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A. W. HULL

2,236,290

THERMIONIC CATHODE

Original Filed Oct. 15, 1927

Fig. 1.

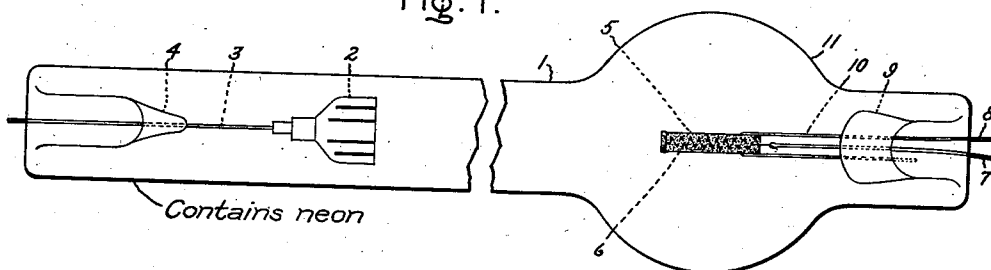


Fig. 2.

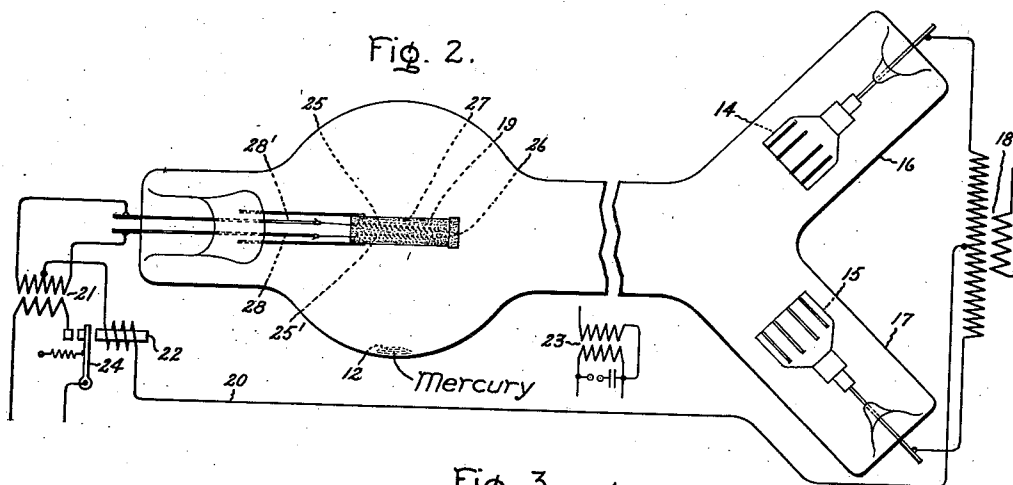


Fig. 3.

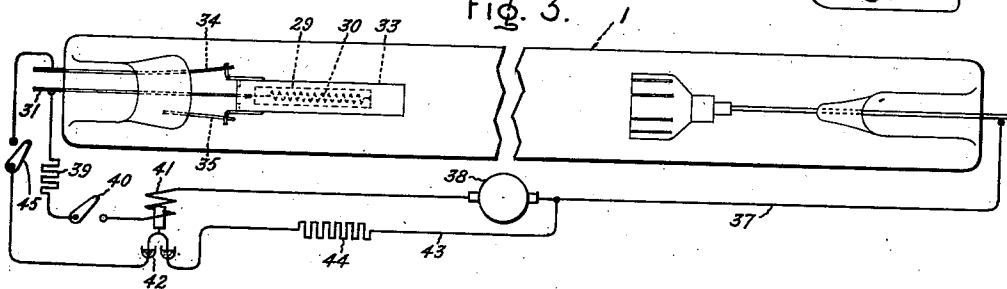
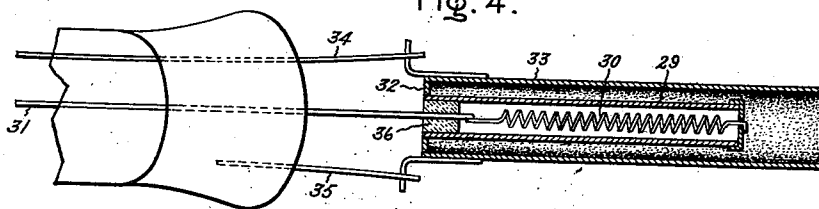


Fig. 4.



Inventor:
Albert W. Hull,
by Harry E. Dunham
His Attorney.

UNITED STATES PATENT OFFICE

2,236,290

THERMIONIC CATHODE

Albert W. Hull, Schenectady, N. Y., assignor to
General Electric Company, a corporation of
New York

Original application October 15, 1927, Serial No.
226,275. Divided and this application August
1, 1933, Serial No. 683,143. Renewed March 24,
1937

11 Claims. (Cl. 176—126)

The present application is a division of my application, Serial No. 226,275, filed October 15, 1927 (on which U. S. Reissue Patent 19,057 has been granted), and is directed to a new form of thermionic cathode which is suitable for use in electrical discharge devices, such, for example, as gaseous glow lamps.

The invention covered by the present application is an improved form of thermionic cathode particularly adapted for gaseous space discharge devices, and made up of a main cathode cylinder, an internal filamentary heater positioned along the longitudinal axis of such cylinder, and a cylindrical metallic envelope concentrically surrounding the heater within the main cathode cylinder.

The above-mentioned reissue patent relates to thermionic cathode gaseous glow lamps constructed to give a thousand hour or longer period of operation with currents higher than 100 milliamperes ($\frac{1}{10}$ ampere). The cathode fall of potential is maintained below a limiting value which I have termed the disintegration voltage. This may be done by so correlating the electron emissivity of the cathode with relation to the space or glow current which the lamp is designed to carry that the fall of potential at the cathode does not exceed the disintegration voltage. The "disintegration voltage" is always greater than the ionization voltage of the gas content of a lamp and in a lamp having a luminous column of appreciable length is materially less than the difference of potential between the electrodes.

While the invention covered by the above-mentioned reissue patent in a general sense includes gaseous glow lamps having cathodes of any form or shape providing their electron emissivity is sufficiently high to support a desired operating current without causing the fall of voltage at the cathode to be greater than the "disintegration voltage," in the preferred embodiments of my invention, indirectly heated non-filamentary cathodes are employed constructed to furnish electron emission capable of supplying a space current which the lamp is designed to carry at a temperature of inappreciable thermal disintegration and which operate either with no potential drop between extremities or operate with potential drop less than the disintegration voltage. Such electrodes, for example, may assume the form of relatively thin walled hollow bodies coated with a thermionically active material and being maintained at operating temperature by radiation or conduction of heat from a suitable heater. In an attenuated gas, electrodes coated with a ther-

mionically active, electron-emitting, material can be operated at a higher temperature than in a vacuum without loss of the coating material but the foundation material slowly evaporates at the most effective operating temperature. Unlike filamentary electrodes which are heated by the application of current at their terminals, electrodes such as herein shown and described will continue to function even after the nickel, or other foundation material has been dissipated to such extent that only a skeleton or lace-work remains. Also, unlike lamps containing filamentary cathodes, no tendency exists in lamps embodying my invention for the discharge to concentrate at the negative terminals. To distinguish such broad area cathodes over filamentary cathodes which burn out quickly in a glow lamp due to local disintegration, cathodes having such effective configuration may be termed "broad cathodes."

Improved form of luminous discharge lamps embodying my invention will be disclosed in greater detail in connection with the accompanying drawing of which Fig. 1 is a side elevation of a positive column type of lamp which is provided with a thermionic cathode and contains a permanent gas; Fig. 2 illustrates an operating circuit for alternating current and also a modification in which mercury vapor is used; Fig. 3 illustrates a direct current operating circuit and also shows in side elevation another modification in which the enlargement of the envelope about the cathode is absent, and Fig. 4 is an enlarged sectional view of cathode structure.

Referring to Fig. 1, the lamp here shown embodying my invention has a tubular envelope 1 consisting of glass, silica, or other suitable transparent material. This envelope has been shown as broken to indicate that it has a considerable and varied length depending in any particular case on conditions. For example, for a 110 volt lamp, containing neon an envelope 2.5 c. m. in diameter and about 50 to 60 c. m. long may be used. The anode 2 carried by a stem 3, which is sealed into the press 4, is of the usual construction, and may consist of nickel, iron, molybdenum, their alloys, or other suitable material. The cathode 5 may be constituted of a relatively thin cylinder of nickel coated with a suitable thermionically emitting material. I may use, for example, an alkaline earth compound, such as barium carbonate, preferably with a suitable binder, such as a solution of a cellulose compound. This cathode is heat treated to render it active.

This treatment consists in raising the temperature of the coated cathode to about 1050 to 1300° C. while the envelope 1 is being evacuated of gas. In the case of a foundation of nickel coated with barium, the forming treatment preferably should be carried close to the melting point of nickel. Evacuation is continued during this heat treatment in order to remove gaseous decomposition products. The barium carbonate is decomposed and a compound or alloy of barium and nickel is formed which has a metallic appearance as contrasted with the white appearance of the barium carbonate coating. During the operation of the lamp the cathode should be heated to a temperature somewhat below the formation temperature of the coating, say, to a temperature of about 1000° C.

The cathode is provided with an internal heater 6 consisting of tungsten, or other suitable material, receiving current by the conductors 7, 8, which are sealed into the press 9, the conductor 7 being joined to one end of the heater 6, and the conductor 8 being joined to the closed end of the cylinder 5. The latter in turn is joined electrically to the opposite end of the heater. The cathode structure is carried by a stem 10 fused into the glass press 9. The envelope 1 is expanded about the cathode into the form of a bulbous cathode chamber 11, to avoid overheating. It is charged after thorough evacuation with a suitable gas, such as neon, for example, at a pressure of, say about several microns to several m. m. of mercury. As shown in Fig. 2, a drop of mercury 12 may be introduced as a source of vapor. The length of the discharge path should be great enough to cause the fall of potential in the luminous column to be greater than the combined fall of potential at the electrodes, and ordinarily should be chosen to cause this potential drop to be several times greater than the combined electrode potential drop. A tube having a diameter of about 2.5 c. m. containing neon at a pressure of about two millimeters of mercury has a voltage drop of about one volt per c. m. with a current of about three amperes. At lower currents the voltage drop is greater as at this pressure the voltage drop varies inversely with the tube diameter. The potential drop is substantially constant over a pressure range from about two to five millimeters. The light intensity varies substantially as the 0.67 power of the current. As the voltage drop across the lamp decreases with increase in current, the luminosity is roughly proportional to the wattage consumption. A neon lamp embodying my invention operating with a drop of potential of about 120 volts in the lamp at a current of 2.9 amperes, and an energy consumption at the cathode of about 34 watts, gave a light emission of about 5350 lumens, that is, an efficiency of the discharge of about fifteen lumens per watt, and an overall efficiency of 10.7 lumens per watt, that is, taking into account losses in the stabilizing resistance and other losses.

A lamp embodying my invention may be constructed for operation either with direct or alternating current. I have illustrated in Fig. 2 a lamp having two anodes 14, 15, located in the branches 16, 17 of the vitreous envelope, these anodes being connected to the opposite terminals of the secondary of a transformer 18. The cathode 19 is connected by the conductor 20 to an intermediate point of the secondary of the transformer 18. An auxiliary transformer 21 is shown for heating the cathode although a battery or

other suitable heating means may be used. The conductor 20 is connected in series with the coil of a contactor 22 to an intermediate point of the secondary of the transformer 18, that is, to approximately the neutral point.

A high frequency device, such as illustrated at 23 may be employed to facilitate starting of the discharge, not only of the device shown in Fig. 2, but in connection with any of the lamps embodying my invention. Such device and its action in starting is well known and hence will not be here described. When an operating current flows through the lamp, the magnet of the contactor 22 is energized, attracting its armature 24 and opening the primary circuit of the cathode heating transformer 21. The main current, which now passes through the cathode heater on its way to the anode maintains the cathode heated to an operating temperature. The cathode of the device shown in Fig. 2 is provided with two heater spirals 25, 25', connected in series with one another and also connected at 26 to the cathode shell 19. These heaters 25, 25' are embedded in suitable refractory, insulating material 27, for example, magnesium oxide, contained within the shell 25. The exterior of the shell 19 is coated with suitable activating material. Current is supplied by the conductors 28, 28'.

The features of cathode structure for gaseous space discharge devices to which my present application is directed are illustrated in Figs. 3 and 4. The cathode cylinder 29 is hollow and contains a single heater spiral 30, one end of which is connected to a supply wire 31, the other end being connected to the shell 29. The shell or housing 29 in turn is electrically connected by the ring-shaped member 32 to the shield 33. The shield 33 conserves heat and coating material which otherwise would be lost by radiation and evaporation from the cylinder 29 and thereby materially increases the efficiency and life of the cathode. Contact is made to this shield by a sealed-in conductor 34. A steadying support 35 is provided at the side of the cathode opposite the point of connection to the conductor 34. The exterior of the shell 29 and the interior of the shield 33 are coated with a material of high thermionic emissivity as described above. A spacing and insulating sleeve 36 consisting of alumina, or the like, preferably is provided between the conductor 31 and the shell 29. Either a fixed gas or a vapor may be introduced into the envelope 1, Fig. 3, after the gas and moisture content have been removed and the cathode has been activated.

The lamp of Fig. 3, which is provided with such a cathode, requires no enlargement about the cathode because of the shielding effect of the cylinder 33. The lamp is shown connected by a circuit 37 to a direct current source 38 in series with a resistance 39, a hand operated switch 40, and the coil 41 of a mercury switch 42. The mercury switch 42 is in a parallel circuit 43 containing a resistance 44 and a switch 45. When the switches 40 and 45 are closed, current flows in the heater circuit 43, which thereupon is opened by the mercury switch, causing a high voltage impulse to be impressed upon the lamp. This action of the coil 41 may be repeated a number of times until the flow discharge is started. If desired a heating current also may be impressed on the conductors 31, 34 to bring the cathode to an operating temperature preliminary to starting, this current being interrupted after the lamp is started.

When the heater 30 is properly proportioned with respect to the energy source 38, the external resistance 39 may be omitted. The current through the gas in the lamp flowing through the heater 30 maintains the cathode at operating temperature. Although in the preferred forms of my invention the cathode heater serves also as a resistance for limiting the space or glow-producing current to or below the limiting value above which the cathode drop of potential would exceed the disintegration voltage and cause excessive sputtering of the cathode by positive ion bombardment, I wish it to be understood that various known means, such as an external resistance or a constant current source may be used for the same purpose.

In a copending application Serial No. 156,713 filed December 23, 1926, now involved in several interferences, claims are made to various broad features of construction of a thermionic cathode comprising a hollow member provided therein with a difficultly vaporizable material which promotes the emission of electrons at elevated temperatures.

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

1. A thermionic electron emitter comprising a cylindrical cathode, filamentary means for indirectly heating the cathode, positioned along the longitudinal axis of the cathode, and cathode shielding means comprising a cylindrical metallic envelope concentric with the heater and within the cathode, said shielding means being electrically connected with the means for heating the cathode.

2. A thermionic electron emitter comprising a cylindrical cathode, filamentary means for indirectly heating the cathode, positioned along the longitudinal axis of the cathode, and cylindrical shielding means comprising a cylindrical metallic envelope concentric with the heater and within the cathode, one end of the cylindrical shielding means being closed and connected to the heating means, the open end of the shielding means serving as a lead-in for the heating current.

3. In a thermionic cathode, the combination with a tubular electron emitting sleeve, of a heater comprising a resistance heating element disposed along the longitudinal axis of said sleeve, and a tubular current supply lead surrounding said heating element and interposed between said sleeve and said resistance element and electrically connected in series with said resistance element.

4. A thermionic cathode comprising a resistance heating element, a current supply lead formed as a metal envelope surrounding and electrically connected in series with said heating element, and an electron emitting member surrounding said envelope in position to be heated by said heating element.

5. In a thermionic cathode, the combination with a tubular electron emitting sleeve, of a heater comprising a heating filament extending

lengthwise of said sleeve, a current supply lead in the form of a metallic protective envelope surrounding said filament and disposed between it and said sleeve and connected at one end with the adjacent end of said filament, and current supply connections to the other ends of said filament and of said metallic envelope.

6. A thermionic cathode comprising a tubular electron emitting sleeve, a tubular current supply lead inside and concentric with said sleeve, and a resistance heating element inside and concentric with said tubular lead and connected at one end to said tubular lead, and a current supply lead connected to the other end of said heating element.

7. A thermionic cathode comprising a tubular electron emitting sleeve, a deep metal cup constituting a current supply lead and positioned inside said sleeve, and a heating filament inside and concentric with said cup and connected at one end to the bottom of said cup.

8. A cathode comprising a cylindrical current supply conductor, a heating element coaxially disposed within said cylindrical conductor and conductively connected thereto, and an electron emitting element enclosing said cylindrical conductor.

9. A cathode comprising a hollow cylindrical current supply conductor with one extremity closed, a heating element coaxially disposed within said conductor and conductively connected to the closed extremity thereof, and an electron emitting element disposed adjacent said cylindrical conductor.

10. A gaseous discharge device comprising an envelope which contains an ionizable medium which is gaseous during normal operation of the device, an anode and a thermionic cathode, said cathode including a hollow enclosure having an opening for the passage of a discharge therefrom, a hollow housing extending into the interior of the enclosure, there being extended electronically activated surfaces within the said enclosure separate from the surfaces of the said housing, and a resistance heater for said surfaces enclosed within the said housing and segregated thereby from the portion of the enclosure which contains the said surfaces.

11. A gaseous discharge device comprising an envelope having therein an ionizable medium which is gaseous during normal operation of the device, an anode within the device and a thermionic cathode in cooperative relation to the anode, said cathode including an elongated conductive enclosure having an opening for the passage of a discharge therefrom, electronically active material applied to the inner wall surfaces of said enclosure, a hollow housing extending longitudinally within the enclosure, and a resistance heater within said housing for maintaining the said inner wall surfaces of the enclosure at a temperature of effective electron emissivity, the heater being segregated by the housing from the main portion of the enclosure.

ALBERT W. HULL.