

April 28, 1936.

E. D. McARTHUR

2,039,102

CONTROL SYSTEM FOR GASEOUS DISCHARGE DEVICES

Original Filed April 28, 1934 2 Sheets-Sheet 1

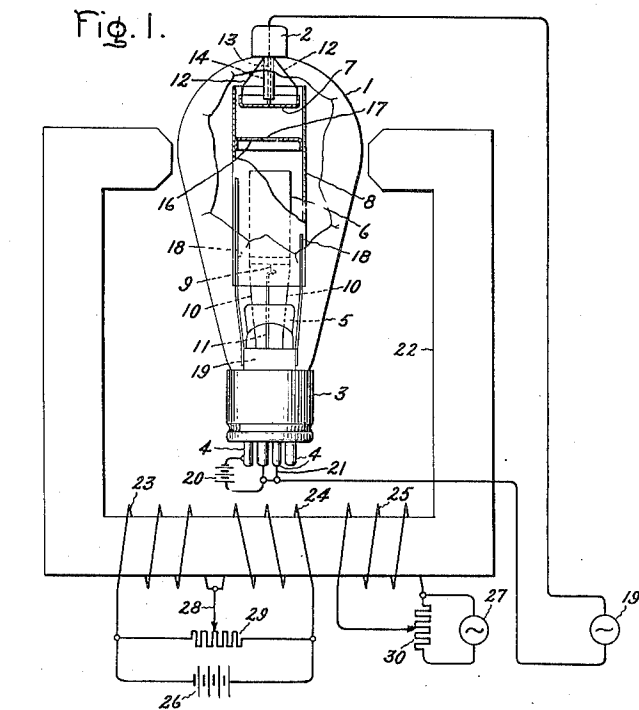
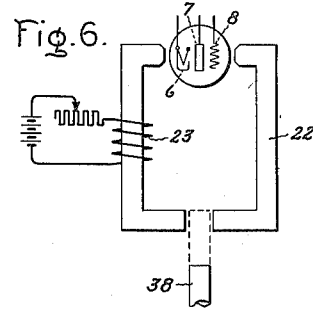
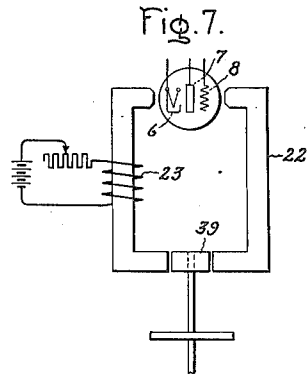
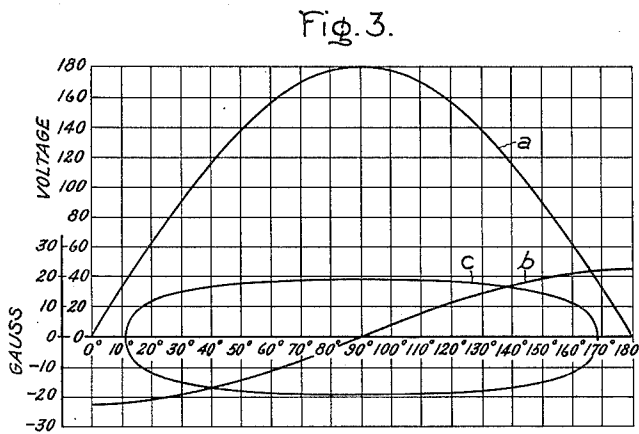
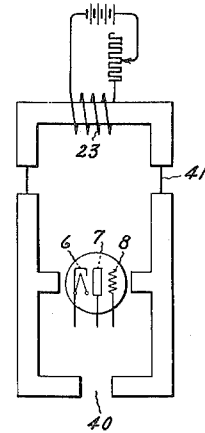
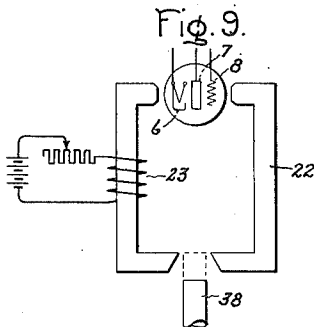
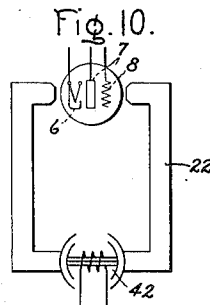


Fig. 8.



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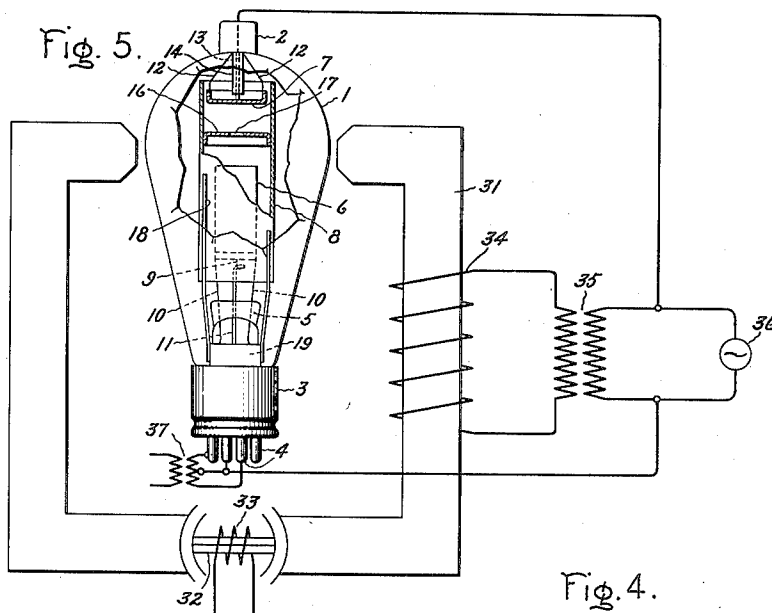
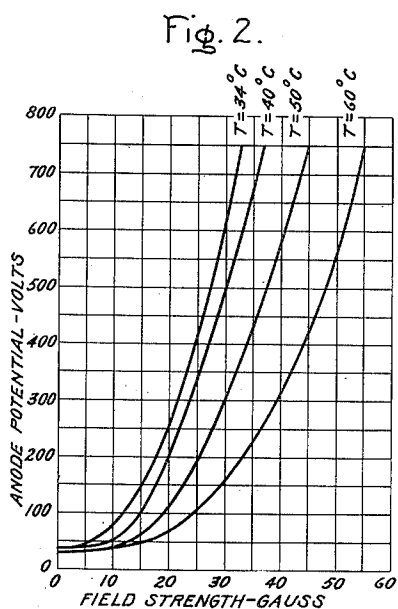
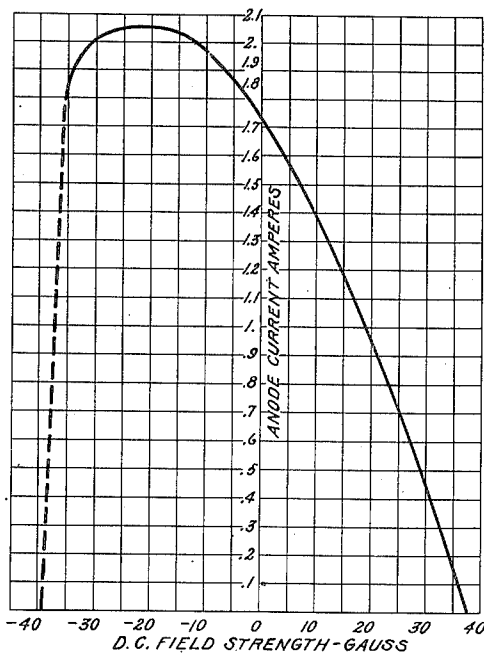
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CONTROL SYSTEM FOR GASEOUS DISCHARGE DEVICES

Original Filed April 28, 1934 2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,039,102

CONTROL SYSTEM FOR GASEOUS
DISCHARGE DEVICES

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Application April 28, 1934, Serial No. 722,919
Renewed January 28, 1936

13 Claims. (Cl. 250—27)

The present invention relates to electric discharge apparatus, more particularly to systems for controlling the initiation of an arc or glow discharge in devices of the gaseous type. Devices of this sort usually contain a plurality of co-operating electrodes and an ionizable medium, such as mercury or inert gas, the purpose of which during operation is to neutralize space charge and to permit cumulative ionization. Tubes of this character pass an arc-like or glow discharge between the electrodes and are capable of handling relatively large amounts of current, since the voltage losses in the tube are reduced to a minimum.

The McArthur application, Serial No. 722,918 filed April 28, 1934 and entitled "Electric discharge devices and control apparatus therefor, assigned to the same assignee as the present invention, discloses and claims a novel form of control for gaseous discharge devices for determining when the arc or glow discharge shall be initiated during each positive half-cycle of the anode voltage. In general, that application discloses the use of a magnetic field for deflecting electrons emitted by the cathode and contained within a deflection chamber, thereby preventing the electrons from reaching the anode and from producing cumulative ionization within the device. That application exemplifies the invention by way of illustration as a tube in which the electrons are emitted from the end of a hollow cathode, i. e. the electrons move in a direction parallel to the longitudinal axis of the tube, through an opening in the deflection chamber, and the magnetic field is illustrated as an electromagnet having pole pieces positioned in the transverse axis of the tube. The strength of the magnetic field is controlled by means of an electrical circuit energized by direct current passing through a variable resistance.

The McArthur application Serial No. 722,917 filed April 28, 1934 and entitled "Electric discharge devices", assigned to the same assignee as the present invention, discloses and claims the adaptation of the magnetic method of controlling the initiation of the arc or glow discharge to a tube in which the electrons move radially or sidewise from a cathode to a surrounding or adjacent anode. In this case, the source of the magnetic field takes the form of a solenoid surrounding the envelope so that the magnetic lines of force pass longitudinally through the envelope and thereby intercept the direction of the discharge which flows transversely of the envelope. The control of the magnetic field in this ap-

plication is exemplified as a Selsyn motor supplied with alternating current, the armature of the motor being adjustable to regulate the phase of the current flowing through the solenoid.

The present invention has for one of its objects, an improvement in the manner of controlling the magneto-motive force provided by the electromagnet, to the end that a modified form of phase control may be applied to the magnetic structure by means of which the initiation of the arc-like discharge in the tube may be more conveniently and accurately controlled. Thus the primary object of the present invention is to provide an improved form of magnetic control for gaseous discharge devices. Another object is to provide a magnetic control for devices energized by alternating current in which the initiation of the arc or glow discharge is determined by the phase relation between the current energizing the device and the magnetomotive force of the control apparatus. A still further object is to provide a control for the devices mentioned in which the magnetomotive force employed for control purposes is varied by changing the magnetic reluctance or resistance of the control apparatus.

The invention will be better understood when reference is made to the following specification and accompanying drawings in which Fig. 1 is an elevational view, partly broken away and in section, of a gaseous discharge device and structure for producing a transverse magnetic field. This figure also shows a circuit for energizing the tube and magnetic structure. Figs. 2, 3 and 4 show certain control characteristics of the apparatus illustrated in Fig. 1. Fig. 5 illustrates a tube similar to that shown in Fig. 1 but subjected to a different form of magnetic control. Figs. 6 to 10 inclusive show modified forms of magnetic control.

Referring more particularly to Fig. 1, numeral 1 designates an envelope of vitreous material which is provided at the top, as shown, with a metal terminal member 2 and at the bottom, with a metal base 3 carrying a plurality of terminal pins 4 insulated from one another. The envelope terminates in a reentrant stem and press 5 and contains a cathode 6, an anode 7 and an electrode 8. The cathode 6 may be of the conventional indirectly heated type and consist of an outer cylinder and an inner cylinder (not shown) secured to the outer cylinder by longitudinally extending vanes (not shown). Recesses formed between the cylinders and vanes may be coated with electronically active material. The inner cylinder con-

tains a centrally positioned heater 9, only the lower end of which is illustrated. This type of cathode is shown and claimed in the Hull and Ruggles Patent No. 1,924,318, granted August 29, 1933.

The cathode is preferably supported from the press by a pair of rigid leading-in conductors 10 which carry the load current, also the current to the heater 9. The return conductor for the heater is constituted of a leading-in wire 11 sealed in the press.

The anode is mounted preferably at the opposite end of the envelope from the cathode and may be constituted of an inverted dish-shaped metal member secured in place by the equidistantly spaced wires 12, and the central wire 13, which carries a pant-leg 14. The wire 13 is extended through the glass envelope to connect with the terminal 2.

Surrounding the anode and cathode, there is a cylindrical metal member 8 provided with a transverse metal web 16 having a central opening 17. The cylinder 8 is mounted in place by a plurality of equidistantly spaced support rods 18 secured to a screw clamp member 19 which surrounds the reentrant stem. Electrical connections are taken from the member 8, or rather, from the clamp 19 to one of the contact pins 4. There are also connections between the cathode 6 and one of the pins 4, and between the heater 11 and another of the pins.

The envelope contains an ionizable medium which may consist of an inert gas such as argon at a pressure of from 50 to 800 microns, or a vapor such as caesium, or mercury.

Alternating voltage may be applied between the anode 7 and the cathode 6 by means of an alternator 43 through an adjustable transformer (not shown). The heater may be supplied with energy from a battery 20 or any other convenient source. The electrode 8 may be either connected directly to the cathode, as indicated, by the conductor 21, or may have a separate bias assigned thereto, either negative or positive with respect to the cathode, provided by a battery (not shown). When a tube and system such as described, is operated, an arc or glow is formed between the cathode and anode during each recurring positive half-cycle of the anode voltage, provided the negative bias on the electrode 8 is not too large.

In order to control the average amount of current flowing through the tube under these conditions, it is of course necessary to determine precisely the point in each positive half-cycle of anode voltage when the arc shall start. For this purpose, there is provided a magnetic field which intercepts the space between the upper end of the cathode 6 and the transverse member or partition 16 of the electrode 8, the field being so directed as to pass through the tube normal to its longitudinal axis. The magnetic field is preferably obtained from an electromagnet which may consist of a U-shaped laminated core 22, with pole pieces directed toward the tube as shown, with some provision for magnetically energizing the core by which to produce the necessary magnetomotive force. One feature of the present invention is concerned with the manner in which this core is magnetically energized.

In accordance with the present invention, I provide the core 22 with three windings 23, 24 and 25, the first two of which are energized by direct current obtained from a battery 26 or other suitable source of electromotive force, and the third coil, i. e. coil 25, is energized by an alternating cur-

rent source 27. The coils 23 and 24 are oppositely wound on the core and are conductively connected together by a mid-tap 28 which is adapted to slide over a potentiometer 29, connected in shunt to the source 26. The current through the winding 25 is likewise adjustable through a potentiometer 30 connected across the source 27.

It is apparent that the effect of moving the tap 28 on the potentiometer 29 is to change the differential amounts of direct magnetomotive force passing through the core 22. When the tap is moved to the extreme left-hand position of the resistance 29, magnetomotive force of one direction is obtained whereas by moving the tap to the other end of the potentiometer, magnetomotive force of the other direction is obtained. Intermediate positions of the tap provide a differential magnetomotive force moving in one or the other direction. Thus, magnetomotive force of some one direction is produced by the coils 23 and 24, and this energy is combined with or superposed on the alternating magnetomotive force produced by the coil 25. It is evident that any desired preponderance of the direct or alternating magnetomotive force may be obtained by proper adjustment of the potentiometers.

As stated in the McArthur application Serial No. 722,918, the effect of the transverse magnetic field in the region of the space bounded by the cathode and the baffle or web member 16, where there is a low potential region, is to deflect many of the electrons emitted by the cathode through large angles and to cause the same to be either collected by the electrode 8, depending upon the polarity of the latter, or else returned directly to the cathode. In either case, these electrons do not pass through the opening 17 and hence cannot reach the anode. Consequently, these electrons are lost insofar as producing cumulative ionization of the gas in the tube is concerned and if a sufficient number of electrons are deflected in this manner, the arc-like discharge will be restrained throughout the entire positive half-cycle of the anode voltage. Obviously, by varying the strength of the magnetic field, greater or less numbers of the electrons may be deflected and consequently, the point in each positive half-cycle of the anode voltage at which the arc shall start may be accurately determined by proper adjustment of the magnetic field.

As stated hereinbefore and in accordance with the present invention, this adjustment is obtained in the structure shown in Fig. 1, by a composite magnetic field, representing the combination of alternating current and direct current energization.

The effectiveness of the direct current magnetic field operating independently of the alternating current field, and the effectiveness of the composite field in providing improved control of the initiation of the arc or glow in the gaseous discharge device are shown in the characteristics depicted in Figs. 2, 3 and 4. In Fig. 2, there is shown a set of curves plotted against the anode potential in volts at breakdown (i. e. immediately prior to the initiation of the arc or glow discharge) as an ordinate, and a direct current field strength in gauss necessary to prevent breakdown under these voltage conditions, as abscissa, for different temperatures of the gaseous medium which in the case of mercury or other vapor, determines the pressure thereof. Thus for a given curve, for example, when the temperature of the mercury condensate is 40° C. and the anode voltage is approximately 500, a field

strength of approximately 30 gauss, in the case of the tube shown in Fig. 1, would restrain the arc or glow from starting. For field strengths less than 30 gauss under these conditions, the arc would start.

Figs. 3 and 4 show the effect of the composite alternating and direct current magnetic fields. In Fig. 3, curve *a* is plotted with voltages as ordinate, and degrees as abscissa, to represent a plot of the positive half-cycle of the voltage applied to the anode. Curve *b* is a plot of the magnetomotive force applied to the tube by current flowing through the coil 25 of Fig. 1, and this curve is plotted with gauss as an ordinate and degrees as abscissa to correspond with those of the anode voltage. Curve *b* may be considered as representing the "alternating current control flux." Curve *c* is also plotted with gauss as an ordinate and degrees as abscissa and represents the "critical" or "breakdown" flux necessary to restrain the arc or glow from being initiated. Data for the curve *c* may be obtained from the static characteristic curve shown in Fig. 2. It will be noted that the curve *c* is constituted of two similar configurations above and below the zero axis, the upper half of the curve representing the critical or breakdown flux for magnetomotive force in one direction and the lower half of the curve representing the same conditions when the magnetomotive force is in the opposite direction. It is apparent that when the flux caused to move through the core 22 is greater than the flux values represented by the upper half of the curve *c*, for a given direction of direct flux or greater than the values represented by the lower half of the curve *c* for the opposite direction of the direct flux, the arc or glow will be restrained so long as the flux in the core remains greater than the amounts set forth. On the other hand, if the flux in the core is less than the values indicated by either half of the curve *c*, depending upon the direction in which the direct flux is moving, the arc or glow will be initiated and will continue to flow throughout the remainder of the positive half-cycle of the anode voltage. Consequently, whenever the curve *b* which represents the alternating control flux introduced by the coil 25, intercepts either half of the curve *c*, the arc or glow will be initiated since the alternating control flux becomes less at times than the amount of flux necessary to restrain the arc or glow from starting. It is therefore apparent that by controlling the positions where the curve *b* intercepts the curve *c*, a positive control of the initiation of the arc or glow may be obtained. Such a control is most conveniently obtained by simply moving the curve *b* vertically upwardly or downwardly until the proper point of interception is made, and this vertical movement may be brought about practically by adding or subtracting direct flux to or from the alternating flux. Thus in Fig. 1, as the tap 28 is moved over the potentiometer 29, greater or less amounts of direct flux are introduced into the core 22, and the effect of the change in the direct flux is superposed upon the alternating flux introduced by the coil 25 to change the vertical position of the curve *b* and hence, to change the position where this curve intercepts the curve *c*. A certain amount of control may obviously also be obtained by keeping the tap 28 fixed but moving the tap on the potentiometer 30, which in effect changes the magnitude of the magnetomotive force introduced by the alternating current while the direct current field remains

the same. It will be apparent that in moving the curve *b* vertically by means of a superposed biasing direct current field of either a positive or a negative character, the net effect is to move the curve *b* to the left or right and hence change its phase relation with respect to the anode voltage curve *a*. Thus by the use of a composite field, representing direct and alternating fluxes flowing through the core 22, a phase control of the smoothest kind is obtained for initiating the arc or glow in the tube 1. Small variations in the alternating or direct fluxes produce small changes in the point in each positive half-cycle of anode voltage at which the arc is started. This phase method of control as applied to a combined tube and magnet system is so gradual and smooth that a continuous variation of the point in the positive half-cycle of anode voltage at which the arc is started, may be obtained substantially throughout the entire half-cycle of voltage.

Fig. 4 graphically depicts the effectiveness of the phase method of control. In this figure, the curve is plotted with the output current in amperes as ordinate and direct current field strength in gauss as abscissa. In the operating condition, shown to the left of the zero vertical axis, the direct field is in the opposite direction to the condition shown to the right of the vertical zero axis. The two conditions of the direct field are of course obtainable by simply moving the mid-tap 28 from one end of the potentiometer 29 to the other end. This curve was taken from data actually obtained when the core 22 had flowing through it, in addition to the direct field referred to, an alternating field of approximately 16 gauss. As the direct field was changed from one direction to another, keeping the alternating field the same, a continuous control of the output current was obtained between approximately -35 gauss direct field to approximately 38 gauss of positive direct field.

It is therefore apparent that I have disclosed a novel form of control employing a magnetic structure in which composite alternating and direct fields are superposed on one another for the purpose of obtaining a continuous control of the output current of a gaseous discharge device throughout substantially the entire positive half-cycle of the anode voltage.

Fig. 5 shows another form of control in which a direct current flux is superposed, either by addition or subtraction, on an alternating flux for the purpose of obtaining an effective phase shift between the magnetic field and the alternating voltage applied to the anode. In this figure, the tube 1 is identical with the tube shown and described in connection with Fig. 1 and further description is unnecessary in view of the similarity of the reference characters. However, in this figure, the heater is illustrated as being energized by an alternating current through a transformer 37. As in the case of Fig. 1, the electrode 8 is connected to the cathode, in this case, to the midpoint of the secondary of the transformer 37, although it will be understood that if desired, this electrode may be biased at any suitable potential with respect to the cathode.

For obtaining the necessary magnetic field, a core 31 is provided with pole pieces which extend toward the tube in a transverse direction, the direction of the pole pieces being such as to intercept the electron-deflecting chamber contained between the cathode 6 and the web or baffle member 16. The lower horizontal leg of the

core 31 terminates in a pair of arcuate portions, leaving a space through which a variable direct flux may be introduced. This flux may be provided by an electromagnet 32 which is adapted to revolve for control purposes, the magnet being energized by a coil 33 connected to a source of direct current (not shown). If desired, a permanent magnet may be substituted for the structure 32, 33. A coil 34 is wound about one of the vertical legs of the core 31, the coil being energized through a transformer 35 connected to a source of alternating current 36. The latter may also be arranged to provide alternating current energy for the tube 1. It is apparent that the tube 1 has a critical or breakdown flux characteristic, similar to that described in connection with Fig. 1, so that when the flux in the core 31 falls below the critical value, the arc or glow in the tube will be initiated and the tube will conduct. The flux in the core 31 may be changed in any degree by simply rotating the magnet 32, which either adds or subtracts the flux introduced into the core by the alternating current coil 34. Obviously, if desired, the magnet 32 may be connected to rotating apparatus, such as a grindstone, so that when the stone is revolving too fast, for example, the flux in the core 31 is of such a value as to ignite the tube 1 and thereby bring into action relays or other control devices (not shown) for reducing the speed of the stone. Many other uses for the revolving magnet as a protective or other form of control will readily occur to those skilled in the art.

Figs. 6 to 10 inclusive show forms of control in which the reluctance or resistance of the magnetic circuit is affected. In these figures, the tube is shown in diagram and similar reference characters are given to the electrodes as in Figs. 1 and 5. Referring to Fig. 6, it will be noted that the core 22 is energized by a direct current coil 23. The core is provided with an air-gap at the lower leg and into this air-gap there may be inserted, in a variable manner, an armature 38 of magnetic material which serves to change the reluctance of the magnetic circuit. Obviously, if desired, the change in reluctance may be superposed upon a change in the electric current flowing through the coil 23 to obtain any desired control of the initiation of the arc in the tube 1. Assuming that the armature 38 is inserted so as practically to close the air-gap, as indicated by the dotted line position, and that the magnetic field passing through the deflection chamber of the tube is just sufficient to restrain the arc or glow discharge, a withdrawal of the armature will permit the tube to conduct. In Fig. 7, the reluctance of the magnetic circuit is changed by a rotating disk 39 of magnetic material which may carry inserts (not shown) of non-magnetic material. In this case, the tube will conduct when the insert enters the air-gap.

Fig. 8 shows the application of the invention to a magnetic system in which not only an auxiliary air-gap 40 in shunt to the air-gap through the tube is provided, but also a core section 41 of small cross-section and capable of being saturated by the magnetomotive force introduced by the coil 23. The length of air-gap 40 may be controlled by a movable armature such as was explained in connection with Fig. 6, or by a rotating disk as explained in connection with Fig. 7.

Fig. 9 shows a magnetic system similar to that described in connection with Fig. 6 except that the auxiliary air-gap is so shaped, i. e. tapered, as

to make the reluctance change at any desired rate as the armature 38 moves.

Fig. 10 shows a magnetic system in which a direct flux moving successively in opposite directions is introduced into the core 22 by means of a rotating armature 42 carrying an electromagnet or a permanent magnet. In this case, the tube conducts when the rotation of the armature causes the flux in the core to fall below a critical value.

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

1. In combination, an electron discharge device comprising an envelope containing a source of electrons, an electron-receiving member and an electrode mounted therebetween, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge, means for producing a magnetic field which intercepts the direction of said discharge, means including a source of alternating current for energizing said device and for producing an alternating flux in said magnetic means, and means including a source of direct current for superposing a direct flux on said alternating flux.

2. In combination, an electron discharge device comprising an envelope containing a source of electrons, an electron-receiving member and an electrode mounted therebetween, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge, means for producing a magnetic field which intercepts the direction of said discharge, means including a source of alternating current for energizing said device and for producing an alternating flux in said magnetic means, means including a source of direct current for superposing a direct flux on said alternating flux, and means for varying the alternating and direct fluxes.

3. In combination, an electron discharge device comprising an envelope containing a source of electrons, an electron-receiving member and an electrode mounted therebetween, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge, means for producing a magnetic field which intercepts the direction of said discharge, said means comprising a metal core having pole pieces mounted transversely of said envelope, a plurality of coils on said core, a source of alternating current for energizing said device and one of said coils, and a direct current source for energizing the other of said coils.

4. In combination, an electron discharge device comprising an envelope containing a cathode, an anode and an electron deflection chamber, said electron deflection chamber comprising a cylinder having a transverse member interposed between the cathode and anode and provided with a discharge opening, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge, a magnetic core mounted on the exterior of the envelope with pole pieces extending transversely of the envelope, in line with said deflection chamber, means for producing a magnetic flux in said core having a strength sufficient to deflect the electrons emitted by the cathode away from said discharge opening, said means including a plurality of coils on the core, two of the coils being wound in opposite direction and energized by direct current, and a third coil energized by alternating current.

5. In combination, an electron discharge device comprising an envelope containing a source of electrons, an electron-receiving member and an electrode mounted therebetween, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge, means including a magnetic structure for producing a field which intercepts the direction of said discharge, said field having a maximum strength sufficient to prevent initiation of said discharge, and means for varying the reluctance of the magnetic structure whereby initiation of the discharge and the average amount of current flowing through the device may be controlled.

6. In combination, an electron discharge device comprising an envelope containing a cathode, an anode and an electron deflection chamber therebetween, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge, means including a magnetic structure for producing a field which intercepts the direction of the discharge within the deflection chamber, said field having a maximum strength sufficient to prevent initiation of said discharge, said magnetic structure including a core member provided with a variable air-gap whereby initiation of the discharge and the average amount of current flowing through the device may be controlled.

7. In combination, an electron discharge device comprising an envelope containing a cathode, an anode and an electron deflection chamber therebetween, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge, means including a magnetic structure for producing a field which intercepts the direction of the discharge within the deflection chamber, said field having a maximum strength sufficient to prevent initiation of said discharge, said magnetic structure including a core member provided with an air-gap, and means for introducing a variable magnetic field into the core at the air-gap whereby initiation of the discharge and the average amount of current flowing through the device may be controlled.

8. In the art of controlling the initiation of a gaseous discharge in a device containing a cathode, an anode and an ionizable medium by means of a direct magnetic field, the method which consists in deflecting electrons emitted by the cathode away from the anode by the direct field, thereby preventing cumulative ionization, and varying the direct field by combining therewith, an alternating field in order to determine when the discharge shall start.

9. In the art of controlling the initiation of a gaseous discharge in a device containing electrodes and an ionizable medium by means of a direct magnetic field, the method which consists

in utilizing the magnetic field to cause the electrons to move in such a direction as to prevent inelastic collisions with the positive ions of the ionizable medium, and varying the field by periodically adding and subtracting variable amounts of magnetic field whereby elastic ionizing collisions in predetermined amounts between the electrons and positive ions are permitted and the gaseous discharge starts.

10. In the art of controlling the initiation of a gaseous discharge in a device containing a cathode, an anode and an ionizable medium by means of a direct current field, the method which consists in deflecting electrons emitted by the cathode away from the anode by the field thereby preventing cumulative ionization, and varying the direct field by periodically adding and subtracting variable amounts of magnetic field whereby cumulative ionization in a predetermined degree is permitted in order to start the discharge.

11. In the art of controlling a gaseous discharge in a device containing a cathode, an anode and an ionizable medium by a direct magnetic field, said device being energized by alternating current and said magnetic field having a maximum strength sufficient to restrain the discharge from flowing during the positive half-cycles of anode voltage, the method which consists in utilizing the magnetic field to reduce the number of ionizing collisions between the electrons emitted by the cathode and the molecules of the ionizable medium, and varying the direct field by combining therewith, a variable alternating magnetic field whereby the position in each positive half-cycle of anode voltage at which the gaseous discharge starts may be controlled.

12. In the art of controlling a gaseous discharge in a device containing a cathode, an anode and an ionizable medium by means of a direct magnetic field, the method which consists in deflecting electrons emitted by the cathode away from the anode by the direct field, thereby preventing cumulative ionization, and varying the direct field by changing the reluctance of the magnetic circuit.

13. In the art of controlling the average amount of current flowing through a gaseous discharge device containing a cathode, an anode, an ionizable medium, and energized by alternating current, the method which consists in magnetically deflecting, by a field of constant direction, the electrons emitted by the cathode away from the anode, thereby preventing cumulative ionization, and varying the field by periodically changing the reluctance of its magnetic circuit whereby the position in each positive half-cycle of anode voltage at which the gaseous discharge starts and the average amount of current through the device may be controlled.

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