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E. D. McARTHUR

2,039,100

ELECTRIC DISCHARGE DEVICE

Filed April 28, 1934

Fig. 1.

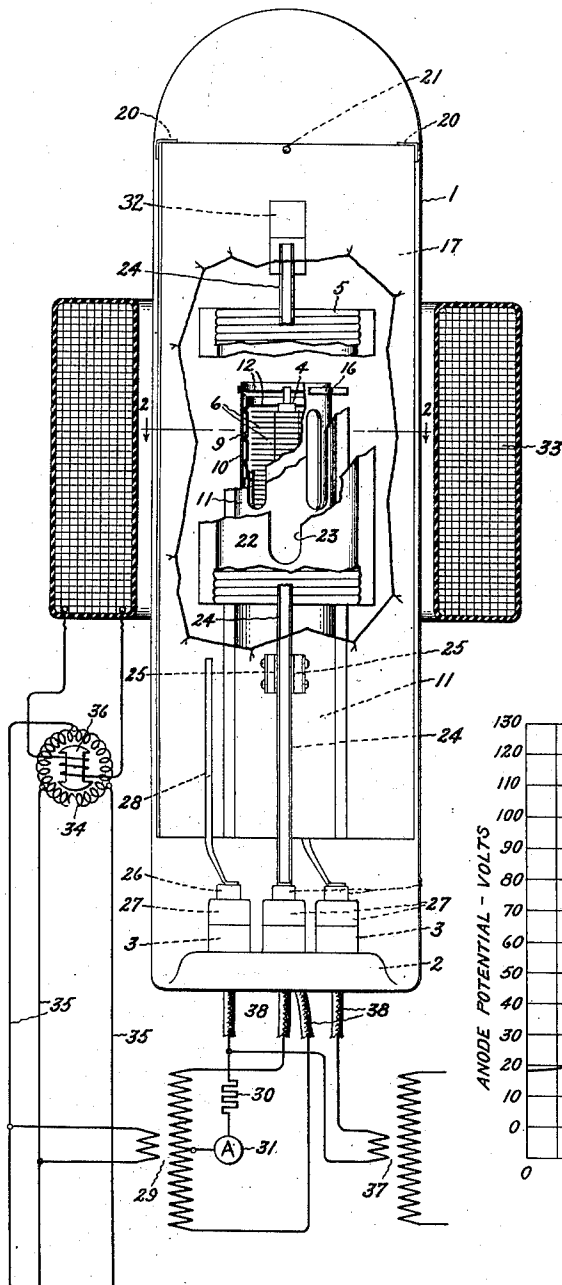


Fig. 2.

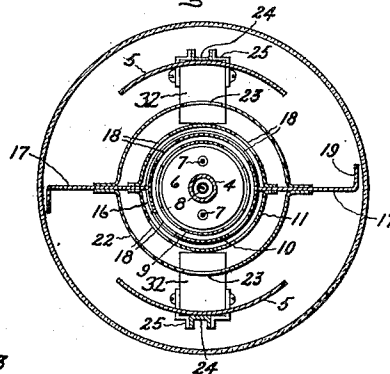
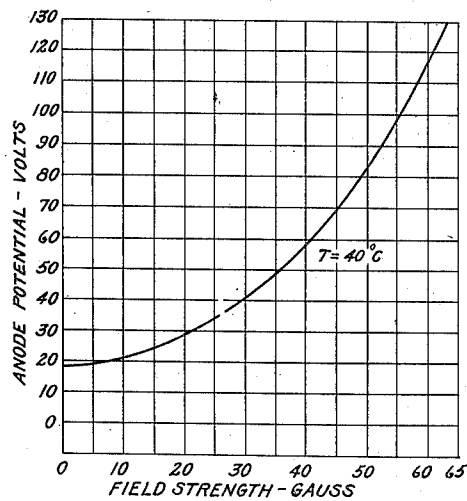


Fig. 3.



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UNITED STATES PATENT OFFICE

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ELECTRIC DISCHARGE DEVICE

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Application April 28, 1934, Serial No. 722,917

7 Claims. (Cl. 250—27.5)

The present invention relates to electric discharge devices, more particularly to full-wave rectifiers for controlling large currents.

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 of 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 ionization within the device. The invention is illustratively exemplified in the McArthur application by a tube in which electrons are emitted from the end of a hollow cathode, the electrons moving in a direction parallel to the longitudinal axis of the tube through an opening in the deflection chamber, and the magnetic field is shown as an electromagnet having pole pieces positioned in the transverse axis of the tube and in the region of the chamber.

The Pike and Elder application Serial No. 715,630 filed March 15, 1934, and entitled "Electric discharge apparatus", assigned to the same assignee as the present invention, discloses and claims a full-wave rectifier, operating on the cumulative ionization principle and in which electrons are emitted radially or sidewise from a cathode to a pair of anodes, so that the direction of the electrons is in general, normal to the longitudinal axis of the tube.

The present invention proposes to adapt the magnetic form of control to the initiation of an arc or glow discharge in a tube similar to that shown in the Pike and Elder application. The magnetic field for controlling a tube of this sort is so arranged as to thread the tube in a direction parallel to the longitudinal axis thereof, in order to intercept the moving electrons.

An object of the present invention, therefore, is to provide an improved form of control for gaseous discharge devices in which electrons move radially or sidewise from a cathode to a surrounding or adjacent anode. Another object is to provide a gaseous discharge device of the kind referred to, with a magnetic control for restraining the arc or glow discharge, or otherwise controlling its initiation, when the anode is charged highly positive with respect to the cathode, and a still further object is to provide an improved gaseous

full-wave rectifier of the concentric electrode type in which the average rectified current is controlled magnetically.

Other objects and features will be apparent as the specification is perused in connection with the accompanying drawing in which Fig. 1 is an elevational view, partly broken away and in section of a rectifier improved in accordance with the present invention. This figure also shows a typical form of circuit which may be employed with the improved tube. Fig. 2 is a cross-section taken along line 2—2 of Fig. 1, and Fig. 3 is a diagram of one of the control characteristics of the apparatus shown in Figs. 1 and 2.

In Fig. 1, numeral 1 designates a cylindrical envelope of vitreous material which is closed at the top by a hemispherical portion and terminates at the bottom in a reentrant glass plate or header member 2 carrying four upstanding glass cylinders 3. These cylinders support the electrode structure and provide for the necessary leading-in conductors, as will be explained hereinafter.

The electrodes consist of an indirectly heated cathode 4, and a pair of oppositely disposed anodes 5 which may take the form of arcuate corrugated strips of metal. The cathode may consist of a metal chamber from which extend a large number of transversely disposed metal disks 6 secured to the metal chamber in any suitable and well-known manner, as for example that shown in the Hull Patent No. 1,924,319 and the Pike Patent No. 1,924,375, assigned to the same assignee as the present invention. These disks are preferably coated on both sides with an electronically active material, such as barium oxide. Metal rods 7 (see Fig. 2) extend longitudinally through the disk structure so as accurately to space the disks from one another at their edges, to render the cathode structure rigid, and in addition to conduct load and heating current to the cathode. The cathode chamber contains a heater which may consist of an elongate spiral 8 of tungsten wire, the purpose of which is to heat the cathode surface to an electron-emitting temperature.

About the cathode structure, there are positioned several heat shields 9, 10 and 11 spaced in any suitable manner from one another, for example by indentation, the purpose of which is to minimize heat radiation from the cathode and hence to increase its operating efficiency. The two inner shields 9 and 10 are preferably of much shorter length than the outer shield 11. All of the heat shields are preferably closed at the top by metal disks, two of which are illustrated and designated by the reference character

12. The intermediate heat shield 10 may be secured to the electrode structure by a pair of metal bands 16, only one of which is shown, which fit snugly about each end of the shield 10 and are welded or otherwise secured to a large metal plate, web or partition member 17, the purpose of which will be described hereinafter. The outer heat shield 11 which extends for about the same length as the plate 17, may be secured thereto in like manner, i. e., by welding. The heat shields 9, 10 and 11 are provided with several large slot-like openings 18, of about the same length as the cathode, equally spaced about the peripheries of the shields and in register with one another.

As will be seen more clearly in Fig. 2, the plate or web 17 extends entirely across the tube, dividing the cylindrical envelope into two equal longitudinal and physically separate sections. The web is maintained in its central position by means of flanges 19 at the outer edges which serve to stiffen the member. The width of the web preferably is less than the interior dimension of the envelope, in which case there is provided a metal wedge 20 of nickel wire at each upper edge of the web to prevent any lateral movement of the latter and at the same time to allow for expansion of the web during tube exhaust or operation. The web 17 extends for a considerable distance beyond each end of the cathode and other parts of the electrode structure. The web may be laterally supported in a direction normal to its width by a pair of rigid rod members 21 which are secured to the web in any suitable manner and which may terminate in bent portions (not shown) fitting snugly within the envelope.

Between the heat shield 11 and the anodes 5, there is a metal shield 22, formed of two semi-cylindrical portions and secured in any suitable manner, as by welding, to the metal plate 17 so as to be concentric with the shielded cathode structure. The shield member 22 is provided with a pair of elongate openings 23 of somewhat larger size than those in the heat shields and positioned in line between the cathode and the respective anodes. These openings are out of register with the openings 18 in the heat shields, and, as illustratively exemplified, are positioned midway therebetween. The metal shield 22 extends along the length of the tube for approximately the same distance as the length of the anodes.

The anodes may consist of heavy rugged material, corrugated metal, as shown, and may take an arcuate form so as to be concentric with the cathode and the surrounding heat shields. The anodes are preferably hung from a pair of upright U-shaped frame members 24 secured, at the top to the web member 17, on each side thereof, by a block 32 of insulating material, and at the bottom, to the outer heat shield 11 by a similar block 32 and a metal strip 25. These blocks may be secured by screws (not shown) to the web 17 and outer heat shield 11 respectively. The frame members 24 terminate at the lower end of the tube, as shown, in inwardly bent portions which are welded or otherwise secured to cap members 26 constituted of a metal which may be sealed, preferably without strain and even with a butt-joint, to a glass cylinder 27.

An example of a suitable metal and glass for a seal of this kind is disclosed and claimed in the Burger and Hull application Serial No. 705,250, filed January 4, 1934, and entitled "Glass-to-

metal seals," assigned to the same assignee as the present invention. As pointed out in the Burger and Hull application, a metal which may be advantageously employed for this purpose, i. e., without the necessity of tapering or otherwise deforming the metal, may consist of approximately 18% cobalt (Co), 28% nickel (Ni) and 54% iron (Fe), and the glass may have the following composition: 65% silica (SiO_2), 23% boric oxide (B_2O_3), 7% sodium oxide (Na_2O) and 5% aluminum oxide (Al_2O_3). A glass of this composition may be readily fused to many of the common glasses of which the envelope 1 and upstanding cylinders 3 are made.

A supporting connection is provided by a rigid U-shaped member 28 directly between the central web 17 and one of the cap members 26. One of the ends of the heater is connected to another of the cap members 26, the other end of the heater being welded to the interior surface of the cathode compartment. Flexible cables 38 may be taken from the interior of the respective cap members 26 to the exterior of the tube. It will be evident that the four cap members together with their associated flexible cables 38 bring separate connections through the tube from each of the anodes, from the cathode structure which is electrically connected to the web 17 and from the free end to the heater contained within the cathode. If desired, a capsule (not shown) containing material for absorbing deleterious gases during manufacture and operation of the tube, may be secured to one of the frame members 24.

After evacuation of the envelope in the most approved and well-known manner, with the electrodes in place, inert gas such as argon or neon, at a pressure between 50 and 800 microns may be admitted to the envelope, or a globule of mercury (not shown) provided, which under operating conditions, produces a vapor pressure between 6 and 25 microns when the temperature of the mercury condensate is between 40° and 60° C.

A tube of the type described operates on the gas ionization principle in which large currents are conducted between the cathode and each anode. For this purpose, alternating current voltage is applied between the respective anodes and the cathode, and when proper circuits are connected thereto, the tube will rectify both half-waves of the alternating current voltage.

The tube structure as described hereinbefore is disclosed and claimed in the Pike and Elder application Serial No. 715,630 referred to hereinafore.

A suitable circuit for energizing a tube of this character is diagrammatically shown in Fig. 1 in which the two anode conductors are connected to the secondary terminals of a voltage step-up transformer 29, the cathode structure of the tube being connected through a load 30, illustratively exemplified as a resistance, and an ammeter 31, to the mid-tap of the transformer secondary. The heater for the cathode is energized preferably through a voltage step-down transformer 37 which is connected to the proper pair of flexible cables 38, passing respectively to the cathode and to the free end of the heater.

The current between the cathode and each anode takes on the character of an arc-like or glow discharge and follows a tortuous path from the cathode through the aligned openings 18 in the heat shields, and the openings 23 in the outer shield member 22 which are out of line

with those in the heat shields, finally reaching the anode 5. Inasmuch as for a given tube of practical dimensions, with 1000 volts on the anode, approximately $12\frac{1}{2}$ amperes per anode or 25 amperes average current for the full-wave rectifier device may be rectified, it will be apparent that the electrical conditions within the tube are severe. The electronically active material coated on the cathode disks tends to sputter off and be driven onto the anode or to condense on any cool surface within reach. This material moves out radially from the cathode through the openings 18 and would normally reach the anodes 5 if it were not for the fact that the openings 23 in the shield 22 are out of line with the openings 18 in the heat shields 9, 10 and 11 and thus a solid metal wall or barrier is presented to the sputtered material. The cylinder 22 may therefore be termed a "sputter shield" since it serves to prevent active material from reaching the anodes 5.

As stated hereinbefore, the web member 17 divides the envelope into two sections and electrically isolates the anodes from one another, thereby preventing undesired discharge between any portions of the electrode structure, either directly across the envelope between the anodes or through conduction paths which may extend considerable distances from the electrode structure. It will be noted that the web 17 is at cathode potential, although it will be understood that if desired, the web may be suitably insulated from the cathode structure and a potential assigned thereto other than cathode potential.

As stated hereinbefore, and in accordance with the present invention, I propose to adapt a tube such as described to the magnetic form of control and thereby control the average amount of rectified current flowing through the tube during each positive half-cycle of the anode voltage. For this purpose, I provide a solenoid 33 about the tube, which causes magnetic lines of force to thread the electrode structure in a direction parallel to the longitudinal axis of the tube and to intercept the direction of the electrons moving from the cathode through the various openings 18, 23 to the anodes 5.

It will be understood that prior to initiation of the arc or glow discharge, the current is constituted almost entirely of electrons and the tube acts as a pure electron discharge device. As explained in the McArthur application Ser'ial No. 722,918, a magnetic field can effectively deflect the electrons out of their normal paths, particularly in a region in which the electrons have relatively low velocity. Such a region has been found to exist between the cathode 4 and the heat shields 9, 10, 11, also between the heat shields and the sputter shield 22. Thus the effect of the magnetic lines passing longitudinally through the tube is to cause a greater or less number of the electrons, depending upon the strength of the field, to be deflected out of their normal paths through the openings and to be intercepted by one of the heat shields or by the sputter shield. The space immediately surrounding the cathode in which the direction of electrons is changed by the magnetic field may be aptly termed an "electron-deflecting chamber." The electrons thus deflected are returned to the cathode, since the shields are all preferably at cathode potential and the effect of the electrons is lost in so far as ionizing collision with gas molecules or atoms is concerned. If a sufficient number of electrons can thus be re-

moved from the area in which they would cause ionizing collisions with gas or vapor molecules, the arc or glow will obviously be restrained for a predetermined length of time and the average rectified current will be reduced accordingly.

In order to control the magnetic field, I prefer to employ a variable inductance, which may take the form of a Selsyn motor 34, the primary of which is energized from a three-phase system 35, one phase of which may also energize the transformer 29, and the secondary 36 is connected to the coil 33. Obviously, by rotating the armature 36 within the field produced by the coil 34, the phase of the current passing to the coil 33 and hence the phase of the magnetomotive force produced within the tube may be accurately controlled.

Fig. 3 diagrammatically indicates the effectiveness of magnetic control as applied to a tube of this sort. The curve shown in this figure represents data taken under actual test conditions, employing a tube of the mercury vapor type, in which the temperature of the envelope or rather the temperature of the mercury condensate was maintained at 40° C. As shown on the curve, if a typical field strength of 45 gauss be applied to the space between the cathode and the sputter shield, the amount of maximum anode potential required to break down the tube, i. e., to cause the arc to start and hence produce rectified current in the load 30, is 70 volts. On the other hand, when the field strength was reduced to approximately 20 gauss, only 30 volts is necessary to break the tube down, i. e., to initiate a glow discharge, under these conditions. It is apparent that the effect of the magnetic field is to control the point in each positive half-cycle of anode voltage at which the arc starts. After the arc has started, the current flows throughout the remainder of the positive half-cycle of anode voltage. Thus by proper adjustment of the magnetic field 33 by the Selsyn motor, the amount of current per half-cycle of voltage may be controlled and the average current over a number of recurring half-cycles accurately determined.

While I have described my invention in connection with a tube which employs a plurality of heat shields and a sputter shield, it is to be understood that the invention is not limited to this form of tube. Obviously, in order to practice the invention, it is necessary to provide about the cathode of a gaseous discharge device some form of baffle, suitably charged with respect to the cathode and preferably of cylindrical configuration, the baffle being provided with one or more openings through which the electrons normally pass on their way to the anode. The function of the solenoid would be simply to deflect the electrons away from the opening or openings and to prevent any further movement of the electrons toward the anode or at least to reduce the velocity of the electrons to such an extent as to prevent ionizing collisions with the molecules or atoms of the ionizable medium. However, as stated hereinbefore, the longitudinal form of magnetic field together with a transverse movement of electrons, as covered in this application, has been satisfactorily practised with a tube of the type described hereinbefore, as illustrated in Fig. 1 and for this reason, the invention has been disclosed in connection therewith.

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

1. An electron discharge device comprising an

envelope of elongate configuration, containing a source of electrons, also an electrode for receiving the electrons emitted by the said source in a direction transverse to the longitudinal axis of the envelope, a member interposed between said source and electrode, said member being adapted to be electrically charged and forming an electron deflection chamber through which the electrons move toward the electron-receiving electrode, said chamber being substantially closed except for discharge openings, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge, means mounted on the exterior of the envelope for producing magnetic lines of force through said chamber in a direction angular with respect to the direction of the moving electrons.

2. An electric discharge device comprising an envelope containing a cathode, an anode and an interposed member adapted to be electrically charged and forming an electron-deflecting chamber, said chamber being substantially closed except for discharge openings, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge and a coil surrounding said envelope.

3. An electric discharge device comprising an envelope containing a cathode coated with electronically active material, and a plurality of anodes mounted about the cathode, an ionizable medium in the envelope at a pressure under operating conditions sufficient to support an arc-like discharge, a heat shield mounted about the cathode, said heat shield having discharge openings, a sputter shield interposed between the heat shield and anodes, said sputter shield having discharge openings out of line with the openings in the heat shield, means for producing a magnetic field which intercepts the direction of said discharge.

4. An electric discharge device comprising an envelope containing a cathode coated with electronically active material, and a plurality of anodes mounted about the cathode, an ionizable medium in the envelope at a pressure under operating conditions sufficient to support an arc-like discharge, a heat shield mounted about the cathode, said heat shield having discharge openings, a sputter shield interposed between the

heat shield and the anodes, said sputter shield having discharge openings out of line with the openings in the heat shield and being connected to the cathode, means for producing a magnetic field which intercepts the direction of the discharge.

5. An electric discharge device comprising an envelope containing a cathode, a plurality of anodes mounted about the cathode, an ionizable medium in the envelope at a pressure under operating conditions sufficient to support an arc-like discharge, a shield mounted about the cathode, said shield having discharge openings, and a metal partition extending through the envelope to form a plurality of compartments each containing an anode and a portion of the cathode whereby separate electrical translating units are provided in each compartment and means for producing a magnetic field which intercepts the direction of the discharge.

6. An electric discharge device comprising an envelope containing a cathode, and a pair of anodes mounted on opposite sides of the cathode, an ionizable medium in the envelope at a pressure under operating conditions, sufficient to support an arc-like discharge, a shield mounted about the cathode, said shield having discharge openings, and a metal partition extending through the middle of the envelope to form two compartments, each containing an anode and a portion of the cathode and a solenoid surrounding the envelope in the vicinity of the electrodes.

7. An electric discharge device comprising an envelope of elongate configuration containing a cathode coated with electronically active material, and a pair of anodes mounted on opposite sides of the cathode, an ionizable medium in the envelope at a pressure under operating conditions, sufficient to support an arc-like discharge, a heat shield mounted about the cathode, said heat shield having discharge openings, a sputter shield interposed between the heat shield and the anodes, said sputter shield having discharge openings out of line with the openings in the heat shield, a partition extending longitudinally through the envelope and electrically separating the anodes from one another thereby preventing undesired discharge and a solenoid surrounding the envelope and positioned in the vicinity of the electrodes.

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