Oct. 4, 1938. H. D. OAKLEY 2,132,183

INDUCTOR COMPASS

Filed June 12, 1936 2 Sheets-Sheet 1

Fig 3

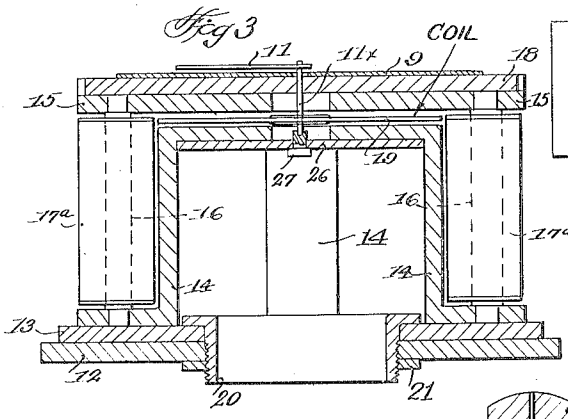
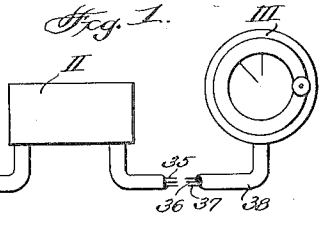


Fig. 1.



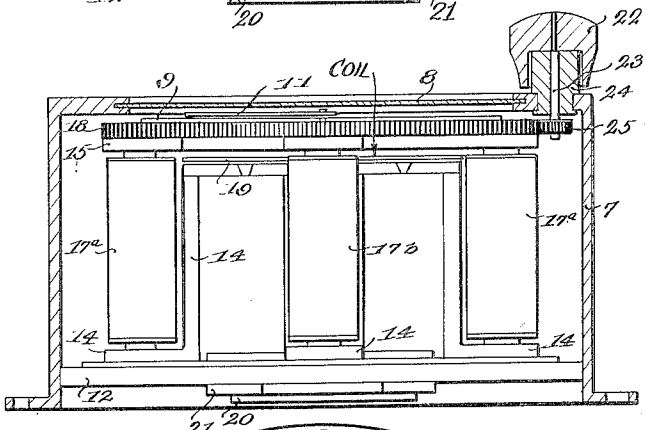
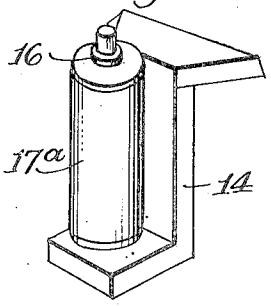


Fig. 2

Fig. 13.



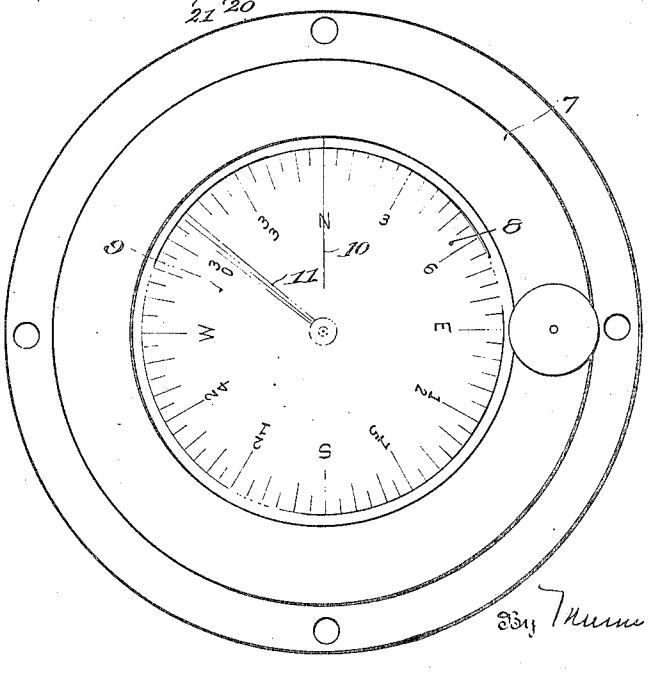


Fig 4.

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INDUCTOR COMPASS

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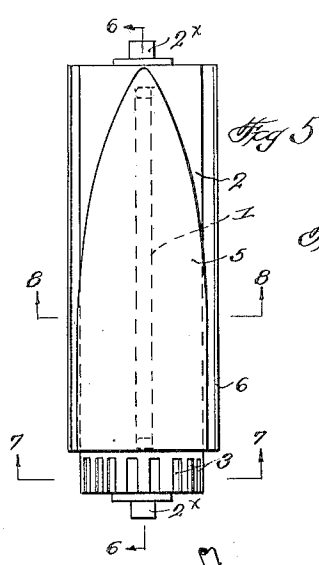

Fig 5

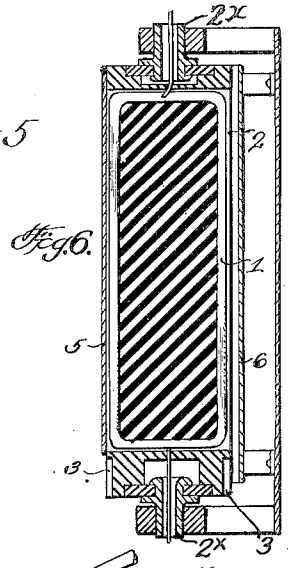

Fig. 6.

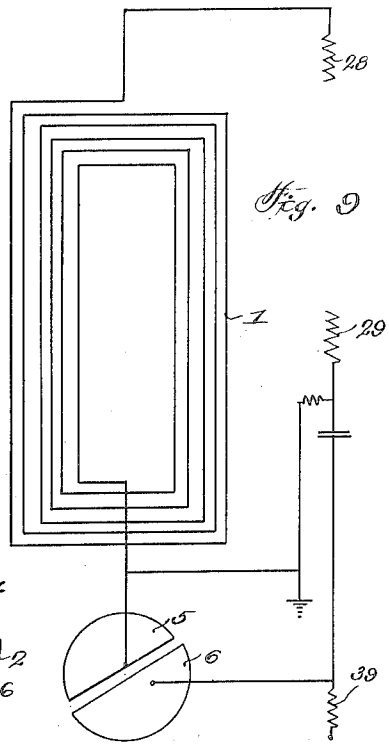

Fig. 9

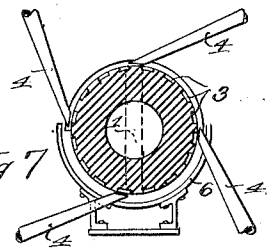

Fig 7

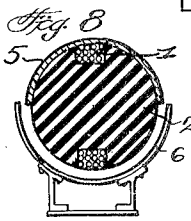

Fig. 8

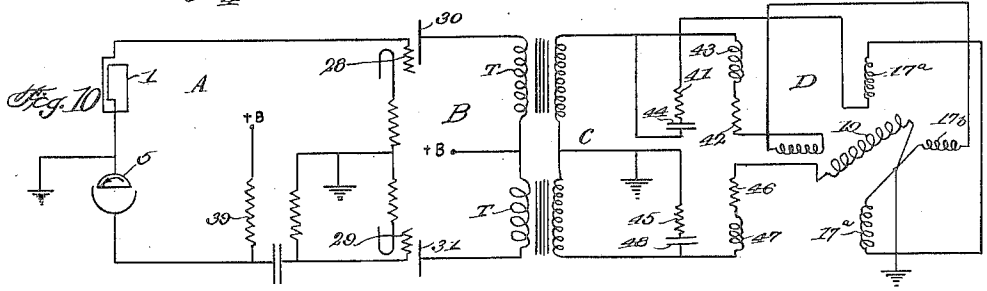

Fig. 10

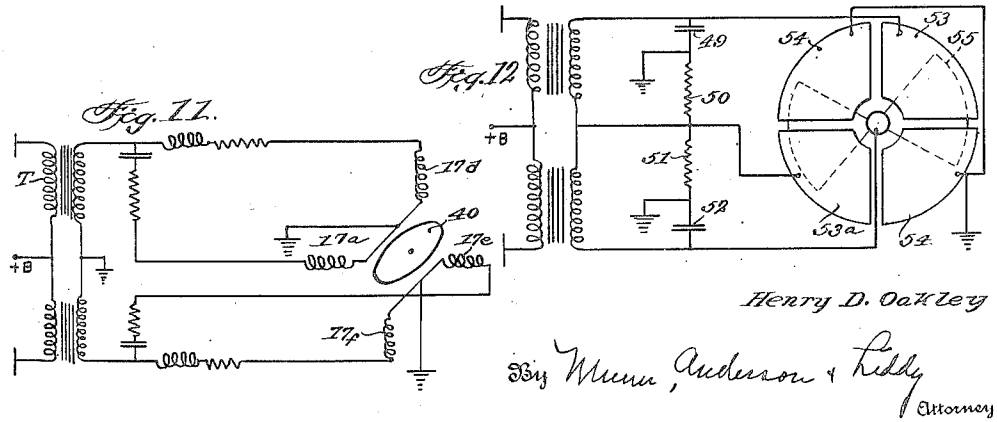

Fig. 12

Fig. 11.

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UNITED STATES PATENT OFFICE

2,132,183

INDUCTOR COMPASS

Henry D. Oakley, Schenectady, N. Y.

Application June 12, 1936, Serial No. 84,956

REISSUED

2 Claims. (Cl. 33—204)

My invention relates to improvements in inductor compasses, and it consists in the constructions, combinations, and arrangements hereinafter described and claimed.

An object of my invention is to produce a device by means of which the course of airplanes, small boats, and the like may be indicated and in which the device also serves as a true compass.

A further object of the invention is to provide a device which is relatively simple in mechanical and electrical construction.

A further object of the invention is to provide a device of the type described which is small in size and of light weight.

Other objects and advantages will appear in the following specification and the novel features of the invention will be particularly pointed out in the appended claims.

My invention is illustrated in the accompanying drawings forming a part of this specification, in which:

Figure 1 is a diagrammatic showing of the general arrangement of the three essential parts,

Figure 2 is a view partly in section of the casing of an indicator, the coils and gearing being shown in side elevation,

Figure 3 is a sectional view through the interior of the indicator with the casing removed,

Figure 4 is a plan view of the indicator,

Figure 5 is a side elevation of a vertically disposed inductor unit,

Figure 6 is a vertical sectional view through the inductor unit on the line 6—6 of Fig. 5.

Figure 7 is a sectional view on the line 7—7 of Figure 5,

Figure 8 is a sectional view on the line 8—8 of Figure 5,

Figure 9 is a diagrammatic circuit view of the inductor units,

Figure 10 is a diagram showing the connections between the inductor unit and the indicator, including the amplifier circuit.

Figure 11 is a diagrammatic view showing the circuit connections of a modified form of indicator.

Figure 12 is a diagrammatic view showing the circuit connections of an electrostatic form of indicator, and

Figure 13 is a view in perspective of a magnet and pole piece in detached relation.

In carrying out my invention I provide a simple inductor for generating an alternating voltage resulting from the relative motion of a coil with respect to the horizontal component of the earth's magnetic field and also to set up another alternating voltage resulting from the varying capacitance between a fixed and a moving electrode.

Referring particularly to Figs. 5 to 9, inclusive, of the drawings I have shown therein an inductor unit including a coil 1 of moderate turns of fine wire which is mounted in a groove in a cylinder 2 made of insulating material. The latter has stub shafts 2× for rotatably mounting the cylinder and the coil on a vertical axis. At the lower end of the cylinder there is a bucket wheel 3 which is rotated by air jets emerging from nozzles 4 as a result of pressure difference, or by other suitable means (not shown). A semi-circular plate or electrode 5, which may be a thin piece of aluminum foil, is secured to the surface of the cylinder 2 to revolve therewith.

A fixed plate or electrode 6 of semi-cylindrical shape is disposed adjacent to and concentric with the electrode 5 as shown in the drawings. In actual use the inductor unit just described will be mounted in gimbals or controlled gyroscopically or by any suitable means (not shown) so that the axis of the rotor will be maintained in a vertical position.

The construction just described forms a simple inductor for generating two alternating voltages of the same frequency. One voltage is set up by the rotation of a coil in the horizontal component of the earth's magnetic field. The other voltage is set up by the varying capacitance between the fixed and the moving plates 5 and 6.

The indicator is illustrated in Figs. 2 to 4. It consists of an exterior casing 7 which bears a circular glass plate 8 beneath which is a compass card 9.

At 10 I have indicated a lubbers line formed on the underside of the glass plate 8, and at 11, a steering and course indicator. Secured to the casing 7 is a base 12 upon which is mounted a bearing ring 13. Carried by the bearing ring are four pole pieces 14. An upper pole piece 15 is connected by the field cores 16 to the lower pole pieces 14 and coils 17ª and 17ᵇ are provided as shown in the drawings. A gear 18 is mounted on the upper pole piece 15 and the compass card 9 is mounted on the gear, as shown, to turn therewith. A coil 19 is disposed between the pole pieces as shown, and this coil is secured to the pivot shaft 11× of the needle 11 so that the latter is turned with the coil. The coil 19 is in the field of the magnetic flux set up by current flowing through coils 17ª and 17ᵇ as will be hereinafter explained. A collar 20 is threaded into the base

12 and forms a guide for the bearing ring 13. This collar is held in position by means of a nut 21. A knob 22 is provided with a shaft 23 centrally disposed in a guide 24 carried by the casing 7. The shaft bears a pinion 25 meshing with the gear 18. A plate 26 having a thrust bearing 27 supports the pivot shaft 11×.

In Fig. 10 I have shown the circuits by means of which the device is operated. In this figure A indicates in general the amplifier input circuit. This includes the inductor coil 1 associated with a grid 28, and the electrode plates 5 and 6 associated with a grid 29. B indicates in general the output circuit including the plates 30 and 31 of the output tubes. Phase splitting and phase control circuits for the electromagnetic type of indicator are shown in general at C and the indicator circuits at D.

Two alternating voltages are set up in the following manner in Fig. 10. The rotating coil 1 is connected between the grid 28 and the ground. The rotating plate 5 is connected to the ground and the fixed plate 6 is connected through a blocking condenser to grid 29. Grids 28 and 29 are biased sufficiently negative so that at no time is there grid current flowing. A fairly high D. C. voltage is maintained between +B and the ground. This potential acting through the high resistance 39 holds a substantially constant charge on plate 6. When the rotor of the inductor units spins an alternating voltage is set up across grid 28 and the ground due to the action of the earth's magnetic field upon coil 1. At the same time that coil 1 is spinning plate 5 is also revolved, and so the capacitance between plates 5 and 6 is fluctuating. Since the charge on plate 6 remains constant and the voltage across 5 and 6 must fluctuate this gives rise to an alternating voltage between grid 29 and the ground. Obviously these two voltages must be of the same frequency since coil 1 and plate 5 are mechanically tied together and rotated as a unit with no relative motion between them. Since plate 6 never changes its position with respect to the ship that is carrying the compass and since the ship does change its position with respect to the earth's magnetic field, it is evident that the phase angle between the two alternating voltages can have any valve between 0 and 360 degrees.

In the system described thus far there is practically a zero current flow, that is, it is a potential operated system. This means that if resistance variations are introduced into the circuits as the stub shafts 2× rotate in their bearings no objectionable affects will be set up in the system.

This arrangement then provides a means for generating two alternating voltages of the same frequency and whose phase angle is controlled by the direction in which the system is pointing with respect to the direction of the earth's magnetic field.

In carrying out the invention use is made of the forces set up by a rotating field acting upon a simple alternating one.

In Figure 10 two sets of coils 17ª and 17ᵇ are shown. These are the field coils of the indicator and are located physically 90 degrees apart. The circuit consisting of the condenser 44, the resistor 41 and the coil 17ª obtains its energy from the same amplifier as does the circuit consisting of the coil 43 and resistor 42 and the coil 17ᵇ. The electrical values of the elements of these two circuits are so chosen that the phase angle between the current flowing in coil 17ª and that flowing in coil 17ᵇ is 90 degrees. The magnetic flux set up by these two currents in the field structure of the indicator then has the well known rotating characteristic. Coil 19 is situated in this field and is mounted on a shaft so that it is free to rotate, and this coil is supplied with current from the other amplifier. This current sets up about coil 19 a simple alternating magnetic field. Since the frequency of the rotating and the alternating fields is the same, the forces set up by the action of the two fields are such that coil 19 assumes the position of rest and this position is determined by the phase angle of the two amplifier output voltages.

The circuit elements 45, 46, 47 and 48 provide compensation to prevent indicator errors which would ordinarily appear whenever the speed of the inductor rotor deviated from some pre-assigned value.

The device as pointed out consists essentially of three units, the inductor unit shown generally at I in Fig. 1, the amplifier unit at II, and the indicator unit at III. Between the inductor unit I and the amplifier unit II are two wires 32 and 33 enclosed in a shell 34 which can be metal tubing or metal braid and forms the ground return of the circuits. Between the amplifier unit and the indicator unit there are three wires indicated at 35, 36 and 37, respectively, enclosed in a shell 38. It will be noted that there are absolutely no mechanical connections between these three units.

From the foregoing description of the various parts of the device the operation thereof may be readily understood. The circuit illustrated in Fig. 10 is for the electromagnetic type, as stated.

Assuming that the rotor has been set in operation, the coil 1 rotating in the earth's field impresses a sine wave of voltage across the grid 28, the battery +B acting through 39 charges the fixed electrode 6. As electrode 5 rotates the capacitance of 6 to ground varies and so the voltage across 6 and ground varies. Hence the voltage impressed across grid 29 varies in the same way. The electrode plates 5 and 6 are so shaped that the voltage wave impressed on the grid 29 is sinusoidal. Thus there are two sine voltages generated. Since the coil and the movable electrode 5 are mechanically connected together and turn about the same axis there can be no frequency difference between the two voltages but since the stationary electrode never changes its position with respect to the moving body to which it is attached, and since the course of the moving body does change with respect to the direction of the earth's field, the phase between the two generated voltages will change and in direct proportion to the course changes.

These two induced voltages are amplified and are impressed on the indicator in the manner shown in the drawings. It will be observed that the coil 19 carries alternating current 3 whose frequency is the same as that of the indicator field. During one revolution of the indicator field the coil 19 is subjected to a sinusoidally varying torque that reverses its direction four times. Because of its inertia the coil cannot follow these torque reversals but takes up a stable position of rest. This position is at the point where the current in the coil is a maximum. The point where maximum current occurs is determined by the phase angle of the two induced voltages in the inductor unit. Therefore the coil takes up a position which is controlled by the heading of the moving body with respect to the horizontal component of the earth's magnetic field. By provid-

ing the movable coil with a needle or pointer, such as that shown at 11, that travels over a 360° scale, shown at 9, the device becomes a compass.

It will be noted that in the device described above the output tube of one amplifier feeds into a phase splitting circuit. This circuit supplies two currents that differ in phase by 90° . To secure a 90° phase displacement between the two field currents the resistances of 41 and 42 must be equal and also the square root of the ratio of the reactance of 43 to that of 44 must be equal to the resistance of 41. Therefore to have proper phase control of the current flowing through the moving coil 19, 45 must equal 41, 46 must equal 42, 47 must equal 43 and 48 must equal 44. The indicator derives its rotating field from these two currents. The other output tube feeds into a phase control circuit from which is obtained a current for moving the coil 19 of the indicator. The reason for using this phase control circuit is to prevent indicator errors which would ordinarily appear whenever the speed of the inductor rotor departed from a pre-assigned value.

In Fig. 11 I have shown a circuit in which a low impedance metal ring or properly shaped iron vane 40 is employed moving in a field which is the resultant of two equal but oppositely rotating fields, and carries the compass needle. In this form there is no external moving coil circuit.

The double field magnetic type indicator with a single turn coil (metal ring) is the simplest, most rugged, and cheapest to build.

The substitution of the electrostatic for electromagnetic effects will produce the same result. In Fig. 12 I have shown the circuits for the electrostatic indicator. 49 and 50 are placed in the phase splitting circuit while 51 and 52 are the phase control circuit. 53 and 54 are the field plates and 55, shown partly in dotted lines, is the moving vane. For proper action the reactance of 49 should be approximately equal to the resistance of 50 and 51 and 52 should have corresponding values.

Each type has its advantages. In the electrostatic type the parts are of smaller physical size and weight and smaller power output is required from the amplifiers to operate the indicator. However, it is not so apt to withstand shocks and vibration to which it will be subject to service and more skill is required in building it. In addition the insulation of all the circuits must be maintained at a high value.

In using either type of this device the navigator rotates the gear 18 by means of the knob 22, thus rotating the field coils 17a and 17b and the chart, so that any point on the scale can be made to coincide with the lubber's line. This enables the navigator to set the compass so that the compass course to be followed lies on the lubber's line. The pilot then simply steers the course so that the needle of the compass aligns with the lubber's line, thus making of this instrument both a compass and a course indicator.

The device has numerous advantages. The mechanical drive between the inductor unit and the instrument board is eliminated. There are no brushes, commutators, or slip rings. There are but two moving parts, the inductor rotor and the indicator moving coil. There are no delicate parts requiring precision adjustments for proper operation of the compass.

The actual compass course of a moving body is shown not merely whether a body is moving along a previously determined course.

Compass readings are not affected by variation in the strength of the earth's field nor are they affected by contact resistances, speed of the induction rotor, or by amplifier gain whether due to changes in supply voltages or aging of the tubes.

I claim:

1. In an inductor compass, an indicator unit having a plurality of field coils provided with pole pieces, a rotatable coil centrally disposed between said pole pieces electromagnetically reacting with and controlled by the field set up by the coils, a needle carried by said coil, a direction chart, a stationary lubber's line, means for rotating said field coils, pole pieces, and chart simultaneously to bring said chart into registration with said lubber's line, and means for producing a rotatable field in said field coils, said means comprising an inductor unit for generating an alternating voltage from the horizontal component of the earth's magnetic field, and a second means for generating an alternating voltage of the same frequency, an amplifying means for each voltage, one of said amplifiers being associated with certain of said field coils for energizing them and the other of said amplifiers being associated with other field coils, said rotatable coil and needle adapted to assume a position of rest, the position being determined by the phase angle of the output voltages of the amplifying means.

2. In an inductor compass, an indicator unit having a plurality of field coils, a rotatable coil electromagnetically reacting with and controlled by the field set up by the coils, a needle carried by said rotatable coil, a chart disposed beneath the needle, means for simultaneously rotating the chart and field coils, a stationary lubber's line, means for producing a rotatable field in said field coils, said means comprising an inductor unit for generating an alternating voltage from the horizontal component of the earth's magnetic field and a second means for generating an alternating voltage of the same frequency, an amplifying means for each voltage, a split phase circuit associated with one of said amplifying means and having connections with certain of the field coils and a phase control circuit associated with the other amplifying means and being connected with the rotatable coil, said rotatable coil and needle adapted to assume a position at rest, the position being determined by the phase angle of the output voltages of the amplifying means.

HENRY D. OAKLEY.