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A. W. HULL

1,955,545

THERMOSTATIC CONTROL FOR THERMIONIC ARC DISCHARGE DEVICES

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Fig. 2.

Fig. 1.

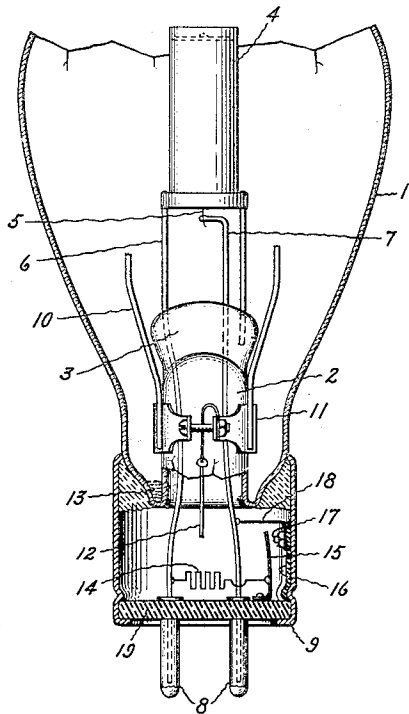
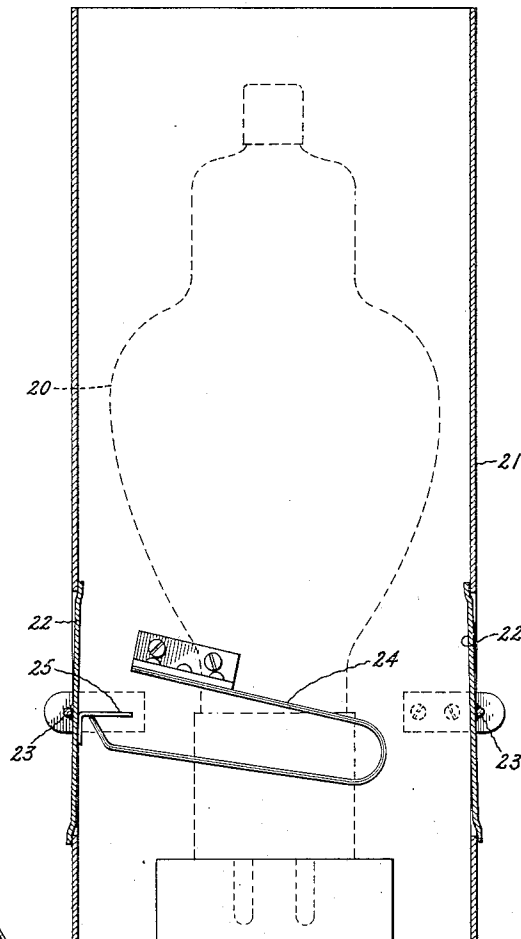
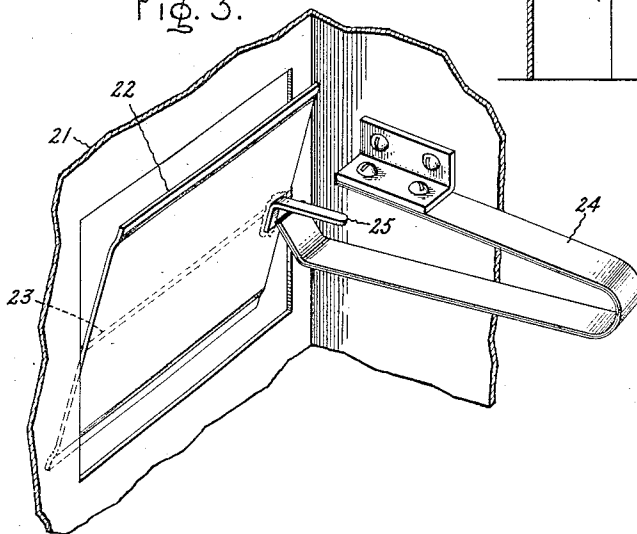


Fig. 3.



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UNITED STATES PATENT OFFICE

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THERMOSTATIC CONTROL FOR THERMIONIC ARC DISCHARGE DEVICES

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11 Claims. (Cl. 250—27.5)

The present invention relates to electric discharge apparatus, and more particularly to devices which carry large currents by means of ionized gas or vapor.

Many of the devices of this sort contain thermionic cathodes of the filamentary and indirectly heated type, and are called "hot cathode devices" to distinguish them from devices which employ liquid pool cathodes. Mercury vapor ordinarily is used for the ionizable medium on account of its relatively low ionization potential, (10.4 volts). When these devices are employed as relays in contradistinction to simple rectifiers, an electrostatic control element is added which usually takes the form of a perforated grid. Apparatus of this general class is operated at such a temperature that the pressure of vapor is sufficient to permit a discharge of arc-like character to form when alternating or interrupted direct current of suitable voltage is applied to the electrodes. The arc is stopped when the plate voltage is reduced substantially to zero. In devices provided with grids, the starting of the arc may be controlled by the bias voltage on the grid, but after the arc has started, the grid loses control when ordinary and practical bias voltages are employed and can neither modulate, limit nor extinguish the arc under these conditions. The starting of the arc in this case may be repeated indefinitely because while the discharge cannot ordinarily be extinguished by the grid, it can be stopped by the removal, periodic or otherwise, of the anode voltage. Upon the re-application of the latter, the grid voltage again determines whether the arc will start and thus, is able to control the average plate current over a period of time. All hot cathode devices serve to rectify the alternating current voltages applied thereto, but as stated hereinbefore, the devices provided with grids, in addition, serve to control the average value of the rectifier current output.

The operating characteristics of these tubes, such as their current-carrying capacity, also the maximum operating voltage and the length of time for deionization after the voltage is withdrawn, are determined to a large extent by the vapor pressure of the ionized medium and this in turn is a function of the ambient temperatures surrounding the tubes. In order that the operation may be uniform over substantial periods of time under conditions of steady applied voltages, it is essential that the tubes, or rather certain portions of the envelope, as will be explained hereinafter, be maintained at a constant predetermined temperature. These devices, when

serving as control or relay units may in practice be positioned in places subject to large temperature variations, and unless the effects of these variations are compensated, the pressure of the vapor within the device will change and may lead to arc-back or failure of the device to commutate properly. It is therefore desirable to employ some form of automatic arrangement which will effectively serve to maintain the vapor pressure in these devices substantially constant under all reasonable changes of ambient and load conditions. An object of the present invention is to provide such an arrangement.

It is found that the mercury vapor, hot cathode type of arc discharge device lends itself particularly well to the automatic control of its vapor pressure. The mercury, which is placed in the envelope as a globule, becomes vaporized and fills the whole tube with mercury vapor, which tends to condense on the coolest portions of the envelope. These portions may be and in practice usually are so positioned as to be remote from the region of the discharge, and are shielded from the heat radiated by the discharge so that their temperatures are almost entirely independent of the load current. It is evident that these envelope portions cannot be completely insulated from the heat effects of the discharge, hence of the load current, on account of the heat conduction through the material of the envelope, also through the contained vapor. The temperature of these portions, however, largely determines the pressure of mercury vapor throughout the whole envelope and this temperature is dependent normally upon the temperature of the air and to some extent upon the load current. Accordingly, I propose to apply the automatic temperature regulation to the coolest portion of the envelope of such devices. One of the many forms which my invention may take is that in which an arrangement is provided automatically to add heat to that part of the envelope in which the liquid mercury and the condensed vapor collects. The operation of my improved arrangement is such that the addition of heat is controlled by the temperature of this part of the envelope in such manner as to maintain the temperature of this part constant. The invention will be more clearly understood when reference is made to the drawing in which Fig. 1 represents a cross-section, partly broken away, of a tube improved in accordance with my invention, and Figs. 2 and 3 show a modified construction.

Referring to Fig. 1, numeral 1 designates a glass envelope which terminates in a stem 2 and

press 3. The latter supports an indirectly heated cathode 4 which contains an axially positioned filament 5 connected to the upper end of the cathode. Conductors 6 and 7 are connected to the lower ends of the cathode and filament respectively, said conductors terminating in contact pins 8 which are secured to the base 9. The stem 2 provides a support for an electrostatic control member of the usual form, of which only a portion 10 of each supporting upright is indicated. These uprights may be secured to the stem by means of a clamp 11. It will be understood that in addition to the cathode and control members referred to, there is also an anode (not shown). A lead 12 for the control member is connected to a contact pin (not shown) in the base. A connection is taken from the anode, preferably through the upper portion of the envelope. The envelope contains a quantity of mercury 13 which settles in an annular reservoir at the lower end of the tube. When voltages of suitable character and magnitude are applied to the electrodes, a discharge of arc-like character is produced between the electrodes, as a result of the ionization of mercury vapor, the arc being characterized by a nearly flat volt-ampere characteristic. As stated hereinbefore, the initiation of the discharge may be controlled by utilizing for the anode energy supply, a source of alternating current or interrupted direct current, and in addition, if desired, by controlling the bias voltage on the grid, as is well understood in the art. Devices of this character have been described by me in an article entitled "Hot cathode thyatrons" in the General Electric Review, vol. 32, No. 2, April 1929, pages 213 to 223 inclusive.

In apparatus of this kind, particularly in devices employing vapor for the ionizable medium, the matter of envelope temperature becomes a factor of great importance. The vapor is continually going through a process of condensation and re-evaporation during which the temperature of the coolest portion of the envelope determines the vapor pressure throughout the envelope. When the ambient temperature changes as in the case, for example, of a device presented alternately to sunlight and shadow, or summer and winter conditions, also when the load changes, the resulting changes in vapor pressure may cause marked variations in the operation of the tube.

In accordance with my invention, I propose to maintain the operation of such a device substantially constant by controlling the temperature of the coolest portion of the envelope and for this purpose, a heater 14 is employed near the lower end of the tube, the heater consisting of resistance wire which is attached at one end to the cathode lead 6 and at the other end, to a thermostatic strip 15 of bimetallic material. The heater and strip members conveniently are contained in the base 9 or in a socket (not shown) into which the base is inserted, in order to conserve heat and to protect the elements from injury. As exemplified, the base is hollow and has secured thereto on the interior, an insulating strip 16 which carries a contact member 17 electrically connected by lead 18 to the filament lead 7. The thermostatic strip may be secured in any suitable manner to a body of insulating material 19 which closes the lower end of the base. The contact member is positioned near the upper end of the thermostatic strip so that when the latter bends or flexes under the influence of heat, con-

nection is made with the contact member, thus connecting the heater directly across the leads 6, 7. Electrical energy may be supplied to the heater conveniently from the same source as energizes the filament. It is evident that the heater, by reason of its position, serves to elevate the temperature of the lower or cooler portion of the envelope which contains the condensate 13. The thermostatic strip 15 is located near the periphery of the base 9, and is so far removed from the arc discharge as to respond almost exclusively to changes of temperature which occur about the lower end of the tube. When the heater becomes energized by reason of a lowering of the ambient temperature or a reduction in load, additional vapor is produced from the mercury condensate, which serves to increase and restore to the desired value, the pressure of the ionizable medium within the active region of the discharge. The increase of vapor pressure restores the electrical characteristics of the tube to their original value, notwithstanding the lower ambient temperature and reduced load, thus maintaining the operation of the device substantially uniform. When the vapor pressure reaches the predetermined value as the result of the heat supplied by member 14, the thermostatic strip bends in the direction opposite to that previously described and opens the heater circuit, thereby allowing the lower end of the envelope to cool.

An improvement on the broad invention claimed herein is disclosed and specifically claimed in the patent application of John H. Payne, Serial No. 541,083 filed May 29, 1931, entitled "Thermostatic control for electron discharge devices", and assigned to the same assignee as the present application. This improvement is shown in Figs. 2 and 3 and no claims specific thereto are made in the present application. The device 20, which may be a rectifier, with or without electrostatic control, and containing mercury vapor or other ionizable medium, is placed in an enclosure 21 provided with ventilating doors or shutters 22. The latter conveniently are arranged to swing on horizontal axes 23 and are suspended in such a manner as normally to move inwardly in the absence of restraint. However, the doors are maintained in the closed position by means of the U-shaped thermostatic strip 24 which is secured to the enclosure in any suitable manner and at a position near the coolest portion of the device. As shown, a projection 25 is provided on each door which rests against the strip so that when the thermostatic loop opens due to increase of temperature, the doors fall of their own weight, leaving openings in the side of the enclosure. The normal cathode heat radiation including the effects of load current, maintains the enclosure with the doors closed, at a sufficiently high temperature in the coldest operating ambient condition. If this radiation is not sufficient, a heater (not shown) may be provided. As soon as the temperature in the enclosure rises above the desired value, the doors automatically and gradually open, finally assuming a stationary position such as to allow a sufficient quantity of air to enter and cool the lower portion of the tube, so that the desired temperature is maintained. This arrangement differs from that previously described in that the desired temperature regulation is obtained without the necessity of supplying a controlled amount of additional heat to the tube.

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

1. A thermionic discharge device including an

envelope, and containing a plurality of electrodes and a material adapted to be vaporized, a portion of said envelope being adapted to operate at a temperature sufficiently high to maintain the vaporizable material in a vaporous condition and another portion of the envelope being adapted to operate at a temperature sufficiently low to cause condensation of a portion of the vapor, and means including a temperature responsive device for automatically maintaining the temperature of the cooler portion only of the envelope at a predetermined value whereby the pressure of the vapor is maintained constant regardless of ambient temperature variations.

2. An electric discharge device comprising an envelope containing a plurality of electrodes and a vapor adapted to be ionized in order to support an arc-like discharge, a portion of said envelope being adapted to operate at a temperature sufficiently high to maintain the ionizable medium in a vaporous condition and another portion of the envelope being adapted to operate at a temperature sufficiently low to cause condensation of a portion of the vapor, and means including a temperature responsive device for automatically regulating the rate at which the vapor is condensed and re-evaporated during operation in response to variations of envelope temperature, whereby the pressure of the vapor is maintained substantially constant notwithstanding the variations of envelope temperature.

3. An electric discharge device comprising an envelope and containing a plurality of electrodes and a vapor adapted to be ionized in order to support an arc-like discharge, a portion of said envelope being adapted to operate at a temperature sufficiently high to maintain the ionizable medium in a vaporous condition and another portion of the envelope being adapted to operate at a temperature sufficiently low to cause condensation of a portion of the vapor, and means positioned at the cooler portion of the envelope and responsive to temperature variations of the envelope for automatically regulating the pressure of the vapor in response to variations of envelope temperature, said means comprising a heater in heat-transferring relation to the vapor condensate and which is energized when the envelope temperature becomes lower than a predetermined temperature.

4. An electric discharge device comprising an envelope containing a thermionic cathode, an anode and a vapor adapted to be ionized in order to support an arc-like discharge, a portion of said envelope being adapted to operate at a temperature sufficiently high to maintain the ionizable medium in a vaporous condition and another portion of the envelope operating at a temperature sufficiently low to cause condensation of a portion of the vapor, and means positioned at the cooler portion of the envelope for regulating the pressure of the vapor in response to the variations of envelope temperature, said means comprising a heater, also a thermostatic member for automatically connecting the heater to a source of electrical energy when the envelope temperature becomes lower than a predetermined temperature.

5. An electric discharge device of the hot cathode and vapor type and including an envelope containing a plurality of electrodes and vapor-producing material, a base for said device, and means responsive to temperature variations and secured within the base, for regulating the temperature of the vapor-producing material in re-

sponse to the variations of envelope temperature whereby the pressure of the vapor in said envelope is maintained constant.

6. An electric discharge device including an envelope which contains a plurality of electrodes and a quantity of mercury, said mercury being adapted to vaporize during operation and to support an arc-like discharge, a portion of said envelope being adapted to operate at a temperature sufficiently high to maintain the mercury in a vaporous condition and another portion of the envelope being adapted to operate at a temperature sufficiently low to cause condensation of a portion of the vapor, and means responsive to temperature variations and positioned near the cooler portion only of the envelope to control the rate at which the mercury condenses on and re-evaporates from the said portion of the envelope, in response to envelope temperature variations.

7. An electric discharge device including an envelope which contains an indirectly heated cathode, a cathode heater, an anode and a quantity of mercury, said mercury being adapted to vaporize during operation and to support an arc-like discharge, a portion of said envelope being adapted to operate at a temperature sufficiently high to maintain the mercury in a vaporous condition and another portion of the envelope operating at a temperature sufficiently low to cause condensation of a portion of the vapor, and means responsive to temperature variations and positioned near the cooler portion only of the envelope to control automatically the rate at which the mercury condenses on the said portion of the envelope in response to the temperature variations, said means comprising a heater connected effectively during operation between the cathode and the cathode heater.

8. A gaseous conduction device of the hot cathode type and including an envelope containing a plurality of electrodes and vapor producing material, a support member for the device in thermal contact therewith, said member containing a heater in heat-transferring relation to said material, and temperature responsive means for regulating the temperature of the heater in response to variations of envelope temperature.

9. A gaseous conduction device of the hot cathode type and including an envelope containing a plurality of electrodes and vapor-producing material, a base for said envelope, said base being hollow and containing a heater in heat-transferring relation to said material, also containing means responsive to temperature variations for energizing the heater when the ambient temperature about the envelope becomes lower than a predetermined temperature.

10. A gaseous conduction device of the hot cathode type and including an envelope containing a plurality of electrodes and vapor-producing material, a base for said envelope, said base being hollow and containing a heater in heat-transferring relation to said material, also containing a relay in heat responsive relation to said envelope, said relay being adapted to cause the energization of said heater when the envelope becomes lower than a predetermined temperature whereby the pressure of the vapor is maintained substantially constant.

11. A gaseous conduction device including an envelope which contains an indirectly heated cathode, a cathode heater, an anode and vapor-producing material, a base for said envelope, said base being hollow and containing a heater in heat-transferring relation to said material,

leading-in conductors for said electrodes including the cathode heater, a plurality of said conductors passing through the hollow portion of the base, said heater being connected to one of said leading-in conductors. a thermostatic strip connected to the heater in said base and in heat responsive relation to said envelope, said strip being adapted to contact with another of said leading-in conductors when flexed in response to a change of envelope temperature whereby the energization of the heater is controlled in accordance with envelope temperature and the vapor pressure in the envelope is maintained substantially constant.

ALBERT W. HULL.

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