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DISTANT-COMPASS.

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For a long time, small fluid compasses were almost exclusively used on aircraft. Such a compass consists essentially of a number of comparatively weak magnets which, supported by a hollow float, turn on a needle point in a vessel filled with alcohol and water. This would answer for ordinary use, if there were on the aircraft no iron parts and no other magnets, like starters, magnetos, dynamos, etc.

The compensation of these disturbances by small magnets is only a makeshift and by no means frees the compass readings from error. The many neighboring movable iron parts, like steering devices, weapons, tools, bombs, etc., even key-rings, knives and the like in the pockets of the occupants, exert, according to their size and proximity, a varying influence on the compass readings which, on the aircraft, are hardly controllable and can not be corrected, any more than the constantly varying influence of the above mentioned magnets.

Every deviation of the aircraft from the horizontal position, in either a lateral or longitudinal direction, likewise exerts an influence on the compass readings. Thus there are generated, especially by sudden changes of position in curved flight, oscillations of the card which may even increase to the complete

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revolutions dreaded by every aviator.

The oscillations of the compass card, due to those magnetic and mechanical influences, are indeed deadened by the compass liquid, but this friction is operative not only in the indicated instances, when the card, with the magnets, oscillates with reference to the compass vessel, but also when the system is at rest and only the vessel turns, as in every curving flight. In the latter case, the card is also carried along and indeed just so much more, the weaker the magnet system and, accordingly, its directive power. On the other hand, the greater the directive power of a magnet system, the greater are its errors of deflection from neighboring masses of iron. These errors call for stronger compensation magnets which, the stronger they are, the more they weaken the directive power of the system. Out of this endless circle there was yet on an aircraft only the unsatisfactory compromise. The employment of a reliable magnetic compass, free from objections, was impossible and one was compelled to make the best of inaccurate and unsatisfactory compasses.

An improvement of the properties of the airplane compass to real serviceableness in aerial navigation is only possible then, when the disturbing causes are eliminated. The Navy prescribes for every compass on shipboard a minimum distance within which there must be no iron. This is impossible on an airplane, since there is no such amount of room free from iron within view of the pilot or observer. It is difficult to install a compass on an airplane at all, on account of the limited space.

On the other hand, the remedy by placing the compasses in magnetically somewhat more favorable position, for instance, on the upper or lower supporting deck, presents many other disadvantages: inconvenient reading of the compass, difficult and inaccurate steering by such a distant instrument, compulsory cessation of the possibility of taking bearings, as also the impossibility of using adjustable indicators and other accessories, mistakes in reading in oblique and side views, insufficient protection of compass against cold and wet, as also against the force of the air current which, in such a location, often tilts the compass or even upsets it. Moreover, only small compasses with weak magnets can be used, since a higher directive power cannot be employed, for reasons already given, and the still unavoidable proximity of iron and because the limited space prevents the installation of larger compasses.

Against the use of the ordinary compass on an airplane there are various further practical considerations. Steering by a reference mark and the general use and complete utilization of such a compass requires too much experience on the part of the pilot, especially of one with little or no knowledge of navigation, while even an experienced and educated pilot finds it too strenuous to watch the card, with its finely divided scale, and, at the same time, attend to the numerous details of managing the airplane, observing, fighting and keeping constant watch of the ever increasing number of instruments. The increasing demands on the pilot emphasize the need of direct communication between him and his observer, in order to do away with time-robbing attempts at speech, signals and makeshifts.

For solving all these problems, there is now a new device, the "distant-compass" constructed by Carl Bamberg, Friedenau, and improved in 1918 by the Seaplane Division and practically tested in comprehensive experiments and use at the front. Since this compass doesnot need to be in sight of the aviators and can be located far from all iron parts, it can be as powerful as those used on ships. This compass is free from error down to the fraction of a degree and at least as reliable as those on large ships. The most favorable location on the ordinary type of airplane is from one to one and a half meters behind the rear seat in the fuselage, where the compass, enclosed in a wooden case (see Fig. 1 at end of article), is protected from the wind and weather. The magnet system is the same as demonstrated its stability in the submarines. Its use on airplanes has greatly increased the accuracy of steering in comparison with the compasses formerly used, and, even while flying in clouds and bad weather, there were no harmful oscillations nor revolutions. Not much compensation is usually necessary, since in every type of machine it is possible to find a location entirely free from magnetic disturbances. The improvement thus obtained consists first in eliminating the compensation, which always requires an expert, and further, in the fact that the directive power of the compass is not weakened by compensation magnets.

The magnet system of this compass is supported in the usual manner in a compass-vessel filled with alcohol and water. In the bottom of the vessel there are two lighting devices (each consisting of a small electric bulb and "condenser"), which throw two cones of light, sharply defined by the condensers, up through the compassliquid (Fig. 2). Both light-cones fall on two selenium cells (Fig. 3) which are applied in an air- and water-tight cap to the vessel (Fig. 4). The electric resistance of the selenium is lessened by the illumination, so that, for instance, an electric current passing through it can cause the pointer of an indicator to move. For the distant-compass, a special precision galvanometer with suitable scale serves as course-indicator (Kurszeiger), with radiumized marks and pointer (Fig. 5).

The magnet system carries a diaphragm which, in a certain position, simultaneously intercepts both light-cones and leaves both selenium cells dark. If now the compass vessel (Kompasskessel) is rotated about its vertical axis, whereby the magnet system remains constantly in the north-south direction, one or the other cell passes out of the diaphragm shadow into one of the light-cones and the pointer moves to one side or the other. In this way, every swing of the compassvessel can be read on the course-indicator and, indeed, so that the amplitude of the oscillation of the pointer is proportional to the deviation from the course. This result is obtained by giving the proper oblique shape to the diaphragm, so asto cause a gradual strengthening or weakening of the illumination and therewith a proportional decrease or increase of electrical resistance in the selenium cells. This method of transmitting the compass indications differs from most other known methods in that it is accomplished without influencing the compass card or weakening its directive power.

Any seaplane or airplane provided with this device can be steered exactly in the desired direction, since every deviation from this direction causes a rotation of the compass vessel with reference to the magnet system, which is immediately indicated. The pilot only needs to turn the rudder right or left according to whether the pointer moves to the left or right. This device has two fundamental advantages over the ordinary compass. First, the pointer moves a relatively longer distance than the card of an ordinary compass, a deviation of 15° from the course causing a motion of about 5 cm. in the former case to only 1 cm. in the latter case, making the accuracy of the reading about five times as great for the former. Second, this compass, like all the other instruments on the airplane, is read on a fixed scale by means of a mobile pointer and thus spares the aviator the special thought required, on all other instruments, for reading the mobile card scale with reference to a fixed steering mark.

If the compass vessel is rotated a certain angle, say 65°, with reference to the longitudinal axis of the airplane, then the new course, if flown according to the course-indicator, will evidently deviate 65° from the original direction, since one of the selenium cells receives the light and thereby brings the course-indicator to one side, until, by the turning of the airplane itself 65°, it comes again into the shade of the diaphragm. At any time during flight, any desired new course can be established by turning the compass vessel the desired angle with reference to the longitudinal axis of the airplane. The compass vessel had for this purpose a suspension device which can be readily rotated by means of a worm gear (Fig. 4).

For this purpose, the compass isplaced in the rear part of the fuselage or other iron-free location. The turning of the compass vessel, and with it the establishment of the course, is then effected by means of a flexible shaft (Fig. 7) which is within reach of the aviators and is turned by a crank. By this shaft a compass card near the crank is simultaneously turned exactly the same angle as the compass vessel, so that on this course-giver (Kursgeber) (Fig. 8) the angle and thus the compass course can be read. Naturally, in such a system with a flexible shaft, several course-givers and course-indicators can be installed, for the pilot and observer and any other persons in any part of the airplane, who are thus enabled to observe and assist in the navigating.

The heat generated by the electric lamps prevents the freezing of the compass liquid, even in very cold weather. The minimum current required for the compass installation is about 10 watts. This current can be obtained by connecting the system with a source of electric current already on the airplane, but is usually supplied by a small airscrew double generator of especial reliability (Fig. 9), specially constructed for this purpose, with an output of 40 volts, 6 milliamperes for the indicator circuit, which flows through the selenium cells, and 8 volts, 2 amperes for the electric lamps, and weighs only 1.8 kg. (4 lbs.). The tension of the generator is kept constant between 3700 and 7500 r.p.m. by an automatic regulator according to the Sumner principle. The best location for the generator is in the air current from the propeller. The number of r.p.m. required for the work of the compass system was found in a test to be about half the r.p.m. of the engine.

The weight of a complete distant-compass set, with two course-givers, course-indicators, generators, cables, shaft, etc., was about 9 kg. (20 lbs.)

<u>Practical Application of the Distant-Compass</u>.

The course to be steered (for example, 130°) is set by the pilot or observer, while the crank of one of the course-givers is turned so that this degree number of the compass card comes opposite the steering mark of the course-giver. Thereby the whole system is adjusted to the 130° course and the pointer of the course-indicator oscillates until the airplane is brought exactly on this course. If, for instance, the previous course was 45° N.E., then, after setting it at 130°, the pointer lies hard to the left. The pilot then turns the rudder continuously to the right, in order to bring the pointer to the middle. When the airplane, in turning to the right, reaches course 100°, then the pointer, with the further turning of the airplane, beginning to move slowly, lies at 130°, it stands on the middle point. If the airplane turns too far, say to 135°, then the course-indicator moves correspondingly to the right until, by steering to the left, the airplane is brought back to the course and the pointer to its middle position. Further holding to the course is accomplished in the same manner, since, on the slightest deviation of the airplane from its course, the pointer moves to the corresponding side and indeed proportionally to the deviation, so that the aviator is always given the measure for the degree of correction in steering. Up to 30° on either side, the motion of the pointer is proportional to the deviation from the course. Above 30° the pointer remains in the same position, This angle of 30° has been found suitable in practice for an ordinary airplane, but it can be varied at will, according to the size and corresponding sensitiveness of the airplane (or airship), by resistance, from 5° to 40°.

Every change of course during flight is accomplished in the manner indicated by setting one of the course-givers for the new course and steering according to the course-indicators, without the necessity of any communication between the occupants by signs, notes, etc. Also the observer or any other occupant can, without any closer understanding, call the attention of the pilot to an object that the latter has not noticed, or accurately indicate a target, since the pilot has only to steer according to the pointer, the accuracy of which makes it possible to steer for the smallest goal.

If it should happen, in curved flight or great changes of the course, that the course set on the course-indicator should be exactly opposite to that followed by the airplane at the time (for example, set on the course-giver: East 90°, airplane flying west = 270°), the course-indicator in this special case, when the difference is just 180°, stands in its middle position, which results from the two selenium cells being located at 180° apart. This position, however, hides no possibility of error, because it is immediately evident that (likewise following from the construction) the course-indicator swings in the opposite direction than when the airplane is flying on the course set. If the airplane, as assumed in the example, is flying west and turns only one degree to the right of this course, the pointer swings to the left and the pilot must therefore steer to the right. Thereby he continually goes further to the right from his false west course, for the pointer remains on the left until the airplane is again on the east course for which the course-giver is set. Only then is the pointer again in its correct middle position. The second and opposite middle position of the course-indicator makes it possible therefore for an airplane that has deviated by a large angle, (around 180°) from its correct course, to be always shown the smaller angle and therefore the shorter way back to its correct course. Every aviator must therefore become accustomed to following the course-indicator blindly, then, whether in clouds or fog, even in battle, after completely losing his bearings, he will immediately return to his correct course, without danger of the compass whirling, even from the most violent motions of the airplane.

The sensitiveness of the pointer, which indicates deviations of fractions of a degree from the direct course, enables the aviator to fly straight ahead and horizontally in clouds and at night. Only this condition enables the use of airplanes for photogrammetric surveying which requires the holding of a straight line and further imparts genuine accuracy to observations from an airplane and from the earth, which unconditionally require straight lines, like speed measurements, etc.. True, there already exists in the Drexler Gyroscope Indicator (Kreiselssueranzeiger) a highly sensitive instrument for facilitating direct flight, but its value is confined exclusively to the aerodynamic field, since it only shows whether, for the time being, the airplane is flying straight ahead or in a curve, and does not enable the holding of a single definite course, like the distant-compass course-indicator.

Furthermore, the distant-compass not only makes possible the general control of one's bearings, but also the accurate determination of compass directions and variations, even without seeing the compass itself, because the card of the course-giver, as long asthe airplane continues on the course set for it, always corresponds to the true magnetic compass card, since the course-givers are always mounted parallel to the longitudinal axis of the airplane. A variation device attached to a course-giver is more convenient and utilizable for compass variations than when attached to the sensitive and mobile compass itself.

The advantages and possible applications of the distant-compass are so numerous that it has become one of the most important instruments for aircraft. This was also demonstrated by its adoption in 1918 for all former naval seaplanes, with the exception of combat airplanes, as well asfor certain types of army airplanes. This device is a very important aid for commercial, as well as military aviation. By its advantages it increases both the safety and economy of aviation. The accuracy of course-steering, which the distant-compass has made many times greater than that hitherto attainable, lessens fuel consumption, facilitates unconditional reaching of one's goal even under the most trying circumstances, and diminishes the intellectual and nervous tension of the pilot, which is of especial importance in long distance commercial aviation.

It is not the purpose of this article to discuss the application of this invention to sea ships. The parallels are readily drawn. Even the farthest evolution possibilities open up favorable vistas. Thus, on a ship, there hasbeen successfully substituted for the indicating instrument a relay enabling the compass to operate the rudder directly. Such a device, which has already been finished and tested, demonstrates the possibility of dispensing with the pilot and replacing him by an automatic and considerably more accurate steering-compass. The lateral steering of an unmanned airplane rests on the same principle.

Translation from the German by D. M. Miner.

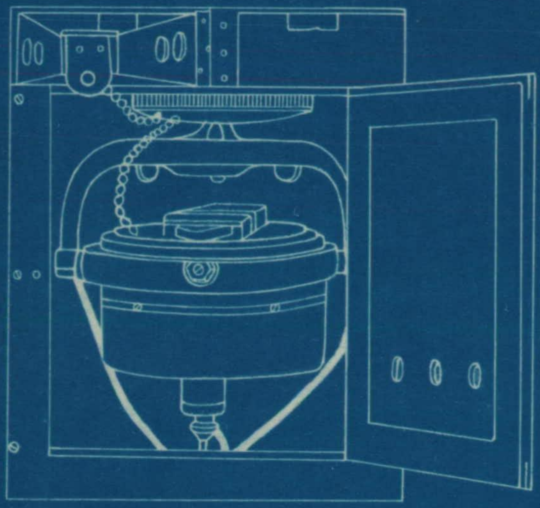

Fig. 1.

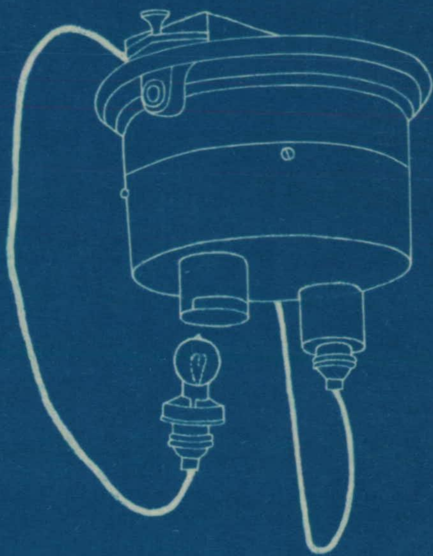

Fig. 2.

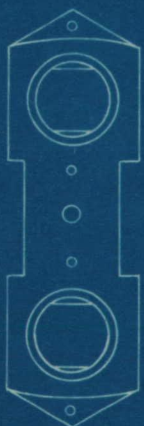

Fig. 3.

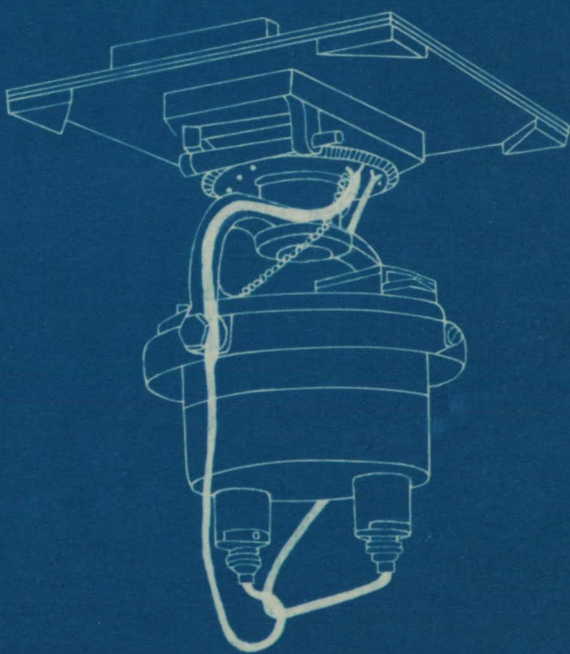

Fig. 4.

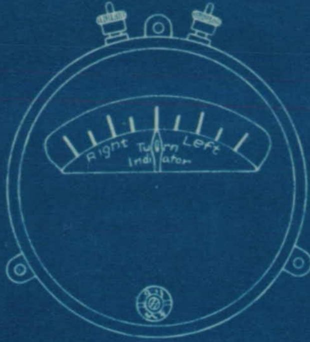

Fig. 5

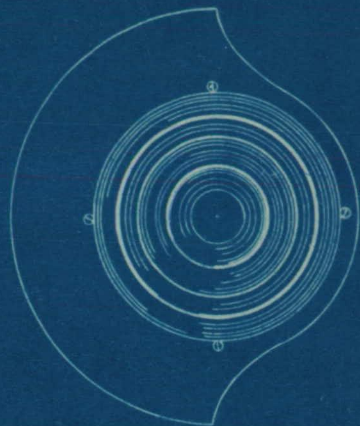
Fig. 6

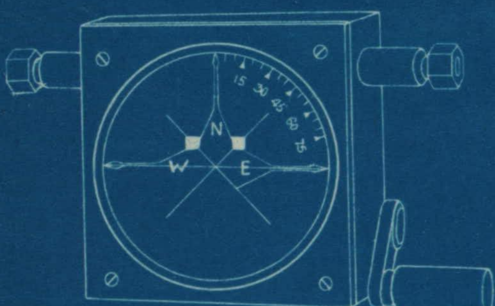

Fig. 8

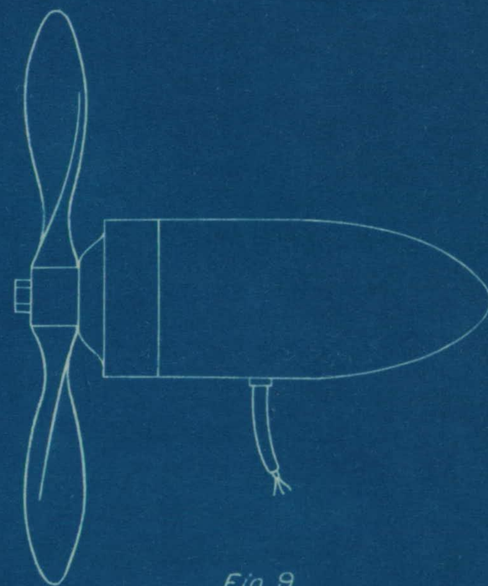
Fig. 9

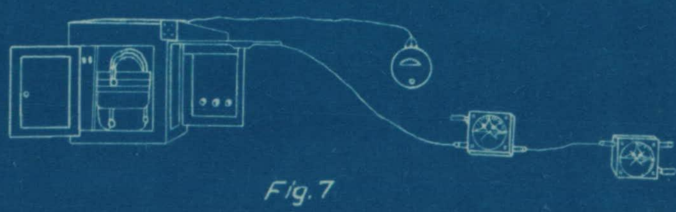
Fig. 7