

March 27, 1934.

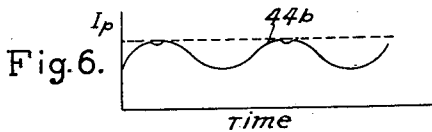
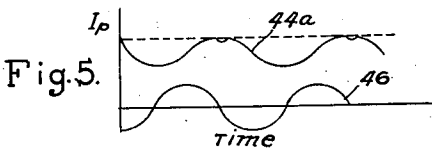
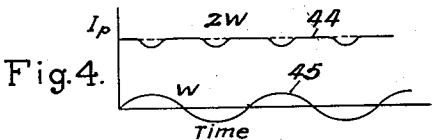
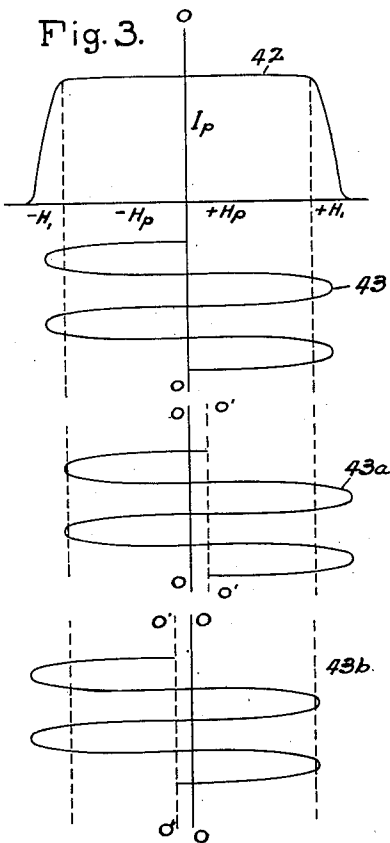
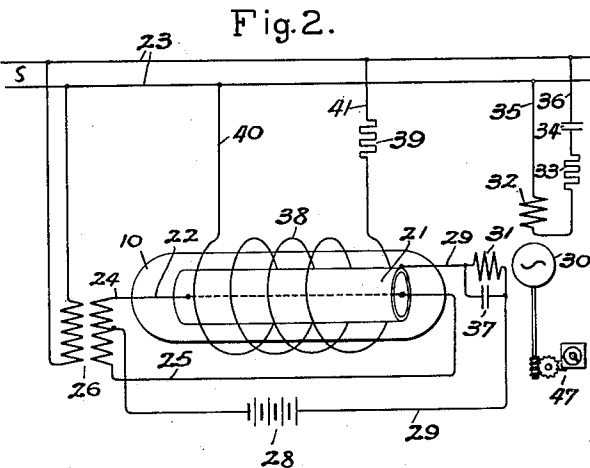
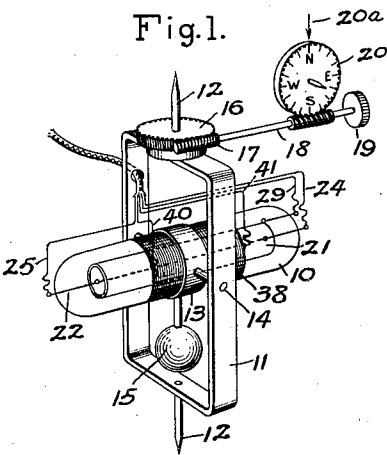
J. D. TEAR

1,952,899

COMPASS

Filed Nov. 19, 1929

2 Sheets-Sheet 1



Inventor:
James D. Tear,
by *Charles E. Tulla*
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March 27, 1934.

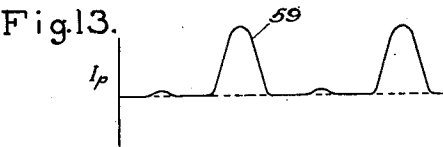
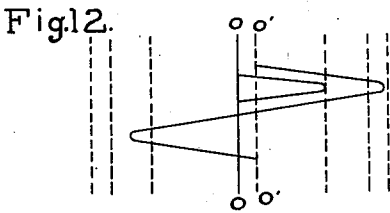
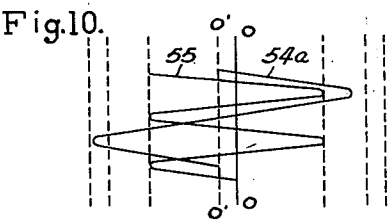
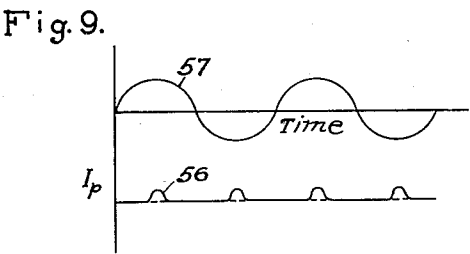
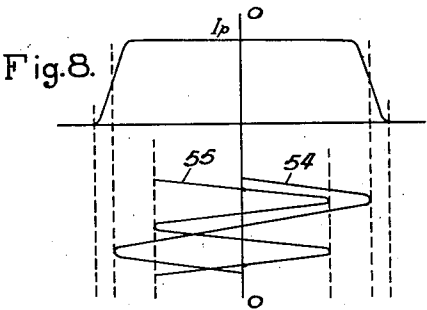
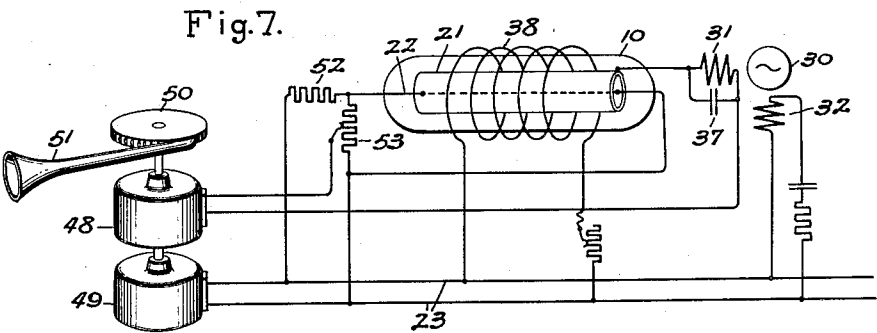
J. D. TEAR

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COMPASS

Filed Nov. 19, 1929

2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

1,952,899

COMPASS

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Application November 19, 1929, Serial No. 408,369

15 Claims. (Cl. 33—204)

This invention relates to compasses and the like, more particularly to compasses for use upon moving bodies such for example as ships and aircraft, and has for an object the provision of a rugged, reliable and efficient compass possessing a high degree of sensitivity.

In the past the mariner's compass has been widely used but this device entailed the disadvantage that sensitivity was usually only obtained at the sacrifice of ruggedness in construction.

A further object of this invention is the provision of a compass, the direction sensitive element of which has no rotating masses, driven elements, driving connections, commutators or brushes such as employed in certain types of compasses, and which may easily be stabilized in a horizontal plane.

My invention although relating more particularly to compasses, also comprehends a simple, reliable and efficient means for controlling operations of an electric motor.

In carrying this invention into effect in one form thereof, I provide a normally partially energized indicating device together with an electric discharge device operable in response to its position in a magnetic field for controlling the completion of the energization of the indicating device, or more particularly of an electric motor.

In illustrating my invention in one form thereof I have shown it as embodied in apparatus that is particularly adapted for installation and use upon moving bodies such for example, as ships and airplanes. It will be understood, however, that its application is in no way limited to use on moving craft of this type since it may without modification be used upon all types of moving bodies and even upon bodies at rest.

For a better and more complete understanding of my invention reference should now be had to the following detailed description and to the accompanying drawings in which Fig. 1 is a diagrammatic view in perspective of the direction sensitive element of the compass together with its mounting; Fig. 2 is a simple schematic electrical diagram of apparatus and circuits forming an embodiment of the invention; Figs. 3, 4, 5 and 6 are typical curves representing electrical characteristics and conditions of the apparatus which serve to clarify and explain the principle of operation; Fig. 7 is a modification; Figs. 8, 9, 10, 11, 12 and 13 are curves representing electrical characteristics and conditions of the apparatus embodied in the modification serving to explain the principle of its operation.

Referring now to the drawings, an electric discharge device 10, the space current characteristic of which is susceptible to the influence of a magnetic field, is suitably mounted upon an airplane by means of any suitable holding device such for example as that represented in the drawings by the rectangular shaped supporting member 11 which is provided with pivots 12 adapted to be journaled in suitable bearings in the body or framework of the airplane. As shown, the electric discharge device 10 is held in a collar 13, that is provided with pivots 14 which are journaled in the rectangular supporting member 11 to provide for the free rotation of electric discharge device about a horizontal axis defined by the pivots. Although free to rotate about the horizontal axis defined by the pivots 14, the electric discharge device 10 is stabilized in a horizontal plane by means of any suitable stabilizing device such for example as the depending pendulum 15 which is attached to the supporting collar 13.

The electric discharge device 10 may be rotated into any desired position of azimuth by means of a mechanical course setting device which as shown comprises a worm wheel 16 secured to supporting member 11, and a cooperating worm 17 mounted upon a shaft 18 which is turned by a manually operable knob 19 suitably secured thereto. A compass card 20 driven by a worm mounted on shaft 18 cooperates with a stationary index member represented in the drawings by index arrow 20a to indicate the number of degrees of azimuth through which electric discharge device 10 is rotated; the north marking N being placed to coincide with the index 20a when the longitudinal axis of electric discharge device 10 lies at right angles with the fore and aft axis of the airplane, i. e. electric discharge device will lie east and west when the airplane is pointed north. It will thus be clear that if knob 19 is turned to rotate electric discharge device 10 in azimuth that the mark on the compass card which is simultaneously rotated into coincidence with index arrow 20a will indicate the course i. e. the direction in which the airplane must be pointed to return the electric discharge device to an east-west position.

The electric discharge device 10 consists of a highly evacuated envelope within which are mounted a symmetrical cylindrical anode 21 and a straight axial filament 22. Electric discharge devices constructed in this manner and the space currents of which are susceptible to the influence

of a magnetic field are sold on the market under the trade name "Magnetron."

In order that there shall be no distortion of the particular magnetic field in which the electric discharge device 10 is located, and with respect to which indications are desired, it is necessary that the supporting and stabilizing means described above should be made of some suitable non-magnetic material such for example as brass.

The axial filament 22 is heated by means of electrical energy supplied thereto from a suitable source of alternating current represented in the drawings by the conductors 23. The source 23 might be a small alternating current generator driven by any suitable driving means such for example as the engine, or by a small wind driven turbine located in the slip stream.

As shown in the drawings the axial filament 22 is connected by means of conductors 24 and 25 across the secondary winding of a filament transformer 26, the primary winding of which is connected to the source of supply 23.

A suitable direct current potential is applied to the plate or anode 21 of the electric discharge device 10 by any suitable means such for example as the "B" battery 28, the negative terminal of which is connected to a mid tap of the secondary winding of the filament transformer 26 and the positive terminal of which is connected to the anode 21 by means of a conductor 29.

The relative position of the electric discharge device 10 in any magnetic field is indicated by means of a suitable electrical indicating device such for example as that represented in the drawings by the electric motor 30, which as shown is provided with a polyphase winding consisting of the two coils or phases 31 and 32 situated in 90 degree relation with each other. The phase winding 31 is connected in series in the output circuit of the electric discharge device 10 between the anode 21 and the positive terminal of the battery 28, while the second phase winding 32 of the motor 30 is connected to the source of supply 23 through a resistance 33 and a condenser 34 by means of conductors 35 and 36. The resistance 33 and the condenser 34 are provided in the circuit of the field winding 32 to produce a displacement in the phase relation between the current which flows in the phase winding 31 and the current which is supplied to the phase winding 32 from the source 23.

In the following discussion it will be assumed that the frequency of the source 23 is represented by the symbol w . It will be noted that a condenser 37 is connected across the terminals of the phase winding 31 of the motor 30. The condenser 37 may be and preferably is designed to provide in conjunction with the phase winding 31 a tuned circuit responsive to the frequency w . Thus, when an E. M. F. having the frequency w is impressed upon the terminals of this tuned circuit, current of frequency w and of a magnitude sufficient to energize the phase winding 31, will be caused to flow therein; while when an E. M. F. of a frequency differing from w is applied to the terminals of this tuned circuit a relatively small amount of current will flow in the phase winding 31.

The space current characteristic of the electric discharge device 10, i. e., the relationship between the space or plate current I_p and the polarizing magnetic field H_p is represented in Fig. 3 of the drawings by curve 42. From this figure it will be seen that the plate current I_p

remains substantially constant for all values of polarizing field both positive and negative between the critical values $+H_1$ and $-H_1$ at which critical points the plate current I drops rapidly to zero with further increases in the strength of the polarizing field.

Thus it will be clear that a polarizing field having a component parallel with the longitudinal axis of electric discharge device and the intensity of which is greater in magnitude than $+H_p$ or $-H_p$ may be employed to effect a variation in the plate current. This variation may be caused to occur with any desired periodicity by any suitable means for causing the polarizing field itself to vary with the desired periodicity, either in magnitude or direction or both.

As shown in the drawings the electric discharge device 10 is provided with a control or polarizing winding 38 the terminals of which are connected to the alternating source of supply 23 through a suitable resistance 39 by means of conductors 40 and 41. The value of the resistance 39 is so chosen that it will permit just sufficient current to flow in the control winding 38 to produce a polarizing field just sufficient to effect a slight variation in the plate current when the polarizing field due to the current in the winding 38 is maximum either positive or negative. It will thus be clear, that the periodicity of these variations of current in the plate or output circuit of electric discharge device 10 will be proportional to that of alternating source 23 from which polarizing winding 38 is energized.

The sensitivity of electric discharge device 10 is dependent upon the uniformity or homogeneity of the polarizing field in which it is located; the condition of maximum sensitivity being obtained when the entire tube is located in a uniform field. Although the polarizing winding 38 is schematically shown in the drawings as being coextensive with but a portion of the tube, for the purpose of revealing the tube and its construction, it is to be understood that in practice the winding 38 will preferably extend beyond the ends of the tube, and the turns of the winding 38 will be so distributed that the polarizing field produced thereby will be uniform and homogeneous throughout the entire region in which the tube is located.

With the above understanding of the elements comprising an embodiment of the invention and the manner in which they are associated with each other, the operation of the device will be readily understood from the detailed description which follows. The knob 19 of the mechanical course setting device is rotated until the longitudinal axis of the electric discharge device 10 occupies an east-west (magnetic) position in the terrestrial magnetic field when the airplane is pointed upon its chosen course. When in an east-west position in the terrestrial magnetic field the plate current of the electric discharge device is substantially unaffected by the horizontal component of the terrestrial magnetic field. If it be assumed that the chosen or predetermined course of the airplane is to be due north then it will be clear that the knob must be rotated until the longitudinal axis of electric discharge device 10 lies exactly athwartship as indicated by the markings on the compass card 20 and its cooperating index arrow 20a.

The electrical constants of the polarizing winding 38 and resistance 39 are so chosen that the alternating current that flows in the wind-

ing will produce an alternating polarizing flux the positive and negative maximum values of which are respectively greater than $+H_p$ and $-H_p$, so that two small variations in the plate current I_p will be produced by each complete cycle of the polarizing flux. Thus if the frequency of the polarizing flux represented in Fig. 3 of the drawings by the curve 43 is of a value w , then the frequency of these small variations in the plate current produced by the polarizing flux will be of a frequency $2w$ as shown by the curve 44 in Fig. 4.

It will be observed that the plate current I_p is unidirectional and that its value is substantially constant except for these small variations which are represented graphically by the series of dips in curve 44. It will be recalled at this point that the phase winding 32 of the polyphase winding 30 is energized from the alternating source 23 the frequency of which is w , which is represented by the timing wave 45 in Fig. 4. Since the circuit formed by the phase winding 31 of the two phase motor 30 and the condenser is tuned to the frequency w , the variations in the current I_p of frequency $2w$ which flows in the plate circuit will have very little if any effect on the phase winding 31. Moreover, since these variations in the current in the phase winding 31 occur at a frequency of $2w$; their total effect toward producing a turning torque of the motor will integrate to zero. Thus, it will be clear that when the airplane is proceeding upon the desired course that the phase winding 31 of the motor 30 will be substantially deenergized and that there will be no tendency for its armature member to rotate, and the armature will, therefore, be at rest which condition will indicate to the observer or pilot that the airplane is upon the desired course.

Since the axis of electric discharge device 10 lies at right angles with the earth's field, when the airplane is on its course, and since its space current can only be effected by magnetism parallel to its axis, it will be clear that as long as the airplane remains on its course, the earth's field will have no effect.

However, if the airplane deviates from its course, electric discharge device 10 will deviate a similar amount from its east-west position, and the earth's field will now have a component parallel to the axis of the device and proportional in magnitude to the sine of the angle of deviation.

This axial component will add to the alternating polarizing field H_p during one half of each cycle and subtract from it during the remaining half. Assuming the direction of deviation to be such that the earth's field adds to the positive half cycles of the polarizing field and subtracts from the negative half cycles, this condition is represented graphically by shifting the axis $O-O$ of the polarizing wave to a new position represented by the dotted axis $O'-O'$ slightly to the right of the axis $O-O$. The polarizing wave will now be represented by the curve 43a symmetrical about the new axis $O'-O'$. Thus, it will be seen that the positive half cycles of the polarizing wave to the right of the axis $O'-O'$ due to the additive effect of the terrestrial magnetic field effect a substantial variation in the plate current I_p , which as shown in Fig. 5 of the drawings causes the first and third dips in the plate current I_p to be greatly increased, whilst the negative half cycles to the left of the axis $O-O'$ due to the subtractive effect of the terrestrial field cause the second and fourth dips in the plate current I_p to be greatly diminished. The effect of increas-

ing the magnitude of the odd numbered variations in the plate current I_p and diminishing magnitude of the even numbered variations in the plate current I_p , the frequency of the variations being represented by $2w$, will be to produce a unidirectional periodically varying current having a complex wave form of frequency w which is graphically represented in Fig. 5 of the drawings by the curve 44a. Thus the discharge device operates an electric valve.

Since the circuit comprising the phase winding 31 to the condenser 37 is tuned to the frequency w , current of this frequency will traverse and energize the phase winding 31 of motor 30. As stated before, the resistance 33 and condenser 34 in the circuit of the phase winding 32 of the motor are so designed that the energizing current which flows in the phase winding 32 will be displaced in phase approximately 90 electrical degrees from the current I_p which now flows in phase winding 31 of the motor. This electrical condition is shown graphically by the curves 44a and 46 in Fig. 5, the complex wave formed curve 44a representing the energizing current flowing in phase winding 31, and the sinusoidal shaped curve 46 representing the energizing current supplied from source 23 to the phase winding 32.

It will be observed that the curve 44a lags the curve 46 by 90 degrees which is to say that the current flowing in phase winding 31 lags the current flowing in phase winding 32 by 90 electrical degrees. It will be understood by persons skilled in the art that when periodically varying currents of the same frequency and differing from each other in time phase are supplied to respective phase windings of a phase wound electrical indicating device that the device will operate to provide an indication and it will also be understood that if such currents are supplied to the respective phase windings of a polyphase motor that rotation will ensue.

Thus, it will be clear that when the airplane is proceeding upon its predetermined course that the motor 30 is only partially energized, i. e., the phase winding 32 is energized and the phase winding 31 is substantially deenergized, as a result of which the motor remains at rest without tendency to rotate. It will also be clear that when the airplane deviates from the predetermined course and the electric discharge device 10 is caused to move a corresponding amount from its east-west position in the terrestrial magnetic field, the energization of the motor is completed, that is a current having the same periodicity as that of the current flowing in phase winding 32 is supplied to the phase winding 31 and as a result rotation ensues, advising the observer that the airplane has deviated from the straight course.

From what has been said above it will be clear that if the airplane deviates from its predetermined course in an opposite direction from its east-west position the effect of the terrestrial magnetic field will be to shift the axis $O-O$ of the polarizing flux to the left. The polarizing flux will now be represented by the curve 43b symmetrical about the dotted axis $O''-O''$. In this event the positive half cycles of the polarizing flux 43 will diminish the odd numbered variations in the plate current I_p while the negative half cycles of the polarizing flux will increase the even numbered variations in the plate current. The result of this will be as before, to produce a unidirectional periodically varying current

having a complex shaped wave form, displaced 180 electrical degrees from the current which was produced when the airplane deviated in the first direction. This periodically varying current is represented graphically in the drawings by the curve 44a and it will be observed that it is displaced 180 electrical degrees from the curve 46 and that it therefore leads the curve 46 by 90 electrical degrees as a result of which the motor 30 is caused to rotate in the opposite direction.

The armature of the motor 30 is connected to drive a revolution counter 47. The motor 30 operates upon the principle of the well-known household watt-hour meters, the speed of rotation of which varies with the input to the motor. Since the voltage applied to the phase winding 32 remains substantially constant and since the alternating component of the plate current I_p which flows in the phase winding 31 varies with the angular deviation of the electric discharge device 10 in the earth's magnetic field, the input to the motor and consequently its speed vary with the angular deviation of the craft from its predetermined course. Assuming a constant speed of the airplane, the number of revolutions of motor 30 is, therefore, roughly proportional to the total amount of deviation from the predetermined course, and the revolution counter will therefore serve as an integrating device to give an indication of the total distance deviated from the course.

In the modification shown in Fig. 7 the elements are the same as those shown in Fig. 2 with the exception that the "B" battery 28 of Fig. 2 is replaced by an alternating current source of supply having a frequency of $2w$. This source of supply is represented in the drawings by an alternating current generator 48 mounted upon the same shaft as the generator 49 which supplies the conductors 23 with periodically varying current of frequency w . These generators may be driven by any suitable means such as that represented in the drawings by the wind turbine comprising the bucket wheel 50 provided with a serrated periphery, and a nozzle 51 which serves to direct a stream of air against the buckets of wheel 50. In the modification of Fig. 7 the filament transformer has been omitted and the filament of the electric discharge device is connected directly across the conductors 23 in series with a resistance 52, and there is connected across the terminals of the filament a resistance 53 to the mid-point of which is connected one terminal of the alternator 48; the opposite terminal thereof being connected to the anode of the electric discharge device in series with one phase winding 31 of the motor as before. The alternators 48 and 49 are so adjusted with respect to each other on their common shaft that a positive maximum potential will be applied to the plate of the electric discharge device each time that the polarizing field due to winding 38 is maximum, either positive or negative. This condition is represented in Fig. 8 of the drawings, the single frequency curve 54 representing the polarizing field and the double frequency curve 55 representing the potential applied to the plate of the electric discharge device.

Electric discharge device 10 is so designed that current will only flow in the plate or output circuit when the plate potential is a positive maximum. Since the alternating potential applied to the plate has a frequency of $2w$ the positive maximums of this potential will also occur at

a frequency of $2w$ and slight unidirectional pulses of current having a frequency of $2w$ will thereby be caused to flow in the plate circuit when the plate potential is a positive maximum. This unidirectional pulsating current is represented by the curve 56 in Fig. 9 which curve as shown is a series of small impulses of current having a frequency of $2w$ compared with the frequency w represented by the timing wave 57.

The series of current impulses represented by the curve 56 is the current which normally flows in the phase winding 31 of the motor when the airplane is proceeding upon the predetermined course and the electric discharge device 10 occupies an east-west position in the terrestrial field. Since the current which is normally supplied to the phase winding 32 of the motor is of frequency w , the resultant torque of these two currents will integrate to zero as will be understood by persons skilled in the art, and there will be no tendency for the armature of the motor to rotate when the airplane is proceeding upon its set course.

When the airplane deviates from its course in one direction and the electric discharge device 10 is simultaneously rotated a similar amount from its east-west position, the terrestrial magnetic field will add to one half cycle of the polarizing field and subtract from the other half cycle. If it be assumed that the terrestrial field subtracts from the positive half cycles of the polarizing field and adds to the negative half cycles as shown in Fig. 10, then the pulses of plate current I_p that occur simultaneously with the positive half cycles of polarizing field e. g. the odd numbered pulses will be increased in value, and the even numbered pulses that occur simultaneously with the negative half cycles of polarizing field will be decreased.

The result of increasing the odd numbered pulses and decreasing the even numbered pulses will be to produce a resultant unidirectional periodically varying current of frequency w and having a complex wave shaped form represented graphically by the curve 58 in Fig. 11. This resultant periodic current is supplied to the phase winding 31 of the motor 30 and cooperates with the current supplied to the phase winding 32 to effect a resultant turning torque which causes the motor to rotate, in a manner that will be clear from the description and explanation in connection with the modification of Fig. 2.

Likewise when the airplane deviates from its predetermined course in the opposite direction and the electric discharge device 10 is rotated from its east-west position in an opposite direction, the periodically varying current represented graphically by curve 59 in Fig. 13 of frequency w and displaced 180 electrical degrees from the current represented by the curve 58, will be caused to flow in the plate circuit and hence in the phase winding 31 of the motor, thereby effecting rotation of the latter in the opposite direction.

This invention is not limited to the use of an electric motor as an indicating device since other forms of indicating instruments may also be employed. For example the motor 30 might be replaced by a torque motor the armature of which is biased by a suitable restoring spring to a central or neutral position indicated by the position of a needle carried by its armature, with respect to a suitably graduated scale. A moving coil dynamometer might also be used as an indicating instrument, the coils of the dynamometer being connected in the place of the phase wind-

ings of the motor 30. It will be understood, moreover, that if a dynamometer is used the resistance 33 and condenser 34 will be so chosen that the currents flowing in the respective coils thereof will be substantially in phase when the airplane deviates in one direction from its course and consequently substantially 180° out of phase when the airplane deviates in the opposite direction from its course, thereby producing respectively opposite indications of the dynamometer.

I would have it understood that the various characteristic curves shown graphically in the various figures of the drawings and employed in explaining the principle of operation of this compass are not necessarily of the exact form and shape of the characteristics which they represent that would be observed if an oscillograph were employed. As a matter of fact the curves shown in the drawings have been exaggerated for the purpose of enabling the principles of operation of the compass to be easily grasped and readily retained in mind.

Although in accordance with the provisions of the patent statutes I have described my invention as embodied in specific elements organized in a particular manner I would have it understood that the apparatus shown in the drawings and described in the specification is merely illustrative and that modifications and alterations will readily suggest themselves to persons skilled in the art without departing from the true spirit of this invention or from the scope of the annexed claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A compass comprising an indicating device, means for partially energizing said indicating device and means including an electric discharge device having an anode and an electron-emitting cathode, the electron flow between said cathode and anode being controlled by the position of said device in the earth's magnetic field for controlling the completion of the energization of said device.

2. In a compass, the combination with an alternating current indicating instrument, of means including an electric valve having an anode and a thermionic cathode, the electron flow between said cathode and anode being controlled by the relative position of said valve in the earth's magnetic field for supplying a periodically varying current to said indicating instrument.

3. A compass comprising means for supplying a periodically varying voltage, means including an electric valve having an anode and an electron emitting cathode, the electron flow between said cathode and anode being controlled by the position of said valve in the earth's magnetic field for effecting variations in the wave form of said voltage, and means responsive to said variations in the wave form of said voltage for indicating direction with respect to the direction of the earth's magnetic field.

4. In a compass, the combination with an alternating current instrument having a pair of windings, means for supplying an alternating current to one of said windings, and means including an electric valve having an anode and an electron emitting cathode for supplying respectively dephased alternating currents to the other of said windings in accordance with the position of said valve with respect to a predetermined position in the earth's field, the space current between said cathode and anode being

controlled by the position of said valve in the earth's magnetic field.

5. A compass comprising in combination an electrical indicating device provided with a polyphase winding, means for normally energizing a portion of the phases of said winding, and means including an electric discharge device having an anode and a thermionic cathode, the electron flow between said cathode and anode being controlled responsively to deviation of said device from a predetermined position in the earth's magnetic field for controlling the energization of the remainder of said winding to effect operation of said indicating instrument.

6. A compass comprising in combination an indicating instrument provided with a plurality of windings, means for energizing a portion of said windings, and means including an electric discharge device having an anode and a thermionic cathode, the electron flow between said cathode and anode being controlled by the positions of said device on respectively opposite sides of a predetermined position in the earth's field for controlling the energization of the remainder of said windings to effect respectively opposite operations of said indicating device.

7. In a compass, the combination with an integrating device provided with a plurality of windings of means for normally energizing a portion of said windings, and means including an electric discharge device having an anode and a thermionic cathode, the electron flow between said cathode and anode being controlled in response to deviations of said device from a predetermined position with respect to the direction of said field for controlling the energization of the remainder of said windings proportionally to said deviation thereby to provide an indication of the total amount of deviation.

8. In combination, an electroresponsive indicating device provided with an energizing winding, and means including an electric discharge device having an anode and an electron emitting cathode, the space current between said cathode and anode being controlled by the position of said device on opposite sides of a predetermined position in the earth's magnetic field for effecting energization of opposite polarities in said winding thereby to effect opposite indications of said indicating device.

9. In combination, a polyphase motor, means for energizing a portion of the phases of said motor, and means including an electric discharge device having an anode and an electron emitting cathode, the space current between said cathode and anode being controlled by the position of said device in a magnetic field relative to a predetermined position for controlling the energization of the remainder of the phases thereby to effect rotation of said motor.

10. In a compass an indicating device provided with a polyphase winding, means for supplying current to a portion of the phases of said device, means including an electric discharge device having an anode and an electron emitting cathode, the electron flow between said cathode and anode being controlled by angular deviation of said device from a predetermined position in the earth's magnetic field for controlling the supply of current to the remaining portion of the phases of said device, and means for controlling the phase relationship of said currents to effect operation of said indicating device.

11. In a compass the combination with an indicating device provided with a polyphase winding

of a source for supplying a periodically varying current to a portion of the phases thereof, an electric discharge device provided with an electron emitting cathode and with an anode connected in an output circuit including the remaining portion of the phases thereof, the current flowing between said cathode and anode being controlled by the position of said device in the earth's magnetic field and variable in proportion to the amount of deviation of said device from a predetermined position in said magnetic field, and control means for said electric discharge device for causing the variations of said output current to have a frequency proportional to the periodicity of said source, thereby to effect operation of said indicating device.

12. In a compass, a polyphase indicating device, an alternating current source for supplying current to one phase thereof, means for supplying current to another phase, means including a control device and an electric discharge device having an anode and an electron emitting cathode, the electron flow between said cathode and anode being controlled by said control device and by the position of said discharge device in the earth's magnetic field and responsive to deviations of said discharge device from said predetermined position for varying the current supplied to said other phase of said indicating device to effect operation thereof.

13. In a compass the combination with a polyphase indicating device of a source for supplying a periodically varying current to one phase thereof, means for normally supplying a substantially uniform current to a second phase thereof, an electric discharge device responsive to deviations from a predetermined position in a magnetic field for effecting variations in said uniform current, and a polarizing coil energized in accordance with the frequency of said source for controlling the periodicity of said variations to effect operations of said indicating device.

14. In a compass, the combination with an electrical indicating instrument provided with a polyphase winding of a source for supplying a periodically varying current to a portion of the phases of said winding and means including a polarizing winding energized from said source and an electric discharge device controlled by said polarizing winding and operable in response to the horizontal component of the earth's magnetic field in positions on opposite sides of a predetermined position in said field for supplying periodically varying currents respectively displaced from each other in phase opposition to the remaining portion of the phases of said winding to effect respectively opposite indications of said indicating instrument.

15. A compass comprising in combination an electric motor provided with a polyphase winding, a source of alternating current for supplying a portion of the phases of said winding, a direct current source for supplying a substantially uniform current to the remaining phases of said winding, means including an electric discharge device provided with an output circuit including said direct current source and said remaining phases and responsive to deviations from a predetermined position in the earth's magnetic field for effecting variations in said uniform current, a control winding connected to said source for causing said variations to have the same periodicity as that of said alternating current source, and means including a condenser and a resistance connected in circuit with said first mentioned portion of said phases to control the phase relation between the currents in the phases of said winding to effect operation of said motor.

JAMES D. TEAR.

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