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H. C. STEINER ET AL

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THERMIONIC CATHODE

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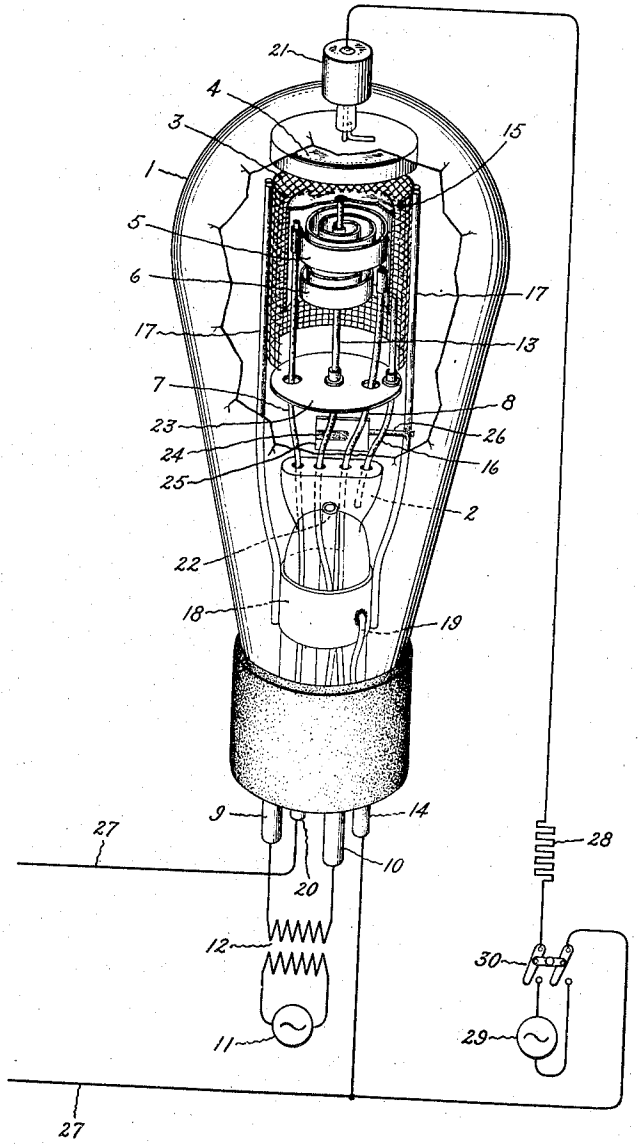

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THERMIONIC CATHODE

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11 Claims. (Cl. 250—27.5)

The present invention relates to gas conduction devices and more particularly to the cathode structure of such devices.

An article in the General Electric Review, April 1929, vol. 32, No. 4, pages 213–223, describes a form of electrical discharge apparatus termed a "Thyratron". The present invention relates to apparatus of this type.

The tube described in the article referred to, is essentially a three-electrode device, into which a small amount of an ionizable medium consisting of an inert gas or a vapor producing substance has been introduced. The presence of the ionizable medium changes the discharge into an arc-like discharge having a flat or slightly negative volt-ampere characteristic. The starting of the arc may be controlled electrostatically by means of the grid member to which a negative charge may be applied, the discharge ceasing only by the removal of the plate voltage. The removal or stoppage of the plate voltage conveniently is accomplished by energizing the plate circuit with alternating current which periodically drops thru zero. Such a tube may thus be used as an electrostatically controlled arc rectifier in which the charge on the grid determines the point in the alternating current cycle at which the arc discharge shall start and hence controls the average value of the plate current. This current may have a magnitude almost without limit except for apparatus cooling and cathode emission considerations; the flow of current may be initially controlled by an expenditure of grid energy of less than one microwatt.

In view of the arc-like character of the current stream, the various elements within the tube must be carefully designed, particularly the cathode. The heated member is normally subjected to considerable positive ion bombardment in the larger size tubes and there is always present the danger of developing localized hot spots with consequent burning out. Hence, it is imperative to provide a filament of relatively large cross sectional area and of rugged construction. Morever, inasmuch as there is a large plate current involved which necessarily passes through some portion of the filament after traversing the arc path, there is the problem of providing a filament lead-in conductor capable of being hermetically sealed within the stem and of sufficient size to accommodate the combined heating and plate currents. The cathode must also be able to supply considerable quantities of electrons, hence calling for a large electron emitting surface in addition to the required large cross sectional area and for carrying the heavy current and for providing ruggedness. In the case of filamentary cathodes of ordinary length which are designed for relatively low voltages, these conditions may be satisfied by the use of metal ribbon wound as a continuous helix either as a vertical convolute or as a single, flat spiral. However, in the event the cathode is designed for higher voltages, in order to offer the proper resistance, the filament is necessarily long on account of its large cross sectional area and it is evident that the amount of space taken up by the helical cathode of the requisite length may preclude its advantageous employment in tubes of limited interelectrode space.

Accordingly, one of the features of our invention contemplates an improved form of cathode for controlled arc devices in which a relatively large electron emitting surface, constituted as a heavy conductor of long length, is confined in a relatively small space and at the same time offers the full measure of effectiveness in presenting the entire active surface to the anode. According to another feature of our invention provision is made to separate the load current from the cathode heating current in so far as the lead-in conductors are concerned thus relieving the filament conductors of the burden of transporting the plate current so that the size of these conductors need only be large enough to carry the heating current. This feature is accomplished by providing an additional lead connected to the center or mid-point of the filament and forming part of the load circuit.

It has been found in the operation of tubes of the kind described that when the ribbon filaments are wound as a helix in the manner proposed by the prior art the force exerted by the magnetic field of the filament, which is of an accumulative character, deleteriously affects the movement of the positive ions and electrons, tending to deflect these particles from their normal path between electrodes and generally to interfere with the starting of the device and operation thereafter. As a further feature of our invention, we propose to construct the cathode in such a manner that there are no magnetic forces present or rather such forces tend to neutralize one another and hence the current is free to move between the electrodes without impediment.

Other objects and features will be apparent as the specification is perused in connection with the accompanying drawing which represents a view partly in cross section of a preferred embodiment of the invention.

Referring to the drawing, numeral 1 designates an evacuated envelope which terminates in a press 2. Within the envelope there are coaxially arranged a cathode structure, an electrostatic control member or grid 3 and an anode 4. In accordance with our invention, the cathode consists of a conductor, preferably of strip material, formed as a plurality of portions, layers or decks 5, 6 of similar configuration such as helices or spirals in opposed relation and in coaxial alignment, wound in the same direction and connected in series. The outer end of each spiral is connected in any suitable manner, for example by forming eyelets, to lead-in conductors 7, 8 which terminate in contact pins 9, 10 mounted in a base of standard design. Alternating current from source 11 may be applied to the contact pins through a step-down transformer 12. The center terminals of the spirals are connected together by a conductor 13 which is extended at one end through the press to a contact pin 14 and at the other end is joined, as by welding, to a cap-like shield 15 which fits over the cathode. It is apparent that inasmuch as the centers of the spirals are joined together and the outer terminals are effectively across the source of electromotive force the current traverses one of the spirals in a direction opposite to the flow of current in the other spiral whereby the magnetic fields of the helices neutralize one another. The cathode is preferably made of nickel and may be coated on one or both sides with electronically active substances such as barium carbonate ($BaCO_3$) or other suitable salts of the alkaline earth metals in order to increase electron emission. The coat may be formed by applying to the surface a paste of the carbonate mixed with suitable binder and heating the filament to a proper temperature. The cap member 15 which also may comprise nickel is closed at the top, open at the bottom and is of a length sufficient to extend at least to the lower edge of the spiral 6. In addition to being supported at the center by the lead-in conductor 13 the cap or shield 15 is joined at the outer surface to a rod 16 which is fused in the stem 2 and hence is rigidly held at two places. The function of the shield will be explained hereinafter. The grid member 3 is fabricated preferably as a mesh or other perforated body of a metal such as a nickel-chromium alloy (nichrome) which ordinarily does not emit electrons except at fairly high temperatures. The grid may take the general shape of a cylindrical cap which fits over the shield member and extends a considerable distance below the cathode, being supported at suitable distance from the cathode structure by means of two sets of diametrically disposed rods 17, which are secured to a band 18 of metal tightly embracing the stem 2. A lead-in conductor 19 may be attached to the band and taken out to a contact pin 20.

The anode 4 comprises a plate member preferably of nickel which is carbonized to offer a black body heat-radiating surface. In order to make contact with the anode, a terminal 21 is affixed to the upper extremity of the envelope 1 and a lead connected in any suitable manner between the terminal and the anode. The envelope is of the tipless type so-called in order to accommodate the terminal, provision being made for evacuating the envelope through a tube 22 in the well known manner.

During operation, the heat produced by the filament is intense and it is desirable to protect the press and stem 2 from the radiated heat by means of a flat circular sheet of metal 23 which conveniently may be affixed to the pair of equipotential conductors 13 and 16 in any suitable manner, e. g., by collars which are pinched to the conductors and are disposed on both sides of the member 23. The remaining conductors may pass through large openings in the member 23. A getter material 24, e. g., magnesium in the form of a small strip, is conveniently affixed to a plate 25 and supported in the proper position by means of a wire 26 secured to the conductor 17. The function of the getter is well known. An inert gas, such as argon, at a pressure between 50–250 microns may be introduced into the envelope during and after evacuation but preferably a drop of mercury (not shown) is employed as the source of positive ion-producing vapor. The operating temperature of the device may be such that the mercury vapor has a pressure less than 1 millimeter.

The input or control circuit comprises conductors 27, one of which is connected to the pin 14 and hence to the mid-point of the filament while the other is connected to the grid contact 20. The output or controlled circuit includes a load 28 shown in the form of resistance but which may constitute a relay or other circuit controlling device and a source of alternating current 29 of suitable voltage to which connection can be made by means of a double pole switch 30.

It is found that during operation, when the cathode and the anode are energized by the respective sources of electromotive force, electrons are emitted through the open or bottom end of the cap member 15 and an electrical discharge of arc-like character is formed between the anode and cathode members. The starting of the discharge may be controlled by a negative charge on the grid of proper potential. The cap 15 serves not only to conserve the heat generated at the cathode thereby increasing the efficiency of this member but also to prevent the electronically active material on the cathode, i. e. barium and its oxides, from being deposited on the grid member 3 to cause deleterious grid emission therefrom as the result of intense bombardment produced by the arc. It is evident that the electrons emitted from the grid are equivalent as far as starting the tube is concerned to an equal number from the cathode and if sufficient in number to cause starting of the arc, no negative voltage applied to the grid can prevent it. A few microamperes of grid emission is generally sufficient to spoil control of the tube.

An inspection of the circuit diagram will show that the load circuit through which a current, ordinarily of many amperes, may flow, is electrically separate from the filamentary circuit and hence no conductor within the tube is required to convey the combined filament and plate currents. By reducing the current to a minimum in the various lead-in conductors, the tendency for leakage at the stem is reduced. Furthermore, it is less difficult initially to seal hermetically small diameter wire in glass than large wire such as would be required to conduct the combined current. The filament being formed as a double-deck spiral in accordance with our invention and one portion being directly placed over the other conserves the space taken up by the cathode member and the arrangement is such as to utilize the interior volume of the cylindrical cap member 15 to the fullest advantage. This ad-

vantage is derived without detracting in any degree from its efficacy as an emitter of electrons or from its ability to offer the entire surface in sustaining the arc with a relatively low cathode drop. The double deck form of filament also lends itself readily to the establishment of an accurate mid-point so as to present electrical symmetry to the various alternating current sources. It is very difficult to determine accurately the mid-tap of a filament transformer for connection to the load circuit, as is proposed in the prior art. Moreover, it is apparent that the lead 13 which is connected to the mid-point of the filament serves as an additional support for both spirals, thus offering considerable rigidity to the entire cathode structure.

Another important advantage of the disclosed filament construction is the fact that there are no deleterious magnetic fields set up around the cathode since the currents in the two spirals are equal and opposite. The absence of these fields lends substantial advantage from an operation standpoint, particularly with respect to the character of the arc stream and the effectiveness of its control. While we have shown the filament as being composed of two spirals, it is obvious that as many pairs as may be desired may be used to advantage. The center of each pair may be connected to the conductor 13 and, if desired, extra leads brought out of the envelope from the extremities of the spirals or the spirals may be connected in parallel to the same outgoing leads.

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

1. An electrical discharge device comprising an evacuated envelope containing a cathode, a grid and an anode, said cathode being a pair of spirals in series and mounted parallelly adjacent to and coaxial with one another for cooperating with the grid and anode members.

2. An evacuated envelope containing a cathode, a grid and an anode, said cathode being a pair of spirals mounted adjacent to and coaxial with one another, said spirals being wound in the same direction and their centers electrically connected together, means for impressing an electromotive force between the free extremities of the spirals whereby the current will traverse the respective spirals in opposite directions and the magnetic fields produced in the two spirals will neutralize one another.

3. An electrical discharge device comprising an evacuated envelope containing a plurality of electrodes including a cathode, said cathode being a pair of spirals mounted adjacent to and coaxial with one another, the centers of said spirals being connected together by a conductor having a terminal.

4. An electrical discharge device comprising an evacuated envelope containing a cathode, a grid and an anode, said cathode being formed as a pair of spirals mounted adjacent to and coaxial with one another, a metallic heat shield disposed about the cathode, the center of said spirals being connected by a conductor which is attached to said heat shield.

5. An electrical discharge device comprising an evacuated envelope containing a cathode, grid and an anode, an ionizable medium in said envelope at a pressure sufficient to support an arc-like discharge at the impressed voltages, said cathode being formed as a pair of flat spirals mounted adjacent to and coaxial with one another and cooperating with the grid and anode members.

6. An electrical system comprising an evacuated envelope containing a cathode, a grid and an anode, an ionizable medium in said envelope at a pressure sufficient to support an arc-like discharge at the impressed voltages, said cathode constituting a pair of spirals mounted adjacent to and coaxial with one another, said spirals being wound in the same direction and their centers connected together.

7. An electrical system comprising an evacuated envelope containing a plurality of electrodes including a cathode, an ionizable medium in said envelope at a pressure sufficient to support an arc-like discharge at the impressed voltages, input and output connections for said electrodes, said cathode constituting a pair of spirals mounted adjacent to and coaxial with one another, the centers of said spirals being connected together by a conductor which is common to each of the input and output connections.

8. An electrical system comprising an evacuated envelope containing a plurality of electrodes including a cathode, an ionizable medium in said envelope at a pressure sufficient to support an arc-like discharge at the impressed voltages, input and output connections for said electrodes, said cathode being formed as a pair of spirals mounted adjacent to and coaxial with one another, a heat shield disposed about the cathode, said spirals being wound in the same direction and their centers being connected by a conductor attached to said heat shield, said conductor being common to each of the input and output connections.

9. An electrical discharge device comprising an envelope containing vapor-producing material, a thermionic cathode of flat spiral configuration, a cooperating electrode, means for controlling the pressure of the vapor produced by said material, said means comprising a member of flat spiral configuration and adapted to be heated, said cathode and member being positioned in parallel planes.

10. An electrical discharge device comprising an envelope terminating in a stem and containing vapor-producing material, a plurality of support wires sealed in said stem and extending interiorly and exteriorly of said envelope, a substantially flat spirally wound thermionic cathode in said envelope and secured to two of said support wires, a cooperating anode, and a substantially flat spirally wound member in said envelope, said member being adapted to serve as a heater and being positioned in a plane spaced from the plane of the cathode, said heater member being secured to another of said support wires and to one of the support wires to which the cathode is secured.

11. An electrical discharge device comprising an envelope containing vapor-producing material, a thermionic cathode, a cooperating electrode, and means for controlling the pressure of the vapor produced by said material, said means including a member adapted to be heated, said member having a configuration similar to that of the cathode and positioned adjacent said cathode.

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