

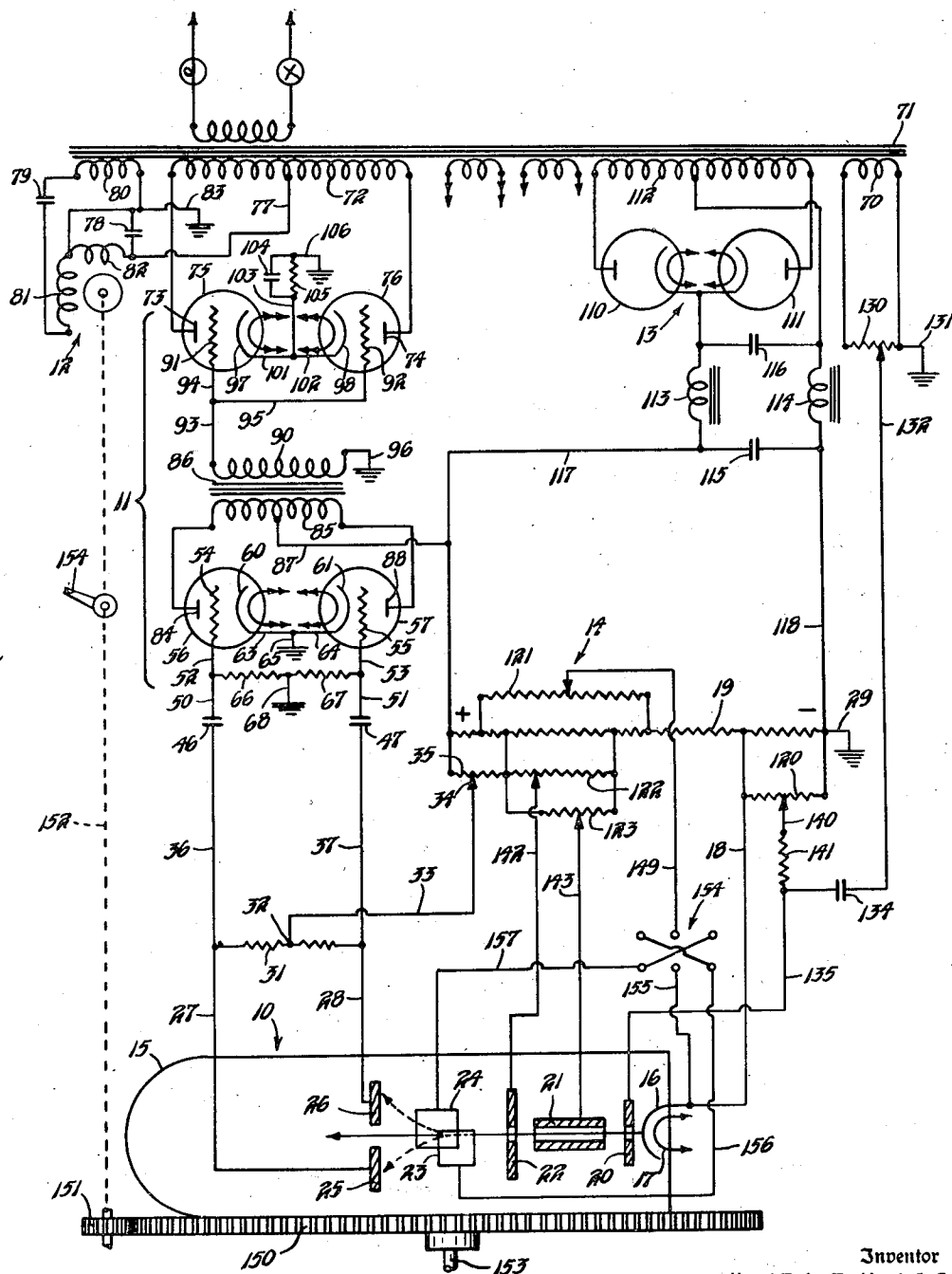
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ELECTRON DISCHARGE COMPASS SYSTEM

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ELECTRON DISCHARGE COMPASS SYSTEM

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This invention relates generally to the art of control devices and more particularly to such devices in which it is desired to operate an indicator or a control mechanism according to the position of a continuously rotatable member. Still more particularly, my invention relates to control apparatus in which the position of a pick-up or controlling member with respect to a magnetic field is continuously made evident or effective at a distance by the operation of an indicator or by the actuation of some controlled device.

I am aware that use has already been made of the deflection of the beam of a cathode ray tube in response to the earth's magnetic field in an attempt to provide remotely or locally indicating compasses, but the known devices are defective in numerous ways. A particular disability common to all prior devices having in mind the consummation of the objects of my invention lies in the fact that they are able to deliver only an insignificant amount of power, and for that reason they are in a commercial sense inoperative except for instruments for viewing said deflection of the cathode ray beam. With my invention, the limit on the power available, controlled in accordance with the position of the controlling element, is set only by the desire of the user.

An object of this invention is to provide an improved remotely indicating or operating compass.

Another object of this invention is to provide an improved electronic system for continuously transmitting the angular position of a continuously rotatable member.

Still another object of this invention is to provide a remotely indicating or operating device which is continuously responsive to the angular position of a controlling or pick-up member.

Yet another object of this invention is to provide a cathode ray tube having a plurality of target plates upon which the beam is adapted to impinge or between which it is adapted to pass, combined with means for modulating the intensity of the beam.

Other objects and advantages of the present invention will become apparent upon a study of the specification and claims, and of the figures of the drawing which is attached hereto and which I make a part hereof, and wherein the single figure is a diagrammatic showing of the electrical circuit and of the cathode ray tube arranged in what I consider a preferred embodiment of my invention, the cathode ray tube being shown in side elevation.

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In the figure, element 10 refers generally to a cathode ray tube. Reference numeral 11 refers generally to the amplifier which I use in association with my cathode ray tube. Reference numeral 12 refers to a split phase motor which is used in accordance with the practice of my invention as is set forth below. Element 13 refers to a power supply and numeral 14 refers to a potential divider arrangement, all of which will be discussed in detail in the specification which follows.

In cathode ray tube 10 comprising a portion of my invention, reference numeral 15 refers to an evacuated and sealed envelope enclosing the electrodes of the tube. A cathode 16 is connected by a conductor 18 to a point on potential divider 14 and thence to ground through a portion of the divider and conductor 29. The cathode is indirectly heated by a filament 17. Coaxial electrodes 20, 21, and 22 are arranged to provide a concentrated beam of electrons moving through the tube in the direction of the arrow. Electrode 20 is a control grid whose purpose is to vary the intensity of the beam current. Electrode 21 is a focusing anode for concentrating the electrons into a beam, and electrode 22 is an accelerating anode for increasing the velocity of the electrons comprising the beam. Physical elements 17, 16, 20, 21 and 22 comprise what has come to be referred to in the art as an electron gun. Spaced on either side of the intended normal position of the electron beam and located at a distance from the accelerating anode are a pair of deflecting plates 23 and 24 whose function, as is well known, is to cause a deflection of the beam away from its normal axis.

I now come to more novel features of my invention. In my cathode ray tube I provide an additional pair of electrodes 25 and 26 spaced along the normal axis of the beam from the deflecting plates, and having the same oppositely disposed relation about the axis of the beam as do the deflecting plates. With respect to one another, however, the pair of deflecting plates is in 90 degree rotated relationship about the axis of the beam with respect to the pair of target plates. I refer to these electrodes as target plates, and these target plates are spaced mutually a sufficient distance so that the properly focused electron beam may pass between them without impinging upon either plate, although deflection of the beam in either direction may cause it to impinge upon one or the other of the target plates.

The operation of this portion of my invention is as follows. It is well known that a cathode

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ray traversing a magnetic field is deflected out of its normal path in one direction or the opposite, depending on the relation of the polarity of the field to the direction of electron flow. In terms of my invention, if the horizontal component of the earth's magnetic field, or any other artificially created field which it is designed to use in the practice of my invention, has a direction H_1 perpendicular to and into the plane of the paper, the beam is deflected from the normal path suggested by the solid arrow into a path suggested by the upper broken arrow, and the beam impinges upon plate 26.

If the influencing field is directed out of the paper, the beam is deflected in the opposite direction, to impinge on plate 25. If on the other hand, the influencing field has a direction parallel to the axis of the ray, the field has no deflecting effect on the path of the beam, causing it to impinge upon neither plate 25 nor plate 26, but rather allowing it to pass through the space between them. Accordingly, it will be seen that if the cathode ray tube comprising a portion of my invention be rotated about an axis other than that of the beam in its normal state, for instance an axis normal to that of the beam and in the horizontal plane of the paper, there is a position of the tube in which the beam is not deflected either upwardly or downwardly. This position I will refer to as the normal or zero position of the tube.

Now suppose my cathode ray tube to be mounted in a vehicle, for example, an aircraft with its axis in fixed relation parallel to the longitudinal axis of the craft, and in such rotated position that the horizontal component of the earth's magnetic field acts in a direction normal to the plane of the paper in the drawing. Then it will be clear that when the axis of the craft is in a magnetically north and south direction, the beam of the tube is undeviated and no potential appears upon either plate 25 or plate 26. As long as the craft continues to travel along the course indicated, this situation continues. However, if the craft deviates from the course indicated, the beam of the cathode ray tube is deflected to fall upon plate 25 or plate 26, depending upon the direction of deviation of the craft from its course, and a potential appears upon the plate receiving the beam. It is clear that by properly focusing the beam and by properly proportioning the space between the plates 25 and 26, the sensitivity of my tube can be substantially adjusted.

If now a modulating potential be impressed upon the control grid 20, and the beam be deflected so that it impinges, for example, on plate 25, a potential modulated in intensity appears upon plate 25 with respect to cathode 16, and the frequency of this modulated potential is the frequency of the modulating potential impressed upon grid 20. I conceive it to be a part of my invention to so modulate the beam, and to make use of the modulated potentials in a manner I am about to describe, and in other suitable applications.

Conductors 27 and 28 lead respectively from plates 25 and 26 to the ends of a resistor 31. Center tap 32 of resistor 31 is adjustably maintained at a high positive potential with respect to the cathode by being connected by conductor 33 to the movable arm 34 of a potentiometer 35, which draws its energy from potential divider 14. Plates 25 and 26 are further connected by conductors 36 and 37, coupling condensers 46

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and 47, conductors 50 and 51, and conductors 52 and 53 to the grids 54 and 55 of vacuum tubes 56 and 57, all respectively. Cathodes 60 and 61 of vacuum tubes 56 and 57 are grounded as by conductors 63, 64 and 65. A pair of resistors 66 and 67 are provided having a common connection grounded as by conductor 68. The other end of one resistor 66 is connected as by conductors 50 and 52 to condenser 46 and grid 54 of tube 56, respectively. The other end of the other resistor 67 is connected as by conductors 51 and 53 to condenser 47 (electrically equivalent to condenser 46) and grid 55 of tube 57, respectively.

Thus it will be seen that there is a continuous direct current path, when the beam is deflected, from the negative terminal of potential divider 14 through a portion of the divider, thence by conductor 18 to the cathode 16 of the cathode ray tube, to plate 25 or plate 26 of the cathode ray tube, to center tap 32 of resistance 31 by way of conductor 27 or conductor 28, to the positive pole of potential divider 14 by way of conductor 33 and potentiometer 35, and back through the potentiometer. There are also a pair of continuous paths for modulated currents from the negative terminal of potential divider 14, through a portion of the divider, thence by conductor 18 to the cathode of the cathode ray tube, to plate 25 or plate 26 of the cathode ray tube, then either to grid 54 of tube 56 by way of conductor 27, conductor 36, condenser 46, conductor 50 and conductor 52 or to grid 55 of tube 57 by way of conductor 28, conductor 37, condenser 47, conductor 51, and conductor 53. The potentials are thus impressed upon the grids of the tubes: the circuits are completed through the resistor 66 or resistor 67 to ground by conductor 68 and thence back to the negative terminal of potential divider 14. The values of resistors 66 and 67 are so chosen that the IR drops across them, which are the potentials impressed on the grids of the tubes respectively, due to impingement of the beam on the target plates are within the range desired.

The modulating potential for grid 20 of my cathode ray tube is taken from one secondary winding 70 of a transformer 71 having a plurality of such secondary windings. A potentiometer 130 is connected across winding 70, and one terminal of the potentiometer is grounded as at 131. The movable arm 132 of the potentiometer is connected to the grid 20 by conductor 133, condensers 134, and conductor 135. Another secondary winding 72 of transformer 71 has its terminals connected to the plates 73 and 74 of a pair of tubes 75 and 76, respectively, while its center tap 77 is grounded through a winding 82 of split phase motor 12 and a conductor 83. A condenser 78 is connected in parallel with motor winding 82. A third secondary winding 80 of transformer 71 provides potential to the other winding 81 of motor 12 through a condenser 79, and one terminal of this winding 81 is connected to the grounded terminal of motor winding 82.

Plate 84 of tube 56 is connected to one terminal of a primary winding 85 of a coupling transformer 86, and the other terminal thereof is connected to plate 88 of tube 57. A center tap of this winding is connected with the positive terminal of potential divider 14 as by conductor 87. Thus, a signal impressed upon grid 55 will cause current to flow through primary winding 85 in one direction, while a signal upon grid 54 will cause current to flow through primary winding

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85 in the opposite direction. One terminal of a secondary winding 90 of transformer 86 is connected to the grids 91 and 92 of tubes 75 and 76 as by conductors 93, 94, and 95. The other terminal of secondary 90 is grounded as by conductor 96, while the cathodes 97 and 98 of tubes 75 and 76 are grounded as by conductors 101, 102, 103, condenser 104, resistor 105, and conductor 106. Condenser 104 is in parallel with resistor 105.

In my drawing I have also shown a conventional power supply for providing the potentials necessary in the operation of my invention. This power supply, as will be seen, comprises a pair of diodes 110 and 111, the plates of which are provided with potentials from still another secondary winding 112 of transformer 71. A filter comprising chokes 113 and 114 and condensers 115 and 116 is provided to smooth out the ripple in the rectified output current, and this filter current is applied to resistor 19 of potential divider 14 by conductors 117 and 118.

It will be seen that numerous potentiometers have been connected in parallel with the resistor 19 at various points for the purpose of adjustably taking off potentials which may be suitably varied. The purpose of potentiometer 35 has already been set forth. Potentiometer 120 is to provide proper bias potential to the grid of the cathode ray tube as by conductor 140, resistor 141 and conductor 135. Potentiometer 122 is to provide a suitable accelerating voltage upon the accelerating anode 22 and is connected thereto by conductor 142, and potentiometer 123 is to provide a suitable voltage on the focusing electrode 21 and is connected thereto by conductor 143. Potentiometer 121 is to provide a proper potential difference between deflecting plates 23 and 24 for a purpose about to be set forth.

Thus far I have discussed only the horizontal component of the earth's magnetic field. However, it must be remembered that there is also a vertical component to this field, and that this component is directed downwardly in the Northern hemisphere and upwardly in the Southern hemisphere. If the cathode ray tube is mounted as I have shown and described, with its axis horizontal and the opposed edges of the target plates also horizontal, the effect of this vertical component alone is simply to deflect the beam longitudinally in the space between the target plates. For moderate vertical components this may not be serious, but for large vertical components, especially in combination with large horizontal components, the force may be sufficient to deflect the beam entirely off the target plates, thus rendering the device wholly inoperative.

Application of proper potentials between plate 23 and 24 brings electrical force to bear, returning the cathode ray to a central position longitudinally of the space between the target plates, but the polarity of this recentering potential must be opposite in the two hemispheres. Thus for a craft which is to be operable in any desired locality means must be provided both for varying this potential in magnitude and for reversing it in polarity. I follow the customary practice and maintain one of the target plates at cathode potential, while impressing the recentering potential upon the other plate. For this purpose I use a reversing switch of the conventional double pole double throw type, as indicated at 154. To the input or center terminals of the switch I connect the cathode 16 and the movable arm of potentiometer 121 as by conductors 155 and 149, 75

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respectively. The output terminals of the reversing switch are connected to plates 23 and 24 as by conductors 156 and 157, respectively. Thus, when switch 154 is thrown in the left position plate 23 is positive with respect to plate 24 which is at cathode potential, while when switch 154 is thrown in the right position plate 23 is at cathode potential and plate 24 is positive with respect thereto: the magnitude of the potential difference in either case is regulable by adjustment of potentiometer 121.

It will now be evident that when the beam is deflected to impinge on one of the target plates an alternating potential is impressed on the grid of one of the tubes 56 and 57. This potential has the same frequency of alternation as does the alternating potential in secondary winding 70, and the phase relationship between the two alternating potentials depends primarily on the characteristics of condenser 134 and of condenser 46 or condenser 47 as the case may be. Since condensers 46 and 47 are electrically equivalent, the grid potential is in the same phase relationship to the potential in secondary winding 70 whether it is impressed upon grid 54 or grid 55. Moreover, the change in phase due to tube 56 is the same as that due to tube 57.

However, the potential across the primary of the transformer 86 due to impressed potential on grid 54 is 180° out of phase with the potential across the primary due to impressed potential on grid 55. The change in phase due to the transformer is the same regardless of which grid supplies the signal potential. Therefore the potentials impressed upon grids 91 and 92 due to beam impingement on target plates 25 and 26 respectively are 180° out of phase and have otherwise a relationship with the potential across secondary winding 70 influenced by the effect of elements 134, 46 (or 47), 56 (or 57), and 86. Since the electrical characteristics of these elements have been selected so that in the present circuit their overall phase shifting effect is negligible, this means that the grid potentials on tubes 75 and 76 are either in phase or 180° out of phase with the potentials in secondary winding 70, and therefore with the potential in secondary winding 72 which has the same primary.

The plate of tube 75 is negative when the plate of tube 76 is positive and at the same instant the grids of both tubes are either positive or negative, depending on the direction of deviation of the beam. Current can flow in tubes 75 and 76 only when the plates are positive, and when tube 75 is conducting current flows through field winding 82 of motor 12 in a direction opposite to that in which it flows when tube 76 is conducting. This corresponds to a reversal of phase in field winding 82, with respect to the current in secondary winding 72 or secondary winding 80 which again has the same primary. The other winding 81 of the motor is always in a fixed phase relationship with the secondary winding 80 and, as is well known, reversal of the phase of current in field winding 82 cause reversal of the motor.

It will therefore now be clear that I have found a means for operating motor 12 in a forward or reverse direction, depending on which target plate of the cathode ray tube is impinged upon by the deviated beam.

I will now point out the utility of my invention. Suppose the cathode ray tube of my invention to be mounted in a craft in such a direction that the earth's magnetic field is that of H₂ when the

craft is on its proper course. If now the craft departs from that course in one direction or the other, the beam will be deflected to impinge on plate 25 or plate 26, and as set forth above, current will be induced in one winding of motor 12 in phase with or 180 degrees out of phase with the current in the other winding which will cause motor 12 to rotate in one direction or the other, depending upon the direction in which the craft veered from its course. This motor may be mechanically connected to operate a control device having to do with returning the craft to its course.

Another modification of my invention may be conceived to operate in the following fashion. My cathode ray tube may be mounted to rotate about an axis which may be, for example, substantially vertical and normal to the axis of the beam. For this purpose I have shown my tube as supported on a large disc 150 arranged for rotation as at 153 and having gear teeth in its periphery for engaging with a gear 151 carried by a shaft 152 operatively associated with motor 12. The axis of the beam may be considered to be approximately horizontal so that the angular position of the beam with respect to the horizontal component of the earth's magnetic field may be varied. The tube may therefore be so set at any time with respect to the earth's magnetic field that, the craft keeping on an appointed course, the beam of the tube will be undeviated. Should the craft now depart from its course, operation of the motor will take place as set forth above, and this motion may be used to operate an indicator at a distant point showing the departure of the craft from its course, and at the same time to cause rotation of my cathode ray tube about the axis to which I referred, so that simultaneously the beam will be brought back into its undiverted position, and the indicator will come to rest at a point showing the extent to which the craft has varied from its course.

It will also be clearly understood that it is within the spirit of my invention to provide a second set of plates similar to plates 25 and 26 but at right angles thereto, so that the beam of the tube will be responsive not only to deviation in a single plane, but deviation in a plane at right angles to that plane. By this means, it will be seen that the cathode ray tube may be maintained in a given position with respect to the earth's magnetic field regardless of the levelness of the axis of the craft in which it is mounted; for instance, in an aircraft which can descend or ascend at a steep angle.

I further wish it clearly understood that I do not intend my invention to be limited to the use of this device in connection only with the magnetic field of the earth, since I conceive it to be a part of my invention to provide this type of indicating or controlling device wherever a controlling and indicating instrument responsive to rotation may be desired. This can be done, as I have pointed out before, by providing an artificially created magnetic field having the desired angular relationship with the beam, the two being mounted for relative rotation as I have set forth above.

While I have shown a preferred embodiment of my invention, it is obvious that many other modifications and adaptations of the present invention will occur to those skilled in the art. Therefore, it should be clearly understood that the invention is not to be limited only to that

form shown and described, but rather by the scope of the appended claims.

I claim as my invention:

1. In a device of the class described, in combination, means normally directing a beam of electrons along an axis to comprise a beam current, said beam being adapted for deflection from said normal axis in response to change in a condition from a normal value, means for modulating the intensity of said beam, target means comprising anodes located about said axis for impingement by said beam upon deflection from said axis, an envelope hermetically enclosing said foregoing means, a source of alternating current of a desired frequency, means energizing said modulating means from said source whereby to modulate the intensity of said beam at the frequency of and in phase with the current from said source, anode circuits including said target anodes, impingement of said beam upon a target anode causing the flow in the related anode circuit of modulated anode current having a component of said desired frequency, means combining said anode currents, the combined current due to impingement of a first of said anodes being in phase with that from said source, the combined current due to impingement of a second of said anodes being of opposite phase to that from said source, an electric motor operable at said frequency upon energization by two currents of said frequency and of displaced phase, discriminator means energizing said motor with a first current which is in phase with or of opposite phase to the current from said source depending on whether said first or said second anode is impinged by said beam, and means energizing said motor with a second current displaced in phase by ninety degrees from the current from said source.

2. In a device of the class described, in combination, means normally directing a beam of electrons along an axis to comprise a beam current, said beam being adapted for deflection from said normal axis in response to change in a condition from a normal value, means for modulating the intensity of said beam, target means comprising anodes located about said axis for impingement by said beam upon deflection from said axis, an envelope hermetically enclosing said foregoing means, a source of alternating current of a desired frequency, means energizing said modulating means from said source whereby to modulate the intensity of said beam at the frequency of and in phase with the current from said source, anode circuits including said target anodes, impingement of said beam upon a target anode causing the flow in the related anode circuit of modulated anode current having a component of said desired frequency, means combining said anode currents, the combined current due to impingement of a first of said anodes being in phase with that from said source, the combined current due to impingement of a second of said anodes being of opposite phase to that from said source, an electric motor operable at said frequency upon energization by two currents of said frequency and of displaced phase, discriminator means energizing said motor with a first current which is in phase with or of opposite phase to the current from said source depending on whether said first or said second anode is impinged by said beam, means energizing said motor with a second current displaced in phase by ninety degrees from the current from said source, means mounting said

envelope for rotation about an axis other than said normal axis of said beam, and means associating said motor in driving relation with said last named means.

3. In a device of the class described, in combination, means normally directing a beam of electrons along an axis to comprise a beam current, said beam being adapted for deflection from said normal axis in response to change in a condition from a normal value, means for modulating the intensity of said beam, target means comprising opposed anodes spaced about said axis for impingement by said beam upon deflection from said axis in a first direction, means for electrostatically deflecting said beam in a second direction perpendicular to said first direction, an envelope hermetically enclosing said foregoing means, a source of alternating current of a desired frequency, means energizing said modulating means from said source whereby to modulate the intensity of said beam at the frequency of and in phase with the current from said source, anode circuits including said target anodes, impingement of said beam upon a target anode causing the flow in the related anode circuit of modulated anode current having a component of said desired frequency, means combining said anode currents, the combined current due to impingement of a first of said anodes being in phase with that from said source, the combined current due to impingement of a second of said anodes being of opposite phase to that from said source, means mounting said envelope in a normal orientation with respect to the ambient magnetic field, in which orientation said beam passes along said axis, movement of said envelope from said normal orientation causing impingement of said beam upon one of said anodes, and means responsive to said combined current for correlating said combined current with the change in orientation of said envelope.

4. In a device of the class described, in combination, an electron gun directing a beam of electrons of modulated intensity along an axis to comprise a modulated beam current, said beam being subject to the effect of a magnetic field, spaced target anodes displaced along said axis in the direction of said beam, means for electrostatically deflecting said beam in a second direction perpendicular to said first direction, an anode circuit for each of said target anodes, said beam impinging a predetermined one of said target anodes for each orientation of said axis with respect to said field, impingement of said beam on each said anode resulting in modulating anode current in the related anode circuit, said anode circuits including means combining currents flowing therein, said combined current changing in phase with respect to a standard with change in the anode impinged by said beam.

5. In a device of the class described, in combination, means normally directing a beam of electrons along an axis to comprise a beam current, said beam being adapted for deflection from said normal axis in response to change in a condition from a normal value, means for modulating the intensity of said beam, means for deflecting said beam with respect to said axis in a selected plane, target means comprising anodes located about said axis for impingement by said beam upon deflection from said axis in a direction having a component normal to said plane, an envelope hermetically enclosing said foregoing means, a source of alternating current of a desired frequency, means energizing said modulating means

from said source whereby to modulate the intensity of said beam at the frequency of and in phase with the current from said source, anode circuits including said target anodes, impingement of said beam upon a target anode causing the flow in the related anode circuit of modulated anode current having a component of said desired frequency, means combining said anode currents, the combined current due to impingement of a first of said anodes being in phase with that from said source, the combined current due to impingement of a second of said anodes being of opposite phase to that from said source, an electric motor operable at said frequency upon energization by two currents of said frequency and of displaced phase, discriminator means energizing said motor with a first current which is in phase with or of opposite phase to the current from said source, depending on whether said first or said second anode is impinged by said beam, means energizing said motor with a second current displaced in phase by ninety degrees from the current from said source, and means energizing said deflecting means to maintain said beam centered with respect to said plane, said energizing means being of reversible polarity.

6. In a device of the class described, in combination, an envelope, an electron gun and a pair of spaced opposed target anodes enclosed by said envelope, said gun emitting a beam of electrons along an axis in the direction of said anodes to comprise a beam current, said envelope having an orientation in which said beam is deflected from said axis by the ambient magnetic field, change in said orientation of said envelope resulting in deviation of said beam from said axis to increase its effective impingement upon a target anode, said deflection of said beam having components in two mutually perpendicular planes, means for neutralizing the component of said deflection in the first of said planes, said first plane passing between said target anodes, means modulating the intensity of said beam at a desired frequency, an anode circuit for each of said anodes, impingement of said beam on each said anode resulting in modulated anode current in the related anode circuit, said anode circuits including means combining current flowing therein, said combined current changing in phase with respect to a standard with movement of said beam in the second of said planes from impingement on one anode to impingement on the other.

7. In a compass: a cathode ray tube including an electron gun directing a beam of electrons along a normal axis from which it is subject to deflection in response to the earth's magnetic field, means energizable to modulate the intensity of said beam, and a plurality of target plates mounted for variable impingement, according as said beam is deflected, to transmit variable target currents; a reversible motor having windings designed for energization with alternating voltage of a selected frequency; a source of alternating voltage of said frequency; means energizing said modulating means from said source to give to said target currents alternating components having fixed phase relationships to said source; means energizing one winding of said motor from said source; means, including means combining said target currents, for energizing the other phase of said motor in accordance with the relationship between said components of said target currents, so that as said relationship re-

verses the direction of operation of said motor also reverses; and controlled means actuated by said motor.

8. In a compass: a cathode ray tube including an electron gun directing a beam of electrons along a normal axis from which it is subject to deflection in response to the earth's magnetic field, means energizable to modulate the intensity of said beam, and a plurality of target plates mounted for variable impingement, according as said beam is deflected, to transmit variable target currents; a source of alternating voltage of a selected frequency; means energizing said modulating means from said source to give to said target currents alternating components having fixed phase relationships to said source; a controlled device; and means, including means combining said target currents, for energizing said controlled device with alternating voltage which reverses in phase with reversal in the relationship between said components of said target currents.

HENRY E. HARTIG.

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