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THERMIONIC CATHODE GAS-FILLED DISCHARGE TUBE

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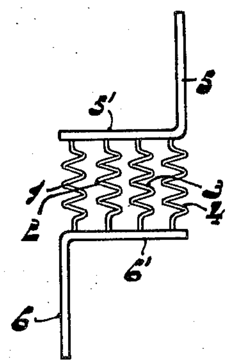

Fig. 1.

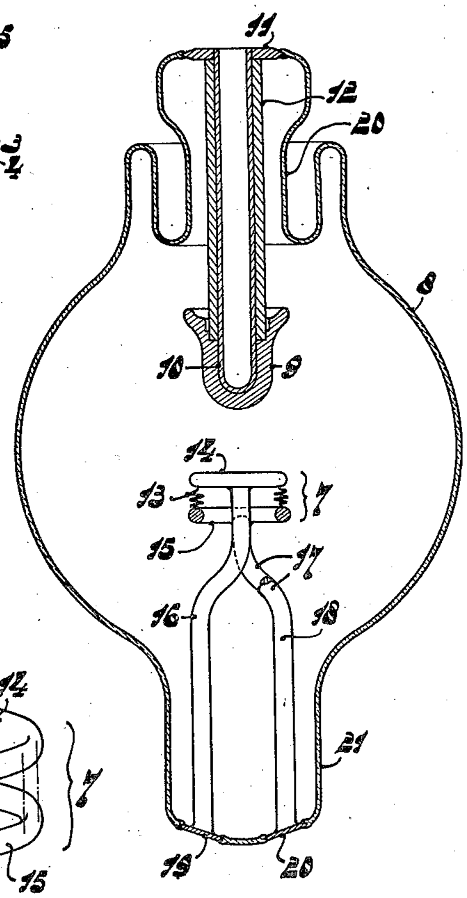

Fig. 2.

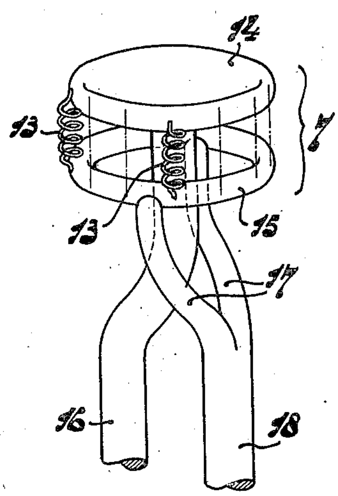

Fig. 3.

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THERMIONIC CATHODE GAS-FILLED DISCHARGE TUBE

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2 Claims. (Cl. 250—27.5)

The present invention relates to electrical discharge tubes of the type having thermionic cathodes and a gas-filling and more particularly to a cathode construction for such discharge tubes, which enables the tubes to handle large discharge currents.

The term gas-filling as used herein also includes fillings of vapor or of mixtures of vapor and gas.

The general purpose of using gas-fillings in discharge tubes of this type, is to enable the tube to handle large currents without large losses, whereby, due to ionization of the gas-filling the building up of space charge is prevented and the current conductivity of the tube is increased by the participation of the gas ions in the current conduction.

Such discharge tubes, in which the discharge has usually the character of an arc, may be used, for instance, as rectifiers which are capable of rectifying large currents with small voltage loss, thus with high efficiency, or may be used for various other purposes, for example as relay-tubes, or as discharge lamps.

However, when such tubes are required to handle very large currents, difficulties are encountered. For instance, a cathode which is to provide an emission current of about 1,000 amperes, requires a very large emitting surface. If such a cathode is to be directly heated by the passage of a heating current supplied from an external source—which in general offers the simplest solution—it has to be given the shape of a single filament of a very great length. Consequently, a high heating voltage has to be used, which brings about the known difficulties of proper insulation, the danger of discharge between different portions of the filament, the difficulty of positioning the lengthy filament, etc. On the other hand, if a lower heating voltage is used, cathodes of such large cross-sections are required as to introduce serious constructional difficulties.

A cathode construction according to the invention obviates the above difficulties, and consists broadly of a composite cathode which consists of a plurality of parallel connected individual cathode members.

Such a general construction is well known for high vacuum tubes, for instance radio tubes, in which cathodes having a plurality of parallel extending and parallel connected members have been used; these members being usually surrounded by a common anode. However, the use of similar constructions in gas-filled discharge tubes was doomed to failure because in such an arrangement it was impossible to achieve a uniform distribution of the current among the individual cathode members. Unavoidable differences in the emitting conditions caused one or another of the members to produce a slightly greater amount of emission current, which in turn increased the temperature of this higher emitting member above those of the others and thus further increased its emission; the recurring cycle of influences being continued, until the emitting member was seriously damaged or even destroyed.

The present invention is based on the realization, that it is possible to so design a cathode member that an accidental increase in its current-emission does not cause any, or at least no important, increase in its temperature, and that it is possible to avoid a local concentration of the discharge arc. This will be more fully explained hereinafter.

The heating of any given portion of a cathode filament, having a length "dx" is influenced by four different causes. These are:

1. The heating current I_f passing through the filament and supplied from outside sources. Assuming a resistance "dR" for the filament portion "dx", the heat resulting from this source is I_f^2dR.

2. The heating up of the cathodes because of the discharge arc. The heat liberated at the cathode from this source is proportional to a function of the arc voltage $E_{b(p)}$ at this point and to the current dI_{em} emitted by this element. The heating up of the cathode element "dx" from this source can be thus expressed as $fE_{b(p)}dI_{em}$.

3. The cooling-off of the cathode-element "dx" because of the energy consumed in producing the emission ϕ. This is also proportional to the current emitted by the element "dx" and can be designated as ϕdI_{em}.

4. The heating of the element "dx" is dependent upon the sum of the various emission currents dI_{em}. These currents pass the element "dx" and are emitted by more distant portions of the cathode. The resulting heating of the cathode element can be expressed as

$$\int_e^x dI_{em}{}^2 dR.$$

Where $e-x$ represents the distance of the farthest cathode element from the element under consideration.

Designating the total heating of the element

"dx" by dW_T, the following equation is obtained:

$$dW_T = I_f^2 dR + fE_{b(p)} d \cdot I_{em} - \phi dI_{em} + \int^x dI^2_{em} dR$$

or

$$dW_T = I_f^2 dR + \int^x dI^2_{em} dR + dI_{em}(fE_{b(p)} - \phi)$$

As the externally supplied heat, i. e. $I_f^2 dR$ remains constant, and the influence of the heat liberated at the arc, namely $fE_{b(p)}$ is comparatively small and does not greatly vary in practice, it immediately appears that the members in which ϕ and in which $dI_{em}^2 dR$ appear, play the most important part in the heating up.

As the work function ϕ of a cathode of a given composition is fixed, a compensation of the above-mentioned positive and negative members can be effected by selecting "dR" small, i. e., by giving the cathode element a small resistance.

Evidently it is not necessary to have the member containing ϕ altogether predominate, so as to effect a cooling off of the cathode element whenever the emission current increases, as there is no objection to the temperature of a cathode element increasing with increasing emission currents, as long as such increased temperature remains below a value at which damaging (possibly the melting) of this element would take place.

In a preferred embodiment of the invention, however, we keep the resistance of the individual parallel connected cathode members sufficiently low as to effect a noticeable cooling-off of these members whenever the emission currents exceed their normal, permissible values.

This phenomenon of the cathode portions cooling off at excessive current values, will be referred to as "dimming".

To obtain a low cathode resistance for a given emitting surface area, the parallel-connected cathode elements are made short and thick. These dimensions can be conveniently designated by the value of the heating voltage applied to the elements. In practice we prefer to so form the parallel-connected cathode elements that the heating voltage across same does not exceed 1 volt.

When using a plurality of parallel-connected cathode elements care has to be taken that the same heating voltage be applied to each cathode element.

In a preferred embodiment of the invention this is obtained by forming the composite cathode of two parallel discs or rings between which individual, parallel-connected cathode elements are provided.

Each ring or disc is provided with a current lead which is so connected to same that the voltage drop through the disc or ring, measured from the connection points of the current leads to any one of the connection points of the cathode elements, has substantially the same value. This can also be promoted by giving the discs and rings ample thickness.

Our invention will be illustrated in connection with some specific embodiments, which will be described in connection with the drawing forming part of this specification, in which:

Figure 1 is a schematic view of a cathode structure according to the invention.

Fig. 2 is a discharge tube comprising a cathode structure in accordance with the invention.

Fig. 3 is an enlarged perspective view of the cathode structure of the tube shown in Fig. 2.

Referring to Figure 1, there are shown four coiled wire cathode members **1**, **2**, **3**, and **4**, which are disposed parallel to each other, and which are also parallel-connected between leads **5** and **6**, the leads being provided with preferably integral bent portions **5'** and **6'**, which are secured, preferably by welding, to the respective ends of the filamentary cathode members. It should be noted that the leads **5** and **6** approach the group of cathode members from opposite sides, i. e., the lead **5** first connects with the member **4** and then successively with members **3**, **2** and **1**, whereas the lead **6** first connects with cathode member **1** and then successively with cathode members **2**, **3** and **4**. As a result of such arrangement the combined voltage drop in the two leads **5** and **6** is the same for each cathode member and consequently the same heating voltage is applied across each of the cathode members. As it also appears from the drawing, the individual cathode members consist of a helical filament having only a few turns.

The leads **5** and **6**, as well as the cathode filament members **1** to **4**, consist, as a rule, of a refractory metal, for instance tungsten, which is preferably provided with a nickel coating. Furthermore, the filament members may be surrounded by a closely wound nickel wire, as described in U. S. patent to Dobben, et al. No. 1,718,123.

The cathode members are provided with an emissive coating, usually an oxide coating of high electron emissivity, for instance, with a barium oxide coating. Instead of making the filament of tungsten, other suitable metals or alloys, for instance nickel or nickel alloys, may be used.

The discharge tube shown in Fig. 2 is a rectifier tube comprising a vitreous envelope **8**. The envelope **8** is provided at one end with a reentrant neck portion **20** in the bottom of which is sealed a metal ring **11**, preferably of chrome iron, the ring **11** carrying the anode **9**.

The active portion of the anode **9** is formed of a hood-shaped graphite member, into the central hollow portion of which extends a metal tube **10**, which tube is secured at its other and open end within the aperture of ring **11**, for instance by being welded thereto. Through the metal tube **10** cooling fluid may pass to the anode. The tube **10** is surrounded by a tube **12** of insulating material, for instance of steatite, to prevent the tube **10** from participating in the discharge.

The composite cathode structure **7** consists of a plurality of parallel-arranged and parallel-connected filamentary cathode members **13**. In the construction shown, twelve of these members are arranged in equal spacing about a circle as indicated in Fig. 3 in dot and dash lines. The cathode members **13** consist of comparatively short and heavy wire which is coiled into a helix of a few turns and are of the general type above described. The cathode members **13** are connected at their upper end to a disc **14** and at their lower end to a ring **15**, the disc **14** and ring **15** being of considerable thickness and extending parallel to each other and perpendicularly to the cathode members **13**. The disc **14** is provided with a heavy current lead **16**, which passes centrally through the ring **15** and is connected at the center of the disc **14**.

The current lead **18** for ring **15** forks into two branches **17**, which are connected to two diametrically opposite points of ring **15**.

Such an arrangement makes it possible to sufficiently insulate the current leads from each other. Furthermore, because of the thicknesses of the disc 14 and the ring 15, and the arrangement of the connecting points of the leads and the cathode members, the voltage drop between the connecting points of the current leads and the connecting points of the individual cathode members is substantially the same. Thus an equal heating voltage across each cathode member is secured.

The current leads 16 and 18 are supported from the other end of the tube, which forms a neck 21 in the bottom of which are sealed two metal discs 19 and 20—preferably of chrome iron—to which the leads 16 and 18 are respectively secured, preferably by welding.

As a gas filling of the discharge tube shown in Fig. 2, mercury vapor may be conveniently used, whereby an excess of liquid mercury is also provided in the tube. Preferably the temperature at the mercury should be such as to give approximately 10 millimeters of mercury vapor pressure.

In one specific type of tube made in accordance with the invention, each of the cathode members is dimensioned for a heating voltage of 0.8 volts and a heating current of about 10 amperes. With such cathode construction a very high degree of uniformity in the burning of the parallel-connected cathode members is obtained. This uniformity can be achieved in tubes for very large currents, for example, 800 amperes and more, built according to our invention. Such cathodes preferably exhibit the above referred "dimming" phenomenon, i. e. when the emission current in a cathode member exceeds the permissible value a lowering of the temperature of this member takes place.

While we have described our invention in connection with a specific application and specific embodiments, we do not wish to be limited thereto. For instance, the discharge tubes of the invention can be used for other purposes, and various deviations of the specific construction, of the gas filling used, etc., may take place without departing from the spirit of our invention.

We wish, therefore, the appended claims to be construed as broadly as permissible in view of the prior art.

What we claim is:

1. A cathode structure for a thermionic-cathode, gas-filled discharge tube comprising a group of parallel-disposed and parallel-connected coiled wire cathode elements, a conductive member connected to one end of each of said cathode elements and a conductive member connected to the opposite ends of said cathode elements, and a current lead connected to each of said conductive members, said leads approaching said group from opposite sides thereof, the combined voltage drops in said conductive members between connecting points of said leads and the connecting points of said cathode elements being the same for each of said cathode members.

2. A composite cathode structure for thermionic-cathode, gas-filled discharge tubes, comprising a disc member and a ring member disposed parallel to each other, a plurality of coiled wire cathode elements mounted in parallel to each other and equidistantly spaced along the periphery of said members, said elements being connected in parallel between said members, a current lead centrally connected to said disc, and a current lead for said ring having two branches, said branches being connected to diametrically opposite points of said ring.

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