May 21, 1940. A. W. HULL 2,201,730

THERMIONIC CATHODE STRUCTURE

Filed June 11, 1938

Fig. 1.

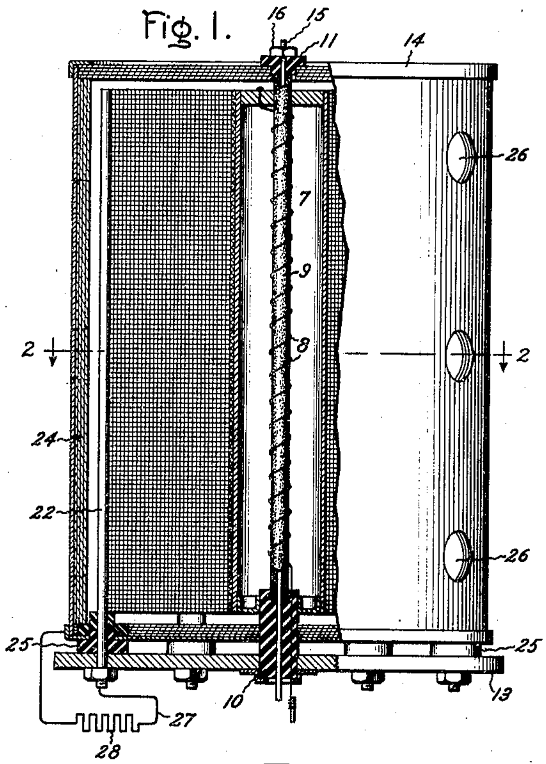


Fig. 2.

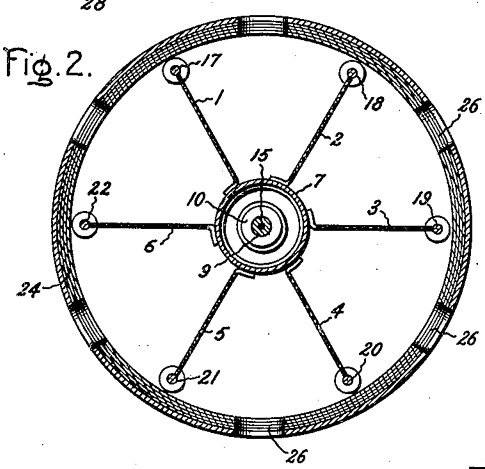


Fig. 3.

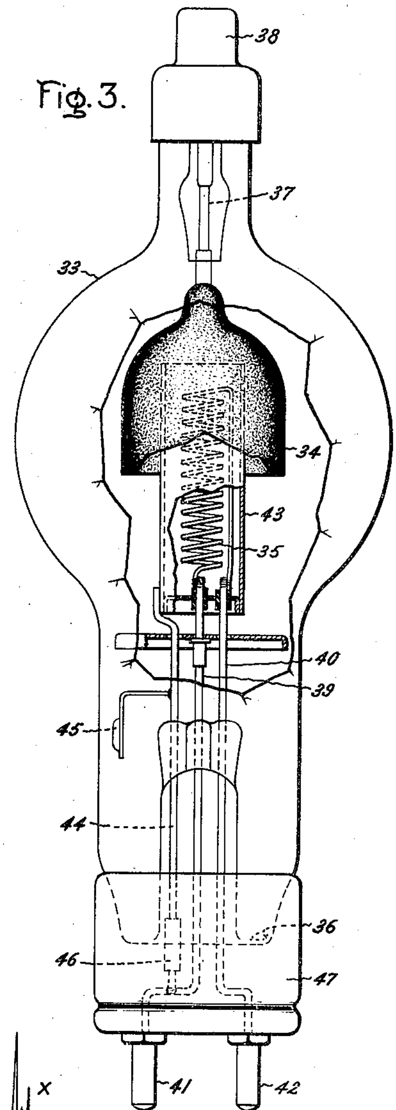


Fig. 4.

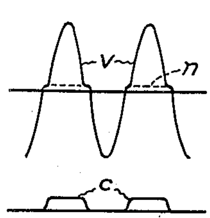
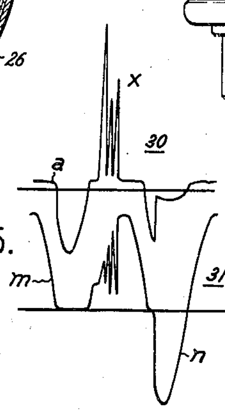


Fig. 5.



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

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2,201,730

UNITED STATES PATENT OFFICE

2,201,730

THERMIONIC CATHODE STRUCTURE

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

Application June 11, 1938, Serial No. 213,228

3 Claims. (Cl. 250—27.5)

The present invention comprises an improved cathode structure for electric discharge devices, in particular for thermionic cathode devices containing a charge of attenuated ionizable gas, such as mercury vapor or argon.

Thermionic cathodes of substantial size ordinarily are surrounded by a shield, which commonly consists of a suitable metal, and the main function of which is to conserve heat. Such a structure is shown in U. S. Patent No. 1,924,318, patented August 29, 1933, to Albert W. Hull and William A. Ruggles. However, the operation of a power device having a shielded cathode which is of the non-selfsustaining type has been found to be sometimes accompanied by undesirable electrical disturbances. For example, surges of abnormal voltage were found to occur in the circuit of hot cathode rectifiers and amplifiers containing such cathode structures during intervals of abnormal current demand, or when, for any reason, the electron emissivity from the cathode temporarily was not equal to the current demand, whether normal or abnormal. Under such conditions the normal thermionic discharge will change to a disruptive arc, a cathode spot forming on the cathode shield, the formation of which is accompanied by undesirable abrupt voltage fluctuations. The disruptive arc also results in the sputtering of some of the shield metal, thus producing a deleterious effect on the electron-emissivity of the cathode. Also, deposition of sputtered metal on interior surfaces is apt to result in short circuits, reverse discharges, and other undesirable effects.

I have discovered a means for overcoming such disturbances. When a high resistance is connected between cathode and heat shield, the formation of a cathode spot on the shield is inhibited while the advantages of holding the heat shield at cathode potential during the non-conducting period are retained. The heat shield thus connected, serves only to intercept heat and other radiations from the cathode, and does not form any part of the electron-emitting cathode structure. For example, with 10,000 ohms resistance, the current to the heat shield is only 1/1000 of one per cent of the normal load current, regardless of the electron emissivity. When resistances of higher value are connected in the shield circuit, the current to the shield is even less.

The accompanying drawing shows in Fig. 1 a side elevation, partly in section, of a thermionic cathode for large power rectifiers which is adapted for operation with a high resistance connected in accordance with my invention; Fig. 2 is a cross-section thereof on the plane 2—2; Fig. 3 is a side elevation of a rectifier having a different form of cathode in which the high resistance connection is mounted in its base; and Figs. 4 and 5 are graphs illustrating the benefits of my invention.

The cathode shown in Figs. 1 and 2 comprises a plurality of vanes preferably composed of gauze (numbered 1 to 6) which are radially mounted on a tube 7 of suitable metal, for example, nickel or molybdenum, in which a heater 8 extends longitudinally. The heater may consist of a wire of refractory metal, such as tungsten, and in the particular structure the heater wire is helically coiled on a suitable refractory support 9, consisting, for example, of a rod of beryllia or alumina. The rod 9 is held between insulating supports 10, 11 which may consist of alumina. The base 13 and the cover 14, on which the supports 10 and 11 are respectively mounted, are bound together by a rod 15 on which is threaded a nut 16. The peripheral edges of the vanes 1 to 6 are connected to rods 17 to 22 which are mounted upon the base 13.

The vanes 1 to 6 are surrounded by a shield 24 so closely that the interior of the shield becomes highly heated. Preferably it consists of multiple layers of metal which are thermally insulated from each other. For example, the shield may consist of thin metal foil, such as nickel, rolled up on itself, the layers being kept slightly spaced by protuberances (not shown) on the foil. The rods 17—22 are insulated from the heat shield by the insulators 25 (Fig. 1). The shield 24 not only conserves heat but reflects heat from the heater 8 and tube 7 upon the vanes 1 to 6, and thereby keeps the vanes at an electron-emitting temperature. The vanes 1 to 6 may have various configurations, but preferably consist of ribbons of closely-woven wire mesh of nickel, or other suitable material. The vanes are coated with oxides or alkaline earths, or other suitable material for promoting electron emission, as is well understood. Electrons emitted by the coated cathode vanes pass from the cathode through the holes 26 in the heat shield on their way to an anode or anodes. The latter are not shown in Figs. 1 and 2 but are shown in Fig. 3, which illustrates a device containing a modified form of cathode.

The electron-emitting portion of the cathode structure is connected fixedly to the heat shield by a circuit which includes a conductor 27 and a resistor 28. This resistor may vary over a wide range, for example, from about one thousand to one million ohms. A resistance value between these limits is sufficiently high to restrict current in such circuit when space current is flowing in the rectifier or other device to a negligibly low value. On the other hand, the conductivity of the circuit is sufficiently high to maintain the heat shield at cathode potential during non-conducting periods of the device.

In the absence of a high resistance, or in other words when the heat shield is an integral part of the cathode or is connected to it by a connection of negligible resistivity, an inadequacy of electron emission by the cathode, when space (load) current is flowing causes the voltage between cathode and anode to rise. A disruptive discharge terminating in a cathode spot on the cathode or heat shield is apt to occur, accompanied by destructive oscillation and sputtering of cathode material.

These conditions are illustrated by Fig. 5, the graph **30** representing voltage and the graph **31** current. During the half wave intervals when the rectifier is carrying rectified current, as indicated at m, the voltage should rise only to a relative low voltage (representing the voltage consumed in the rectifier) as indicated at a. When the above-mentioned abnormal arcing condition occurs, the voltage alternately rises to very high values and falls, as indicated by the jagged lines x. During the next half wave the rectification of the tube frequently breaks down, current conduction occurring in the reverse (undesired) direction as indicated by the portion n of the current graph **31**. Such voltage disturbances and reverse current conduction may have serious consequences in the load circuit of a rectifier and also damage the rectifier itself by reason of the attendant volatilization of metal from the seat of the arc discharge.

When, however, the heat shield is insulated from the cathode, except for a circuit having a high resistance and which is independent of the anode circuit and the circuit for heating the cathode, then a rise of voltage between the anode and the cathode, due for example to insufficient emission, does not cause a cathode spot under the conditions producing the arcing illustrated by Fig. 5. The voltage drop may rise as high as 150 volts without causing sputtering as illustrated in Fig. 4 by the voltage curve v and the current curves c. The voltage drop which would occur during normal operation is indicated by dotted lines n in this figure.

While the envelope and cooperating anode structure have been omitted in Figs. 1 and 2, Fig. 3 shows a rectifier device as an entirety, the cathode being a modified embodiment of my invention. The rectifier is made up of a glass envelope **33**, an anode **34** and a cathode **35**. The envelope contains either a gas, for example, neon, helium, nitrogen, or the like, or a metal, such as mercury or caesium vapor, as indicated by the drop of metal indicated at **36**. The anode is supported by a stem **37** sealed into the envelope and connected to the external contact **38**. The cathode also is of the externally-coated type. It comprises a helix mounted upon the current supply conductors **39**, **40**, which are connected to external contact devices **41**, **42**. The cathode helix is coated with oxide of alkaline earth, or other suitable activating material, for promoting electron emission. A mixture of barium and strontium oxide ordinarily is preferred for coating the cathode. The cathode may be of the so-called overwound type such as shown in U. S. Patent No. 1,777,253 to Bruijnes et al., that is, it consists of a foundation wire upon which is wound a finer wire, thereby providing greater surface and crevices for holding the activating material. Surrounding the cathode is a shield **43** which is mounted on a support wire **44** on which is mounted a capsule **45** for supplying a gas absorbing or "getter" material to be distilled to the walls during the exhaust of the device.

Connected between the shield conductor **44** and the cathode conductor **39** is a high resistance **46** which is mounted in this instance inside the base **47**.

The resistance **28** (Fig. 1) or **46** (Fig. 3) should be of such high value that any substantial current flow through it would result in a higher voltage drop in the tube than is normal for a discharge emanating from the heated electron emitter **35**. As such an abnormal voltage drop cannot occur under normal operating conditions, the result is that no substantial part of the normal load current flows through this resistance to the heat shield, even though the shield may be hot enough to emit electrons. Under abnormal conditions, such as the overload condition described above, the voltage drop may rise above the normal value, and in this case the resistances **28** and **46** should be high enough to prevent the formation of an abnormal arc or cathode spot with its seat on the shield. On the other hand, the resistance between the cathode and the shield must not be so high that charges may accumulate on the shield. As above indicated, the resistance may have a value roughly within the limits of one thousand and one million ohms, but in some cases may be even of higher value.

Various changes and modifications may be made without departing from my invention. While the drawing shows a two-electrode thermionic device, my invention is equally applicable to amplifiers and other devices containing a greater number of electrodes.

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

1. An electric power rectifier comprising an envelope, a charge of gas therein, cooperating electrodes, one of which is a cathode operating at an elevated temperature at which thermionic electron emission occurs, a consumption circuit subject to overloads connected to said electrodes, an electrically conductive heat shield closely adjacent said cathode, said shield so closely surrounding said cathode as to be subject to disruptive discharges during abnormal conditions, a circuit connected between said cathode and said heat shield, said circuit having a sufficiently high impedance to substantially prevent such arcing.

2. An electric rectifier comprising an envelope, a charge of attenuated gas therein, one or more anodes, a cathode constructed to be independently heated to an elevated temperature of thermionic electron emission, means for heating said cathode, a heat shield so closely surrounding said cathode as to become heated to an electron-emitting temperature, a circuit, independent of said heating means, connecting said cathode and shield, and a resistor in said circuit having a sufficiently high value to restrict current in said circuit to a negligibly low value, and thereby suppressing abnormal arc discharges which otherwise tend to occur.

3. An electric discharge device comprising an envelope, a charge of gas therein, an anode, a thermionic cathode including an oxide-coated ribbon-shaped electron-emitting member, a heat-

er therefor, a consumption circuit subject to abnormal current demand connected to said electrodes, and a metal heat shield closely adjacent said cathode member, said member and shield being insulated from one another except for a connecting circuit which is independent of said anode and said cathode heater, said circuit being fixedly connected between said emitting member and said shield within said envelope, and a resistor in said circuit, said restorer having a resistance value which will maintain said shield at cathode potential during periods of absence of space current between anode and cathode and will restrict current in said circuit to a negligibly low value during periods when such space current is present in said device.

ALBERT W. HULL.

CERTIFICATE OF CORRECTION.

Patent No. 2,201,730. May 21, 1940.

ALBERT W. HULL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, second column, line 1, claim 3, for the word "restorer" read --resistor--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 2nd day of July, A. D. 1940.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal)