The Earth Inductor Compass

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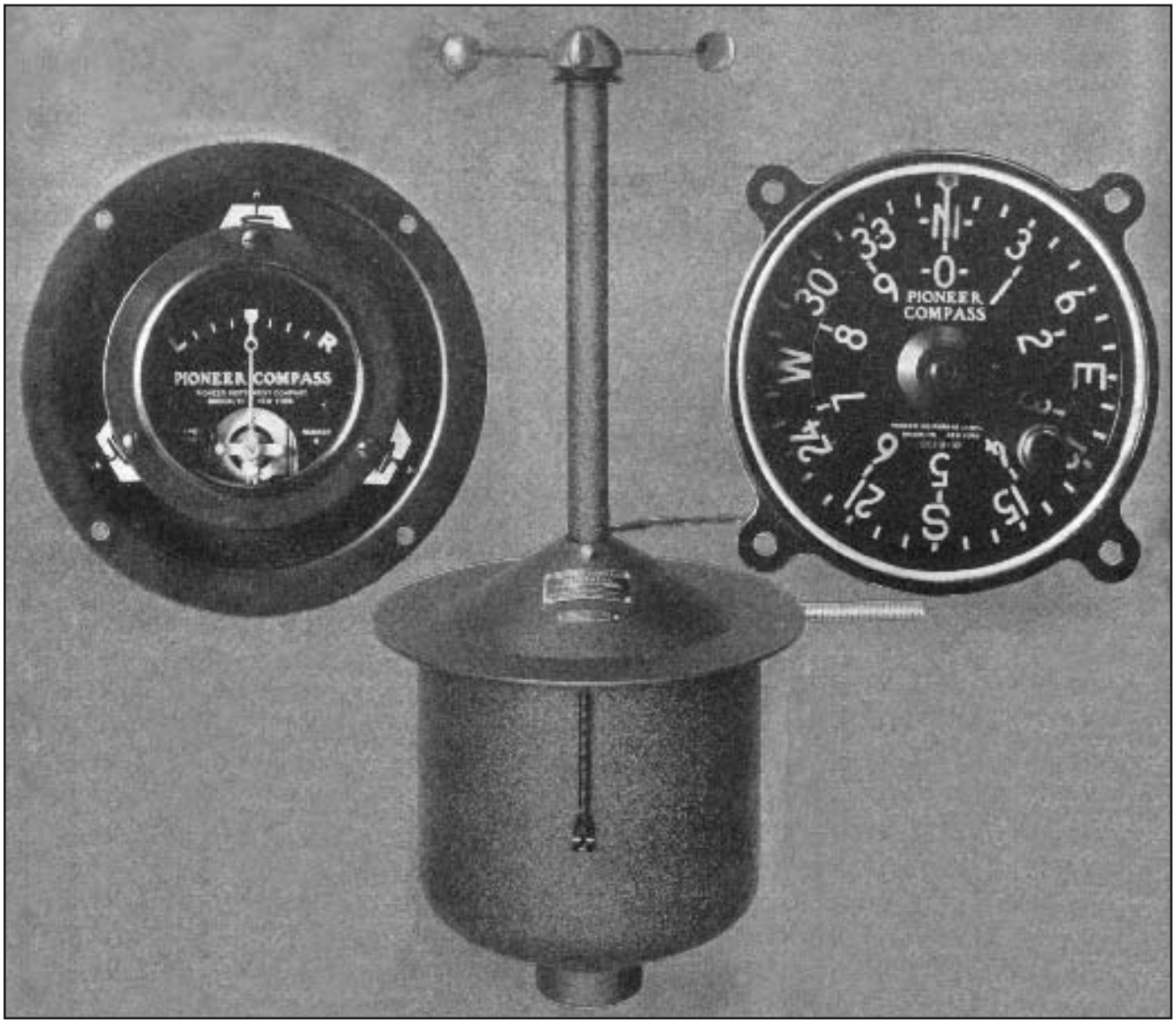
Vintage Airplane **editor's note: Long gone from our modern instrument panels, the Earth Inductor Compass (EIC) was a marvel of modern engineering when Charles Lindbergh used one in May of 1927 to help keep the *Spirit of St. Louis* headed in the right direction during his solo hop across the North Atlantic. Its method of operation is fascinating. Here's an explanation of the inner workings of the EIC from one of the engineers responsible for its creation in the mid-1920s.—HGF**



The Earth Inductor Compass consists of three major units—a generator, a controller and an indicator. Associated with these are a casing and shaft, which establish a mechanical connection between the generator and the controller and a cable which electrically connects the generator and indicator.

The generator is the same in principle as any electric generator, except that it has no artificially induced field. It has an armature, a commutator, and a pair of brushes. The armature unit is supported on gimbals so that its position will be undisturbed by ordinary rolling and pitching of the airplane. A windmill drives the armature and commutator through a universal joint. The brushes are supported for orientation about a normally vertical axis, and electrical connections are made to them. The earth's magnetic lines of force running from north to south form the poles of the generator.

The controller is a purely mechanical device. It is connected to the generator through the shaft and casing. Rotation of the controller causes a corresponding rotation of the brushes of the generator. Dials upon the face of the controller show the angle through which the brushes have been orientated in relation to the airplane.

The indicator is a galvanometer, which is electrically connected by means of the cable to the brushes of the generator. The position of the hand of the indicator, therefore, shows the electrical potential being produced by the generator. The operation of the compass depends upon the rotation of the armature of the generator, which cuts lines of flux of the earth's field and generates electricity. It is exactly similar in action to an ordinary D.C. generator.

There is a little four-cupped windmill and paddlewheel on top of the fuselage inside of which is placed the generator. This is the armature driver. When the plane is in the breeze created by the propeller, or by the motion of the plane though space, it rotates this little dynamometer type of wheel at high speed.

As the armature rotates it cuts the magnetic lines of force of the earth, which run from north to south, and produces a voltage which is sufficient to indicate on the compass, which, as you will note by the cut, is a zero centered galvanometer. As in any ordinary electrical generator, there is a position of the brushes which will give the maximum output this position obtains when the brushes make contact with the commutator bars which are connected, at any instant, with the coil, which is directly between the two pole pieces at that instant. If the brushes are moved so as to make contact with a coil which forms an angle with respect to the pole pieces, this coil naturally is not being cut by as many lines of force as would pass through it if it were exactly between the former, and consequently would generate a lower voltage.

ONCE THE COURSE IS SET THE PILOT HAS ONLY TO KEEP THE PLANE SO HEADED THAT THE HAND OF THE COMPASS ALWAYS REMAINS ON ZERO, AND HE WILL ALWAYS BE ON THE CORRECT COURSE.

By this same line of reasoning one can readily see that a point will be reached where the coil is at right angles to the pole pieces and consequently no voltage is induced. This also applies to the compass generator. We consider the earth's flux or lines of force as forming north and south pole pieces of this generator.

The controller is connected to the brushes by a flexible shaft, and when it is turned it rotates the brushes around the commutator by means of a worm drive. When the controller is set to read north and the plane is headed in this same direction, the brushes will be east and west. In this position they are connected to a coil which is at right angles to the earth's magnetic flux and do not produce any current to work the galvanometer. The pointer of the latter will stay on dead center.

In the same manner, if the controller is set to a due eastern position and the plane headed east, the brushes will again make contact through the commutator with a coil which is at right angles to the earth's lines of force and the meter will again read zero. If the plane is now turned a little to the left and the controller still remains on "east," the meter will show a reading because the coil is being cut by some lines. If it is turned further to the left, it will cut a greater amount of flux and give a higher reading to the left on the meter.

If the plane is headed to the right, it will read less and less, and when it is headed in the direction indicated on the controller, it will read zero. Moving it further to the right the meter will again read on the side marked "right."

The course to be followed is set on the controller dial; this moves the brushes to some position around the armature; the plane is now pointed until the hand or the compass meter reads zero, i. e., it remains in the exact center. A deviation of the needle to the left indicates that the plane is to the left of the course set on the controller and it must be brought back to zero by heading the plane more to the right. Once the course is set the pilot has only to keep the plane so headed that the hand of the compass always remains on zero, and he will always be on the correct course.

An unknown direction can be determined by rotating the control-

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ler dial until the compass reads zero, when the course will correspond to the point indicated on the controller. The latter has thirty-six divisions each corresponding to ten points on the compass.

It will be seen that a direction exactly opposite to the figured course will give a zero reading, but this is easily avoided by noting that on the correct heading the indicator hand always moves in the direction in which the craft turns; should it move opposite, the reverse heading is indicated.

In order to fully appreciate the advantages of the Pioneer Earth Inductor Compass, it is necessary to consider the characteristics of ordinary magnetic types used on aircraft.

The directive force of a magnetic compass depends upon the reaction between its magnets and the earth's magnetic flux. So long as the magnetic element of such a compass remains horizontal, the magnets tend to align themselves with the horizontal projection of the earth's flux, and the compass tends to indicate the angle of heading in degrees from magnetic north. At best the north-seeking tendency in not great, as the torque due to the reaction between the magnets and the earth's flux is small.

A magnetic compass is affected by magnetic or ferrous materials in its immediate vicinity. These are principally the engine with its ignition accessories and parts of the aircraft control system. The latter, being movable, produces errors of varying magnitudes. Structural parts of the aircraft, if of ferrous material, may affect the compass, even though unmagnetized, due to induction from the magnetic needles themselves. To a large extent these magnetic errors may be corrected by the use of compensating magnets, but such compensation is uncertain and must frequently be checked if any accuracy is to be assured.

The outstanding feature of the earth inductor compass is the disassociation of the magnetic element from the indicating element. Instead of using magnetic needles, the direction responsive element of the earth indicator compass is an electric generator the same in principle as any electric dynamo except that no artificial field is used, the earth's flux serving for a field. The output of such a generator is dependent upon the angular relation between its brushes and the earth's flux. With such a generator the problem of stability becomes relatively simple, as the revolving armature, acting as a gyroscope, actually resists motions tending to disturb its stability.

As to its value we have but to point again to the New York-Paris flight in which young Lindbergh confidently staked his life on the accuracy of this "aviator's eye."