Aug. 30, 1932. A. W. HULL 1,874,753

CONTROLLED ARC DISCHARGE APPARATUS

Filed March 23, 1929

Fig. 1.

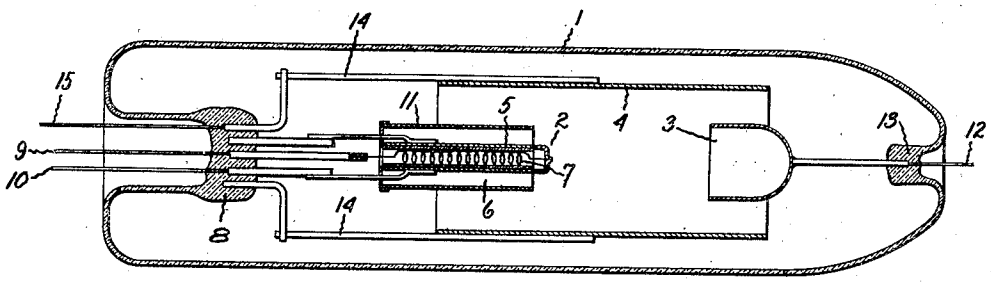
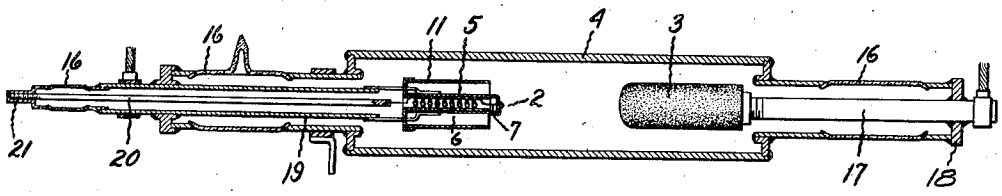


Fig. 2.



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UNITED STATES PATENT OFFICE

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CONTROLLED ARC DISCHARGE APPARATUS

Application filed March 23, 1929. Serial No. 349,436.

The present invention relates to thermionic discharge devices containing an ionizable medium and which are provided both with cooperating electrodes for maintaining an arc-like discharge and also an electrostatic control electrode (or grid); the invention is directed more particularly to a novel construction and arrangement of the grid electrode for use in this type of apparatus.

Electric discharge apparatus which is provided with control electrodes may be divided into two general classes: (1) Devices in which the space current is mainly electronic and is continuously variable by variations in potential of the grid electrode. In some cases such devices contain sufficient gas to modify by its ionization the electron current for special purposes, such as the detection of radio signals, but ionization of gas, generally speaking, is a secondary phenomenon in this class of devices. The voltage drop increases with an increase of current, that is, the volt-ampere characteristic is positive. (2) Devices, in which a sufficiently high negative potential on a control electrode entirely prevents the flow of space current, but a lower negative grid potential or a positive potential permits space current to flow between the main electrodes, the grid potential after the establishment of current flow having no effect. The flow of current can only be interrupted in this type of device by removing the plate potential which is conveniently done by energizing the plate circuit with alternating current and by employing the grid to determine by suitable bias at what point in the alternating current cycle the plate current shall start to flow, i. e. by trigger action. Such devices contain gas or vapor, at a pressure high enough to cause the resulting ionization to neutralize space charge completely and to operate with a voltage between anode and cathode not appreciably higher than the ionization potential of the residual gas. The current voltage characteristic of such devices is generally flat or slightly negative, that is, the voltage drop decreases with an increase of current. The dischage is considered as being arc-like in its characteristics.

Controlled-arc discharge apparatus to which my invention relates, belongs to the second class of devices and has heretofore been constructed in several representative types which differ mainly in respect to the position of the control member or grid. In one type, the control electrode constitutes a metal mesh arranged across a glass envelope transversely of the discharge space, in another type, the grid surrounds the anode, and in still another form, the grid member surrounds the cathode. All of these constructions are operative and useful but there are certain difficulties attending the same. While the first two mentioned types have advantages in operation, they are also subject to two limitations, viz., that the voltage of the control member must be positive in order that the tube may start, hence requiring the expenditure of considerable amount of energy for control purposes and secondly, that this voltage is rendered indefinite by the random potential assumed by the walls of the container due to the lack of an electron obstruction between the cathode and the envelope; this potential depends upon the degree of ionization, vapor pressure and other factors. The type of control in which the grid surrounds the cathode and which in turn may be entirely surrounded or nearly so, by the anode, is free from the disadvantages set forth. It has reliable and reproducible characteristics with such values of negative grid voltage that very little energy is required for control but there is present a limitation of a different kind, viz., the maximum current that can be controlled is limited to the value that will heat the grid to the point of electron emission; in other words, when the control member is positioned close to the cathode its increased effectiveness gained by reason of its position is partially lost on account of the increased absorption of heat in this position which may cause the grid to emit electrons. In tubes with barium coated cathodes this limiting current is of the order of one-half an ampere per square inch of grid surface where reliable control with small energy consumption is desired. In all the prior types of construction the grid constitutes a mesh or perforated structure, through the openings

of which the arc current must pass. One of the objects of the present invention is to provide an improved control arrangement which avoids the difficulties of all the above mentioned types while retaining their advantages. The improvement consists, in brief, of a novel form of grid member which may take the configuration of a hollow cylinder or other shape suitable for cooling, the member being of sufficient length and positioned within the tube in such a manner that it completely surrounds the arc path between the anode and cathode. The cylinder may be separate from the envelope or combined therewith; in the latter case, the container within which the anode and cathode are disposed may be fabricated of metal, suitable provision being made to insulate the cathode, anode and grid members from one another. The improved grid member which constitutes the feature of the present invention and will be described hereinafter has been found to control the starting of an arc discharge, i. e. to perform the function of an electrical trigger as accurately as does a mesh grid interposed transversely between the cathode and anode and is not open to the objections which ordinarily accompany a grid of this sort. It also has the advantage of being easily cooled thus precluding deleterious grid electron emission and allowing large currents to be controlled by elements of moderate size. It is necessary to point out that while in hard vacuum or pure electron discharge tubes the problem of grid emission is of some importance, in arc discharge devices any emission from the grid is particularly disadvantageous due to the fact that a small amount of emission by the grid may start the main arc, even though the grid potential be very negative. It is apparent that electrons emitted by the grid are equivalent as far as "starting" the arc is concerned, to an equal number emitted by the cathode and if sufficient in number to cause starting, no negative voltage can thereafter prevent or control the discharge. A few microamperes of grid emission are generally sufficient completely to spoil the control at 110 volts on the plate whereas in hard vacuum tubes, grid emission of many times this amount is not considered deleterious to the extent of substantially impairing the translation efficiency of the tube. The invention will be better understood when reference is made to the accompanying drawing, in which Figs. 1 and 2 show in cross section exemplary embodiments.

The device shown in Fig. 1 comprises an elongated glass receptacle 1 in which are mounted a cathode unit 2 which will be described in detail presently, an anode 3 which is shown as a cup but may be a disc, rod, or other form and may be made for example of nickel and an electrostatic control electrode 4 also constituted of nickel, or other suitable metal, which will be briefly referred to as a grid. The discharge space contains an attenuated gas or vapor, for example, argon at a pressure between 5 to 250 microns of mercury, or vapor derived from a globule of mercury introduced into the envelope; when mercury is employed, a portion of the envelope should be maintained at a temperature sufficient to produce a vapor pressure less than one millimeter.

The cathode which may consist of nickel or iron comprises a central enclosure 5 upon which are mounted by welding or otherwise, outwardly extending vanes 6 and inside of which is positioned a heater 7, in the form of a helically coiled wire of tungsten or other suitable refractory material. The heater 7 should be insulated from the enclosure 5 in any suitable manner to prevent short-circuiting of the coil during operation of the device. Electrical connections to the heater 7 may be made in any convenient manner through the press 8 by means of leading-in conductors 9, 10. One end of the helical filament may be connected as by welding to the end of the enclosure 5. About the enclosure 5 there is positioned an outer cylinder 11 arranged concentrically with the enclosure and closed at the end remote from the anode and whose main function is to reduce the radiation heat losses from the vanes 6, thus to conserve the heating current required to maintain the cathode at a desired elevated temperature. The vanes 6 and adjoining surfaces within the enclosure 11 are coated with a suitable material of high electron emissivity of a rare earth metal, an alkaline earth metal or a compound of an alkaline earth metal, e. g., barium carbonate, so that when the filament 7 is energized preferably by alternating current, electrons are emitted by the surfaces formed by the vanes and travel toward the anode. Such a cathode coated with barium carbonate should be formed by heating in a vacuum to a temperature adjacent the melting point of nickel, gas given off being pumped out of the envelope.

Electrical connection is made to the anode 3 by means of a conductor 12 which is sealed in the press 13 of the envelope. The features of the cathode construction herein described are covered by my copending application, Serial No. 156,713, filed December 23, 1926, and also application, Serial No. 268,976, filed April 10, 1928, by myself jointly with William A. Ruggles.

The improved form of grid consists of a metallic cylinder 4 which is arranged concentrically about the cathode and anode and is interposed between these electrodes and the interior surface of the envelope. The cylinder is of such a length as to extend substantially to the rear surfaces of the electrodes completely encompassing the same in the manner shown and is positioned within the

envelope by means of support wires 14 secured to the outer surface of the grid in any suitable manner, as for example by welding, the support wires being affixed in the stem 8 and one should be carried to the exterior to serve as a lead-in conductor 15. In view of the fact that the grid is removed from the concentrated arc path between the cathode and anode its temperature remains relatively low and hence no electrons are emitted by the grid even under high current density but at the same time it has been found that its control function is quite effective. Moreover, it will be noted that the position of the grid, in substantially surrounding the cathode, effectively shields the discharge path from the effect of electrostatic charges on the envelope, thus vesting solely in the grid the property of effecting the trigger action. It has been further observed that in operation, a grid of this character and in this position affords a positive control of the arc current between the two active electrodes when charged with a negative voltage bias whether supplied by a direct current potential or an alternating current potential in proper phase with respect to the anode voltage, and hence there is substantially no expenditure of energy for control purposes. If desired, the heat-radiating capacity of the control member may be enhanced, hence further removing the possibility of undesired electron emission, by affixing to the external surface of the cylinder, heat radiating fins or, as will be described in connection with other figure, by exposing the control member directly to the air in which case it may comprise a portion of the envelope.

Thus, in Fig. 2, the grid element 4 constitutes a portion of the envelope in the region of the electrodes 2 and 3, said electrodes being insulated from one another and from the control member by means of glass portions 16 interposed between metallic portions which constitute the remainder of the envelope. The manner of sealing glass to metal is well known and will not be described in detail. In this figure, the anode 3 is shown as a graphite rod provided with a screw thread to receive the conductor 17 which is secured to a metal cap 18 terminating the envelope.

It is evident that the types of control member described, i. e., which assume the general form of a cylinder or other shape of closed perimeter and located external to the cathode and anode between which an arc discharge takes place are not well adapted for use in high vacuum tubes on account of the excessive space charge limitation, which restricts the current at practical voltages to values very small compared with those that can be obtained with grid-controlled arc discharge devices. For example, in a tube of the type shown in Fig. 1 or Fig. 2, the maximum pure electron current depends, according to the Child-Langmuir space charge equation, on the ratio of control cylinder diameter to distance between cathode and anode. In order to obtain satisfactory control this ratio should not be much greater than $\frac{2}{3}$. With this ratio the maximum current at 100 volts is 1 milliampere. This is very small compared with the currents obtained in practical pure electron tubes. On the other hand, the tube shown in Fig. 2, when used as an arc discharge device, has a normal rating of 300 amperes at 12 volts. This current can be controlled by the same energy and with the same reliability as the 1 milliampere of pure electron emission. For example, with 20,000 volts impressed between anode and cathode, a negative potential of 20 volts prevents the flow of any current, while 19 volts negative potential allows the full 300 amperes to flow. Thus 6000 kilowatts of power can be reliably controlled by a variation of potential of 1 volt applied to the grid with an expenditure of energy of the order of 1 microwatt.

The cathode unit 2 may be similar to that described in connection with Fig. 1 and is mounted at the proper distance from the anode by means of a hollow metal tubing 19, which is connected to one terminal of the cathode to constitute a lead-in conductor. The other cathode lead-in wire is formed by an insulated conductor 20 which passes through the center of the tubing 19 and is attached to a metal contact cap 21.

Devices of the character described, when energized by alternating current of a voltage sufficient to produce an arc-like discharge, may be used for relay and other purposes which require large amounts of current e. g. of the order of many amperes, this current being reliably controlled by the application of direct or alternating current energy of the order of a fraction of a microwatt to the grid.

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

1. In electrical apparatus, the combination of an evacuated envelope containing an anode, cathode and an electrostatic control electrode associated therewith, a charge of inert gas in said envelope at a pressure sufficient to sustain an arc-like discharge, said control member comprising a body of metal positioned wholly remote from the concentrated discharge path but substantially surrounding the entire length of arc path.

2. In electrical apparatus, the combination of an evacuated envelope containing an anode, and a cathode, an electrostatic control electrode adapted to cooperate therewith, a charge of inert gas in said envelope at a pressure sufficient to sustain an arc-like discharge, said control member comprising a body of metal positioned wholly remote from the con-

centrated discharge path and substantially surrounding the cathode and anode.

3. Electrical apparatus comprising an evacuated cylindrical envelope containing a plurality of cooperating electrodes, an electrostatic control electrode adapted to cooperate therewith, a charge of inert gas in said envelope at a pressure sufficient to sustain an arc-like discharge, said control electrode being constituted of a metallic cylinder which extends substantially to the rear surface of each of said electrodes.

In witness whereof, I have hereto set my hand this 22nd day of March, 1929.

ALBERT W. HULL.