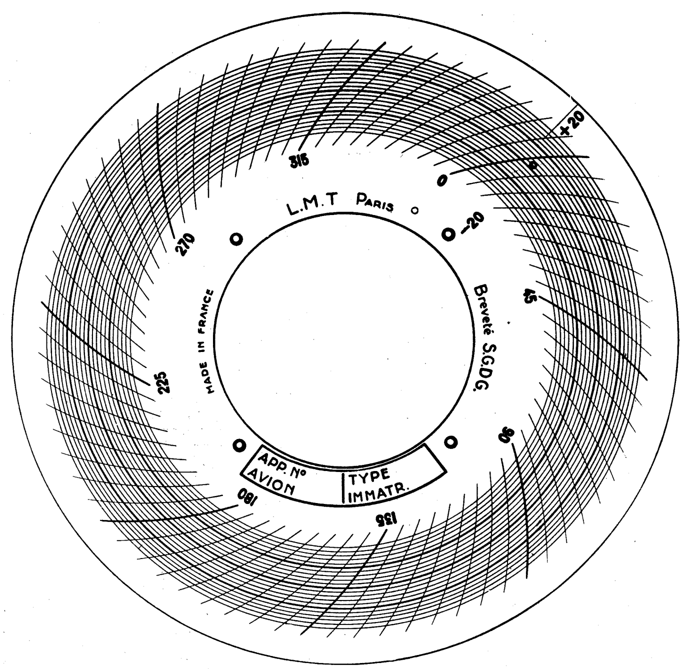


FIGURE 8C

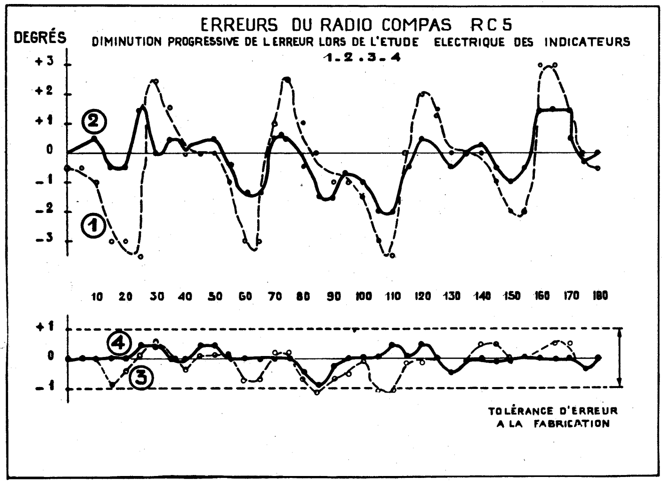


FIGURE 9
CURVES SHOWING THE ATTENUATION OF THE INDICATOR'S ERRORS DURING THE DEVELOPMENT OF THE APPARATUS AND REMAINING ERROR IN SERIES MANUFACTURED

airport, but this process is not as advantageous as continuous transmission.

If necessary, further non-directive transmitters can be installed on regular air routes to serve as beacons. Such installations exist now in Europe at Croydon and Le Bourget.

In this connection, it should be stated that modern broadcasting stations utilize the so-called "anti-fading" antennae, which also reduce the night error; also the modern type of radio-beacon utilized in the U. S. A., employing antennae instead of loops, gives a very good range at night.

The pilot and the navigator must have a map of their flying area, giving them information on the transmitters that can be utilized, as well as their range without night error, their power, their normal wavelengths, and call signals.

Navigation with the Radio-Compass

The easiest method of navigating with the radio-compass consists in tuning the radio compass on a given station situated at the aerodrome of destination, and then to operate in such a way that the indicators show the angle as zero degree. In this way, the airplane always flies in the direction of the station and, if the wind is nil, it flies in this direction along a great circle. In most cases when drifting by wind, a curve is traced that pilots and navigators call the "drift-curve."

Figure 10 illustrated such a curve. An airplane equipped with a radio compass always has its axis directed towards station B, but the wind causes deviations from the course and should be allowed for. On such a curve, it is easily seen that the angle indicated by the magnetic compass, i.e., the magnetic course followed by the airplane, constantly changes; and, therefore, the true course of the plane also constantly varies. It should be noted that this curve is exaggerated for illustration purposes. The true course varies from 90° to 54° and in the end the airplane reaches the station in the wind's direction on a 37° true course. If it reaches the transmitter's aerial, it passes exactly over this antenna facing into the wind. Indication is given to the pilot by the rise of the volume of reception; and, after having passed by a 180° change in indication, the pilot is enabled to read the wind direction from his magnetic compass.

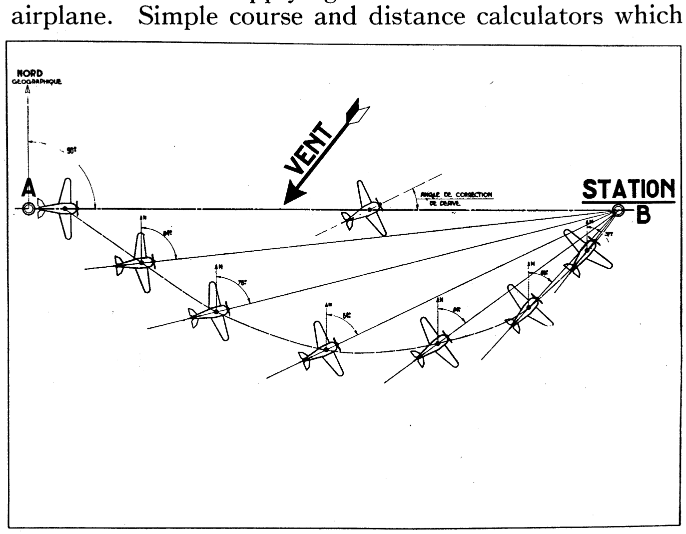
But it is possible to fly along a straight course between two points by allowing for the drift. If, after flying for a few minutes towards the station, the pilot finds that the magnetic compass angle is getting smaller, it means that the plane is drifting towards the right and that the wind is blowing from the left. Then the pilot must adjust his course with the aid of the R.C. 5 radio compass. By a method of trial and error, the correct drift angle can be found and thus the airplane can be maintained on a great circle course towards the station. It is the course which gives a constant reading of the magnetic compass with a constant indication of the R.C. 5 radio compass. Thus, when the correct drift angle has been determined, the pilot flies with the magnetic compass and radio compass readings corrected for drift.

The methods just outlined were described by us in 1927 in "L'ONDE ELECTRIQUE" and apparently they were new at that time.

Referring to the left portion of Figure 11 assume that, from the point A, the pilot wishes to maintain a course 30° from the geographic north. He notes after a certain time that, with a 0° bearing of his radio compass on transmitter A, his magnetic compass indicates a difference of 5°. This difference enables him to determine the approximate distance he is off his course. If the angular difference had been negative, the pilot would have known that he was on the left of his course. The same process can be utilized with station B, but in this case a positive difference indicates a deviation to the left, and vice versa, The sign and the value of the difference after a determined time of flight give to the pilot the sign and the value of the drift due to the wind permitting the pilot to correct the major part of the drift.

The right portion of Figure 11 represents a general case where there are no stations either at the point of departure or destination, but where there is a suitable station situated on the side. Formulae for determining the distance of the plane from this station are indicated in the illustration.

Obviously, neither the pilot nor the navigator would have the time for applying these formulae on board an airplane. Simple course and distance calculators which



(CURVE 4)
FIGURE 10
DRIFT DUE TO WIND

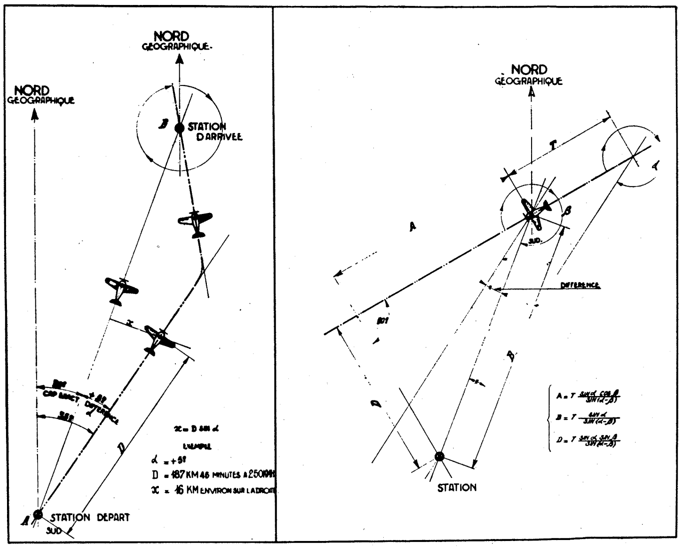


FIGURE 11
NAVIGATION BY THE RADIO-COMPASS

can be read very quickly have been made and are a part of the "Radio-Navimeter." Given, on the one hand, the distance traveled from T_1 (the product of speed by time known) to T_2; and, on the other hand, the angles of two bearings taken on the station, the pilot can determine his distance from the station. Information of this character is, of course, highly useful and is readily obtainable by reference to a regular broadcasting station in cases where a transmitter is not available at the points of departure or arrival.

Suppose that the plane is going in a certain direction and that it keeps a steady course. The pilot looks at the radio compass indications and, for example, reads 30°, at the same time noting the exact time. After an interval of 5 minutes at an airspeed of 300 km. per hour, i.e., after flying 25 km., he reads 36°. On his Radio-Navimeter (rear part) he finds the coefficient 4.78 for 36°, and a simple multiplication of this coefficient by the distance he has just flown will give him the distance at which he is from the station, i.e., about 120 km.

When flying a fair distance away from the transmitter the possibility of not knowing the location of the transmitter is small. However, near the transmitter, it might be difficult to locate the exact position (180° fault).

There are two main methods of coping with this situation: (1) there is the intensity variation of the received wave given by the distance indicator, which naturally increases or decreases according to the direction of flight to or from the transmitter very quickly near this transmitter; (2) a 90° deviation to the right of the true course and maintaining this course on the magnetic-compass. A decrease of the radio compass reading indicates that he is flying towards the station, whereas an increase points to the fact that he is flying away.

The larger the difference in these readings the nearer the airplane is to the transmitter.

In general as the radio compass gives the possibility of taking bearings all around the plane, on a great number of stations, it is always possible to determine the position of the plane by a number of bearings, thus eliminating the 180° ambiguity.

Applications to Landing

The fact that, with a radio compass, the airplane passes just over the station towards which it has been flying, leads to the possibility of using the R. C. 5 for landing under conditions of bad visibility.

With the radio compass the exact location of a transmitter can be found; thus this transmitter becomes a marker beacon. From this very accurate position, the pilot can take the true direction of the landing field with the directional gyro, since he knows the position of the transmitter acting as a marker.

First, it should be noted that the airplane is fitted with a sensitive altimeter which, before the landing, must be adjusted to the actual atmospheric pressure of the aerodrome.

Second, a directional gyro is of great assistance to the pilot during the last stages of the approach.

The passing above the radio station is accurately noted. The attention of the pilot is called by the variation of the distance indicator and when he passes just over the antenna the radio-compass indication turns to the left during a few seconds, comes back to zero, turns to the right a few seconds and again comes back to zero.

Comparisons with Other Methods of Navigation by Radio

First, let us compare the radio-compass with other direction finders used on airplanes. The radio-compass gives automatically the indications that, with a direction finder, can only be secured by a skilled operator.

The trend is more and more towards automatic operation and, inasmuch as a direction finder does not operate automatically, the indications are that the radio-compass will find increasing application in aerial navigation. In contrast with the radio-compass, the direction finder makes it necessary for the radio operator to take bearings of the transmitter and pass them on to the pilot in order that the latter may make the necessary course adjustments. Further, course adjustments on the part of the pilot are not made by direct indication, but through the medium of another navigating instrument, either the magnetic compass or the directional gyro.

The correction, if made with the help of the magnetic compass, will always be 3° or 5° behind, thus making the course unsteady. When operations have to be rapid, the direction finder cannot be used and, for instance, cannot be used for passing directly over marker beacons or transmitters used as markers. Further, with an ordinary airplane direction finder, the operator must find the point of minimum reception, which is diffiuclt to determine on board a plane on account of the engine noise, while, with the radio compass, the noise question is quite secondary since the indication is automatic. With a radio-compass the pilot navigates directly and, inasmuch as this instrument has less inertia than a magnetic compass, the course is held more accurately and with less effort.

If we compare the radio-compass to radio beacons giving a definite route, we find that the indication of radio-compass combined with the use of the beam gives a large field of applications. Tuned on the radio range beacon, the radio-compass easily permits the finding of the beam if the plane is distant from it. It is also possible to determine the distance by taking bearings on adjacent

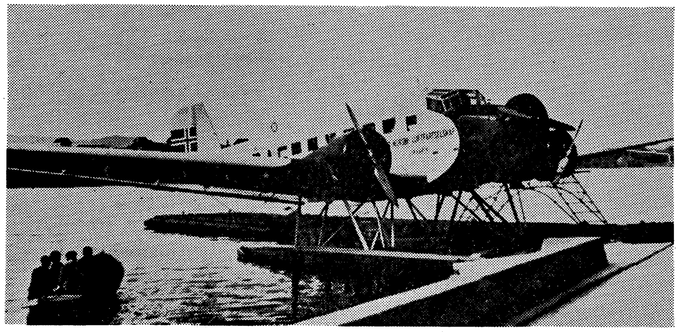


FIGURE 12
SEAPLANE EQUIPPED WITH AN R. C. 5 RADIO-COMPASS

stations (broadcasting or beacons); and the passing above the beacon is accurately determined.

Military Use

The military plane fitted with a radio-compass can navigate without any assistance. It is not possible for ground observers to find out what station the plane is using for its navigation. This station may very well be a broadcasting station, serving as a radio beacon. Also, the transmitter may be changed frequently.

The radio-compass can be utilized on powerful stations situated at a great distance, thus permitting navigation over several hundred kilometers. When desired, the pilot can abandon this station to pick up a weaker station, which cannot be heard at a few hundred km. distance, but which will permit the pilot to traverse the 50 or 100 km. to the transmitter and from there to the airport where he must land.

Rain Static

Another important advantage of this type of radio compass is that it does not utilize a separate antenna for its operation; on account of this and because the loop is completely shielded, this radio compass may be satisfactorily operated under rain static conditions when operation may be impossible with an "homing device" using a separate antenna.

FIGURE 14
SIKORSKY S-43 EQUIPPED WITH R. C. 5 RADIO-COMPASS

Some Applications

Figure 12 shows a Norwegian seaplane equipped with an R.C. 5 radio-compass and Figure 13 the pilot's cockpit of the same plane in which are seen the indicators and the control unit of the equipment.

Figure 14 shows an American Sikorsky plane S. 43 utilizing the R. C. 5 equipment.

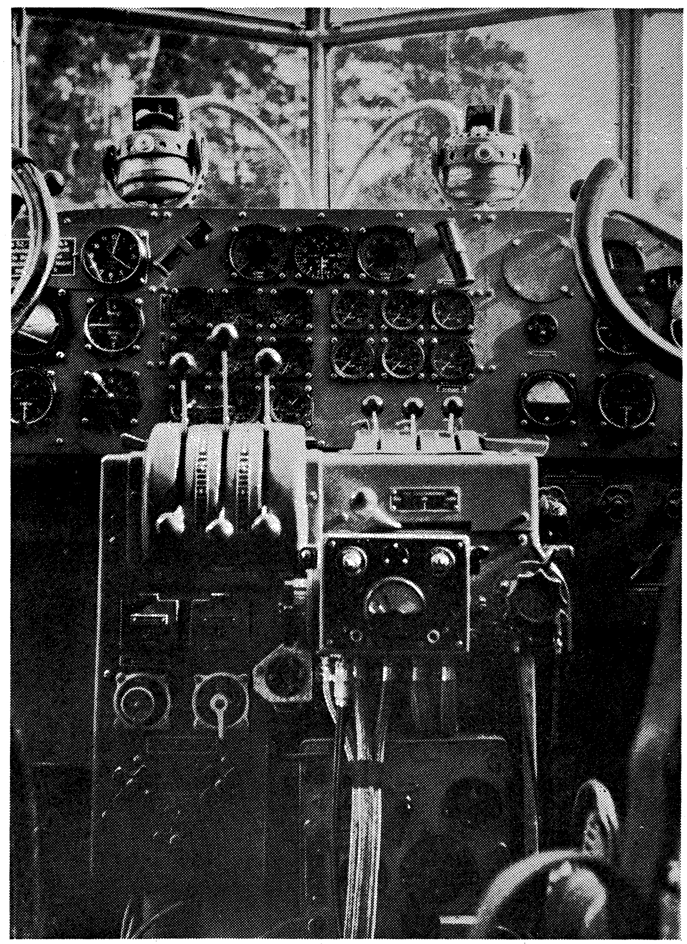


FIGURE 13
PILOT'S COCKPIT OF THE SEAPLANE

On the map, Figure 15, is indicated the registered course of a plane guided by a 50-watt transmitter located at Reims, with a radio-compass and an automatic pilot combined directly on board. The course made corresponds exactly to the action of the wind. The drift was not corrected so that the drift course might be seen.

The map in Figure 16 shows an airplane position taken on board. The errors are indicated. The true determination of this position should be noted if the bearing of Koenigswursterhausen is eliminated. The error of 2° on Koenigswursterhausen does not give as good a determination, due to the distance of 800 km. from this transmitter. This bearing has not been taken for "position"

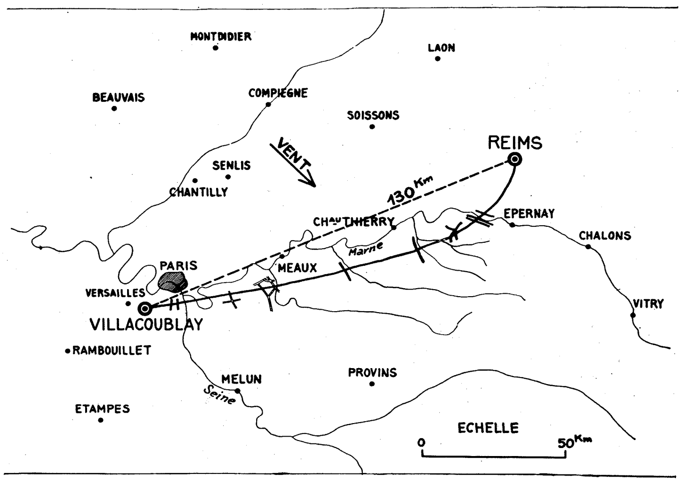


FIGURE 15
AUTOMATIC FLIGHT BETWEEN VILLACOUBLAY AND REIMS, WITH RADIO-COMPASS COUPLED TO "ROBOT PILOT"

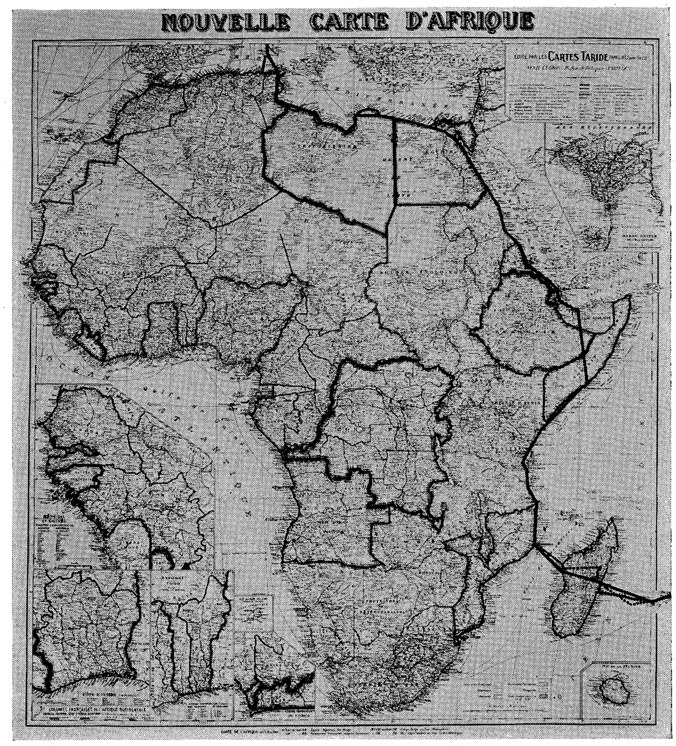


FIGURE 17
COURSE FOLLOWED BETWEEN FRANCE AND LA REUNION ISLAND

but to see if direct "homing" to Koenigswurtserhausen was possible. On the map, Figure 17, is indicated the flight made by the aviators Laurent, Togue, and Lenier, to the small island of La Reunion, which demonstrated the usefulness of the radio-compass to find a small island far out at sea, even under fog. The plane had drifted, as shown on the map of Figure 18, and without the aid of the small transmitter at La Reunion and the R.C. 5 compass, the men and the plane would have been lost.

This plane was the second to reach this island—a number of them were lost at sea—and after this flight, the Governor imposed the use of radio compasses for all flights to La Reunion.

This short series of examples is given to show some practical applications of the R.C. 5 radio-compass. However, many military applications cannot be indicated here.

In the United States, this type of radio-compass has been demonstrated to various persons interested in air navigation. During a period of a few weeks, about 40 flights were made; position was determined within a few miles 50 times; 70 homing flights were made and at the end of each one, the passing above the station on which the radio-compass was tuned was verified, demonstrating the accuracy of each passing.

The stations used were radio-range beacons and the broadcasting stations.

All navigation during these flights was made with the radio-compass, watching the ground only for checking and control purposes. The demonstrations proved the

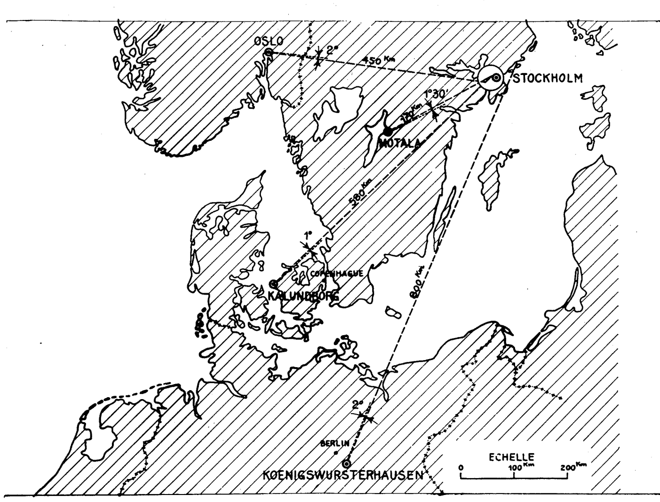


FIGURE 16
POSITION DETERMINED BY 3 AND 4 BEARINGS

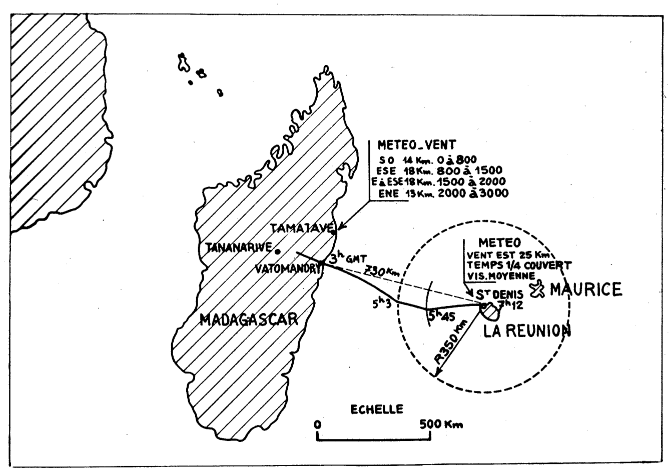


FIGURE 18
COURSE FROM MADAGASCAR TO LA REUNION ISLAND

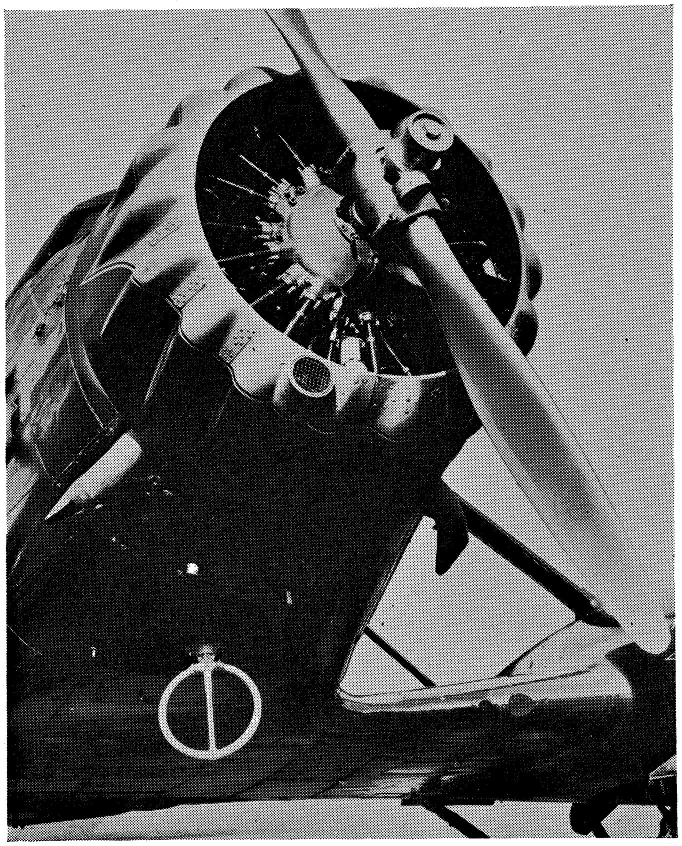


FIGURE 19
STINSON TRI-MOTOR EQUIPPED WITH R. C. 5 RADIO-COMPASS

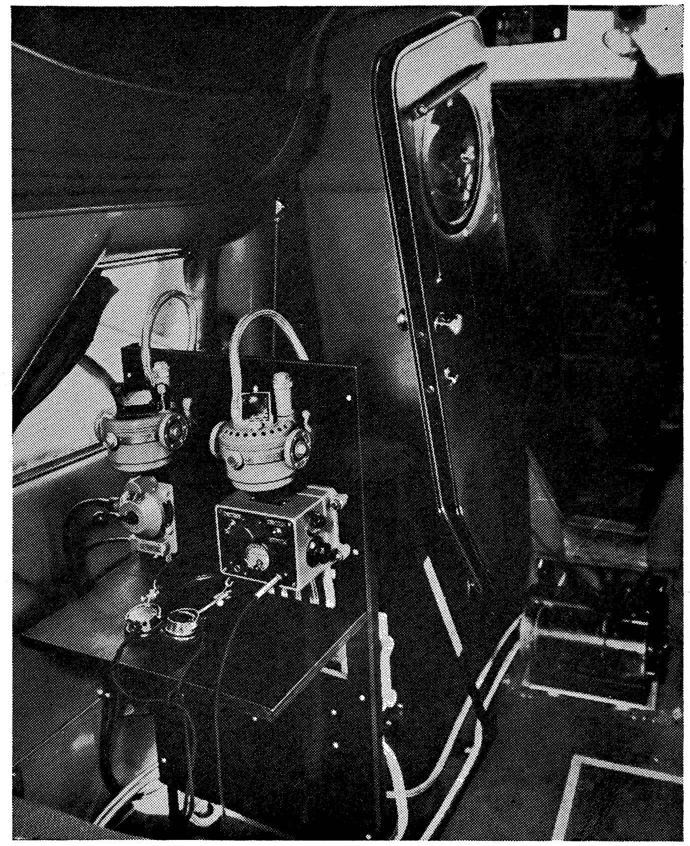


FIGURE 20
INSTALLATION IN THE STINSON

possibilities of using the radio compass alone, but the best method is the combined use of radio-range beam and radio-compass indication.

Figure 19 shows the loop on the Stinson tri-motor used for demonstration, and Figure 20 shows the instrument-carrying rack, mounted in the cabin to facilitate the demonstrating operation and indications.

This series of tests has awakened considerable interest in the United States for this **real** radio-compass directly indicating angles of bearings.

H. BUSIGNIES