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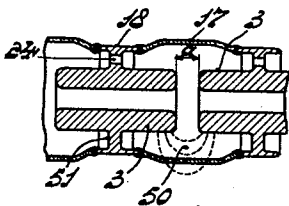
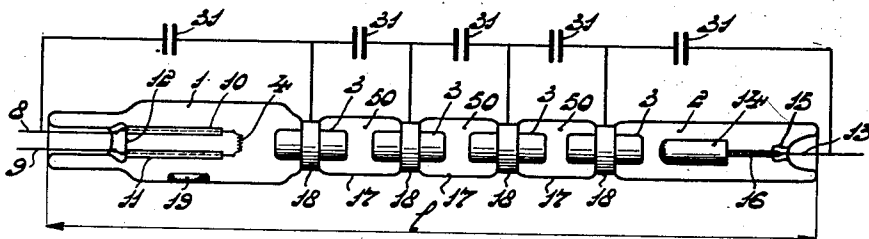
J. G. W. MULDER ET AL

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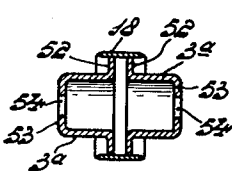
INCANDESCIBLE CATHODE DISCHARGE TUBE HAVING A GASEOUS FILLING

Filed May 15, 1933

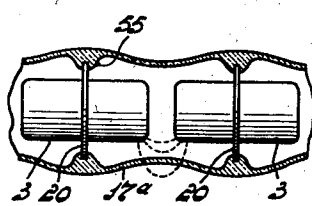
**Fig. 1.**



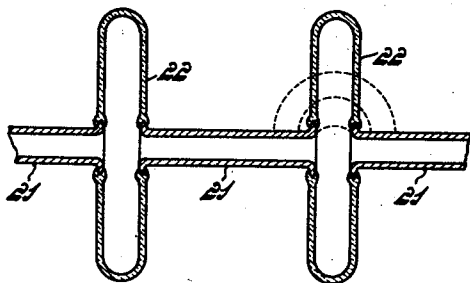
**Fig. 2.**



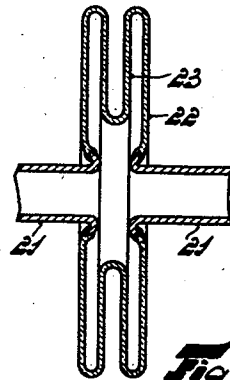
**Fig. 2a.**



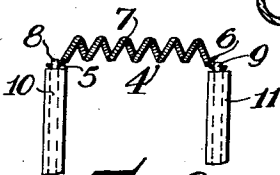
**Fig. 3.**



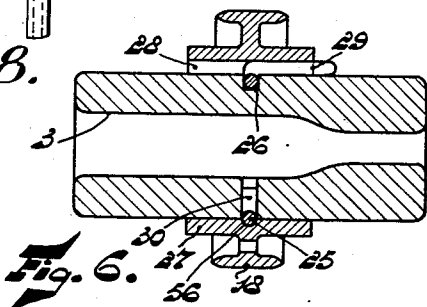
**Fig. 4.**



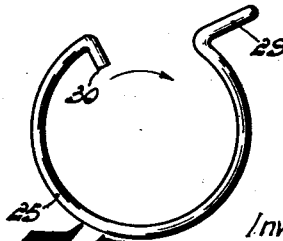
**Fig. 5.**



**Fig. 8.**



**Fig. 6.**



**Fig. 7.**

Inventors  
JOHANNES GIJSBERTUS  
WILHELM MULDER  
and  
ALFRED KUNTKE

Attorney *Charles E. Schuman*

## UNITED STATES PATENT OFFICE

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INCANDESCIBLE CATHODE DISCHARGE  
TUBE HAVING A GASEOUS FILLING

Johannes Gijbertus Wilhelm Mulder and Alfred Kuntke, Eindhoven, Netherlands, assignors, by means assignments, to N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands, a Dutch company

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In Germany May 13, 1932

13 Claims. (Cl. 250—27.5)

The present invention relates to vapor or gas-filled incandescent cathode discharge tubes and more particularly to such discharge tubes adapted to be used for very high voltages.

Incandescent cathode discharge tubes containing gas or vapor have various inherent properties which are highly advantageous in many applications, for instance, as rectifiers for the rectification of alternating current, and the adoption of such tubes for this purpose has made great progress in the last few years, especially for low and medium voltages.

However, when such tubes are to be used for very high voltages, for instance, for the rectification of voltages of 10,000 to 200,000 volts and more, various difficulties are encountered, which hitherto have only been partly overcome.

One of the difficulties of these tubes is in connection with their ignition. It has been found that such tubes, which have gas fillings of very low pressure, ignite in operation only at very high voltages, i. e. the tube only ignites close to the peak value of the operative half cycle of the alternating current, and at that, due to the influence of the wall of the discharge space, the ignition is rather irregular. In similar tubes designed for lower voltages the gas pressure is much higher and the tubes ignite at relatively low instantaneous voltage values of the operative cycle, and the above referred to irregularities in ignition are also absent.

Therefore, to avoid the difficulties encountered with the ignition, wherever such gas filled hot cathode tubes have been used for the rectification of voltages above 10,000 volts, for instance, in connection with X-ray installations, it has been the practice to sub-divide the voltage over a plurality of rectifier tubes connected in series, and to insure the right voltage distribution, suitable impedances are connected across the individual tubes.

However, a series arrangement of such individual rectifying tubes has various drawbacks. Among others, the efficiency of the installation is reduced as each tube requires its own electron-producing means (the incandescent cathode and heating current transformer therefor); furthermore, the duplication of parts, for instance, of the supporting means, renders the equipment more expensive and cumbersome.

Applicants have found that in previous high voltage gas filled incandescent cathode discharge tubes, the ignition difficulties are to a great extent due to the fact that the electric charges, which due to the high voltages and low gas pres-

ures, the glass portions of the tube may assume, exert a considerable influence on the discharge of the tube, distorting the electric field acting on the discharge and thereby increasing the ignition voltage of the tube, and rendering the ignition irregular.

According to the invention, the discharge path is altogether or at least to a large extent withdrawn from the influence of the electric charges of the tube wall, so that the effect of such charges on the ignition of the tube is altogether eliminated or at least greatly minimized.

Furthermore, the invention makes it possible to provide discharge tubes for very high voltages which have very small overall dimensions.

Gas filled incandescent cathode rectifier tubes have but a relatively small voltage drop during the operating half-cycle of the alternating current, whereas during the non-operative or inverse half-cycle they have to stand substantially the full working voltage. To withstand such high voltages without back discharge, insulation of sufficient length has to be provided between the electrodes to stand such voltages, and this applies to the main electrodes as well as auxiliary electrodes and to all metal parts within the tube or on its outside between which high voltage differences occur.

According to the present invention, one or more metal bodies forming auxiliary electrodes are so constructed and disposed that within the tube the distances between the opposite ends of adjoining metal bodies and the distances between the ends of the metal bodies and the ends of the adjoining main electrodes is quite small, while at the same time a long insulating wall portion of the tube separates these parts. For reasons hereafter set forth, such arrangement permits a much shorter construction of the tube and at the same time the danger of back discharge is eliminated.

The upper limit of the voltage which may be applied between two metal bodies without leading to a breakdown (disregarding their shape and individual variations between different gases) depends on the distance between the bodies and the pressure of the gas. According to a known law, generally referred to as the law of Paschen, the breakdown voltage is determined by the product of the distance ( $d$ ) of the bodies (electrodes) and the pressure ( $p$ ) of the gas atmosphere between same.

This product has two values, for a given value of the striking potential the difference between which decreases with the voltage. There is a

minimum value of the voltage, hereafter referred to as the minimum voltage value depending on the nature of the gas, to which belongs only one value of the product  $pd$ . Lower voltages cannot produce breakdown, whatever the distance or the gas pressure may be.

In the case of a construction in which the auxiliary electrodes form sleeves in the wall of the discharge tube, the distance between the sleeves is the same at the inner and at the outer side. The product of this distance times the pressure inside the tube must be so high that the voltage prevailing between the sleeves during the inverse half cycles does not produce a breakdown. Because the pressure is very low, for instance, of the order of .01 to .001 millimeters of mercury, the necessary distance is much higher than the distance required at the outer surface of the tube, where atmospheric pressure prevails. Thus, in the case of previous constructions where the electrode distance on the outside and the inside of the tube are the same, to prevent the possibility of back discharges the distances between the ends of the sleeves at the inside of the tube have to be much larger than the distances required at the outer surface of the tube.

In a tube according to the present invention the conditions for the inner and outer sides of the tube are different. The distances between the electrodes inside of the tube are made so small that the product of electrode distance times the gas pressure is below that value which corresponds to the minimum striking voltage according to Paschen's law. Increasing the voltage requires a reduction instead of an increase of the electrode distance and the smaller this distance, the greater the safety against breakdown. Thus, with an arrangement according to the invention, the length of the tube may be determined solely by the requirements imposed for sufficient insulation strength between the electrodes at the outer surface of the tube, which results in the possibility of making very short tubes even for very high voltages. The conditions to be satisfied in a tube according to the present invention are: the distances at the outer side of the tube should be so large that sparking over is prevented, and the distances at the inner side of the tube wall should be so small that no back ignition occurs.

However, as discharge paths may exist between portions of the adjacent metal bodies which are longer than the distance between the opposing ends of such bodies, it is also necessary to prevent such discharge paths from being sufficiently long as to cause a back discharge. Applicants' invention, as shall be more fully explained later on, limits such discharge paths within the tube to such lengths which may not give rise to such back discharge.

According to the invention, one or more metallic bodies form the auxiliary electrodes which are disposed in proper spacing between the anode and cathode and along the discharge path, and which are insulated from each other. These bodies are hollow and, for instance, of cylindrical shape, and surround the discharge path. The distances between the ends of adjacent bodies, as well as between the ends of such bodies and the adjacent insulated main electrodes are so small as to prevent a back discharge by inverse voltage. These metal bodies or auxiliary electrodes may be provided with electrical connections leading to the outside of the tube, or may be connected to metallic sleeves which form part of the tube wall,

or may be integral with such sleeves. However, the metal portions falling outside of the tube or forming part of the tube wall are at a considerably greater distance from each other or at least are separated by insulating portions of considerably greater length than is the distance between the adjacent ends of the metal bodies within the tube.

These metal bodies thus are axially disposed within the tube and sub-divide the distance between the cathode and anode, and form a series of free paths which are so short that no back discharge can take place. In the positive half cycles however the ignition takes place without trouble, due to the electron emission from the cathode and the favourable distribution of the voltage.

The inside diameter of the metal bodies or auxiliary electrodes and thus the cross-section of the discharge path is kept as small as admissible in view of the current density, but the diameter of the electrode chambers is preferably considerably larger and approximately equal to the length of the glass portions between adjacent electrodes. However, the diameter of these glass portions is limited so as to prevent the occurrence of long discharge paths between the metal bodies.

In view of such arrangement, the metal bodies shieldingly surround the discharge path, so that the discharge is not affected by the charges on the glass wall portions of the tube.

The path between adjacent ends of the bodies is of the order of 10 millimeters or less and the higher the voltage the smaller the distance or the more sub-division of the tube is required.

The invention will be more clearly described by reference to the accompanying drawing, which represents by way of example, several embodiments thereof.

Figure 1 is a schematic side view of a discharge tube according to the invention and represents a rectifier tube for the rectification of very high voltages, also showing condensers connected across the individual tube sections.

Fig. 2 is a section through part of the tube of Fig. 1.

Fig. 2a is a sectional view through a portion of a discharge tube showing a modification of the embodiment of Fig. 2.

Figs. 3, 4 and 5 are sections of portions of tubes embodying different modifications of our invention.

Fig. 6 is a section through an auxiliary electrode of a still further modification in which the auxiliary electrode proper is connected by means of a resilient ring to the respective metal sleeve forming part of the tube wall.

Fig. 7 is a perspective view of the resilient ring used in the embodiment of Fig. 6.

Fig. 8 is an enlarged side view of an incandescent oxide cathode adapted to be used in a rectifier tube according to the invention.

Referring to Fig. 1, the discharge tube there shown has a substantially cylindrical shape of comparatively small diameter and comprises on one end a cathode chamber 1, on the other end an anode chamber 2, and in between a plurality of intermediate chambers 50, three of which are shown in the device illustrated.

The walls of the cathode and anode chambers are of glass or other suitable vitreous material, and similar material is used for the wall portions of the intermediate chambers 50.

Between each of two adjoining chambers the tube wall is formed by a metallic sleeve 18, which is welded to the glass and which is of a material adapted to be air-tightly welded to the vitreous

portion of the envelope, and is preferably of chrome-iron.

Disposed within the cathode chamber is an incandescible oxide cathode 4, more fully shown in Fig. 8. The cathode consists of a helically coiled core wire 5 of a highly refractory material, having a comparatively high electrical resistance, for instance, of tungsten. Wound around the helical core wire 5 is a helically coiled auxiliary wire 6 consisting of a material which may be less refractory and which is well suited to be coated with a highly electron-emissive substance. The auxiliary wire 6 may be, for instance, nickel, and the highly electron-emitting substance 7, for instance, barium oxide.

The auxiliary wire 6 is in intimate electrical contact with the core wire 5 preferably throughout its whole length, and the core wire is connected at its two ends to suitable current lead-in wires or supports 8 and 9. The supports 8 and 9 are sealed in a pinched stem 12 and extend outwardly in known manner.

To protect the supports 8 and 9 from the impact of ions they are preferably surrounded by insulating sleeves 10 and 11 of a suitable refractory material, for instance, of alumina. The alumina sleeves 10 and 11 extend inwardly close to the joint between the core wire 5 and the supports 8 and 9, respectively, whereas on their outer end the sleeves are suitably secured in the stem 12.

Disposed within the anode chamber 2 is an anode 14, which may be of carbon or other not easily vaporizable material, or which is at least provided with a coating of such a material. The anode is supported by a lead-in wire or support 13 properly sealed in a pinched stem 15. The supply wire 13 is also preferably surrounded by an insulating sleeve 16 similar in material and function to the sleeves 10 and 11 of the cathode side. The insulating sleeve 16 may also serve as the main support for the anode and is properly secured to the stem 15.

The discharge tube is provided with a suitable gas filling as used in such tubes, for instance, a filling of a rare gas, argon, neon, etc., or a mixture thereof, or the gas filling may consist of one or more ionizable vapors or may be a mixture of one or more of such vapors with one or more gases.

If the gas filling consists of or comprises vapors, such vapors should be so selected that their pressure can be readily maintained by the presence of a small amount of the vaporizable material and may be for instance, mercury, sodium, magnesium, etc., as otherwise special measures are required for regeneration, when a considerable portion of the gas has been absorbed in operation.

If a material like magnesium is used, as a rule special heating means have to be provided, although in some cases the incandescent cathode of the tube may serve for this purpose. However, other vaporizable substances, for instance, mercury, have sufficient vapor pressure even at room temperature, and such materials are to be preferred. In the preferred form of our invention we use mercury, which at the normal operating temperature of the tube and without additional ignition means, provides for a vapor pressure of .001 to .01 millimeters.

Connected to the metal rings or sleeves 18 of the tube or forming an integral part therewith are metal bodies 3 forming the auxiliary electrode proper (see Fig. 2). The bodies 3 have the shape of a bushing, which is provided with an integral peripheral central flange 51, which is in-

tegral with or is connected to the metal sleeve 18. The inner diameter of the body 3 is kept as small as admissible in view of the current density.

It will be noted that each body 3 extends with its two ends in two adjoining chambers and that the distance between the opposing ends of adjoining bodies and between that of the two end bodies 3 and the main electrodes, is small. In operation the voltage between the main electrodes is sub-divided by these auxiliary electrodes.

For the reasons above stated, the glass portion 17 of the wall of the chamber 50 is considerably larger than is the distance "a" between the ends of two adjoining bodies 3, whereas the diameter of the chamber 50 is preferably about equal to the length of the glass wall portion 17.

The members 3 have a comparatively thick wall, the purpose of which is to further remove the discharge path from the glass wall and insure that the discharge be unaffected by the charges on the wall 17.

The tube is properly exhausted and a drop of mercury 19 is provided in the tube. The discharge space is filled with mercury vapor having a pressure which depends on the temperature of the coldest portion of the tube and which is sufficient to reliably initiate the ignition at room temperature.

The tube is preferably operated in a vertical or inclining position and in such a way that the cathode portion is at the bottom,—thereby an ascending air current is produced, which passes along the tube wall and cools the same.

Preferably, apertures 24 are provided in the flanges 51 of the members 3, so that the mercury which may condense on the colder part of the tube, can flow back into the cathode chamber.

Instead of providing the metal bodies 3 integral with the sleeves 18, the two may be formed by separate pieces. The latter form of construction has the advantage that the oxidization of the metal, which may take place when the sleeve is sealed to the glass, does not affect the members 3. If the bodies 3 are also heated to incandescence, during such sealing operation, they may be covered with an oxide layer, which during operation may gradually volatilize and deposit on the glass parts of the wall, due to which the glass parts lose their insulating capacity. This is altogether avoided if the metal sleeves are sealed in the tube independently and the bodies 3 are subsequently inserted.

A further advantage of separating the sleeve members 18, from the bodies 3 is that these parts may be made of different material. The material for the sleeves should be one which is well adapted to be hermetically sealed to glass, for instance, chrome-iron. On the other hand, chrome-iron may be moistened by mercury and when mercury is used in the discharge tube, the condensing mercury may deposit on the chrome-iron and cause back discharge. To avoid this, the bodies 3 are preferably made of a material which is not moistened by mercury, for instance, of carbon or zirconium, or they are provided with a coating of said materials; for instance, metal rings and loosely inserted carbon bushings form a very suitable combination.

To further insure the proper voltage division between the sub-divided portions of the tube, suitable impedances, preferably condensers 31 may be connected across adjacent electrodes, as is shown in Fig. 1. Instead of condensers or in addition thereto other impedances may be used for this purpose, for example resistances.

Instead of making the body 3 as a thick-walled bushing as shown in Fig. 2, it may be also formed of comparatively thin-walled material, as illustrated in Fig. 2a.

5 In Fig. 2a the body 3 is formed of two complementary cup-shaped members 3a, which on their adjacent ends are provided with outwardly bent annular flanges 52, which are welded to the ring 18. At the opposite end the members 3a are provided with inwardly bent annular rims 53, which form central apertures 54, which confine the discharge to as small diameter as permissible in view of the current density. Of course the bodies 3 of Fig. 2 may if desired instead of by two cup-shaped parts, be formed by one single bushing of thin walled material having inwardly flared rims, and being centrally fixed in a separate ring.

Various further modifications of the invention are possible. For instance, as shown in Fig. 3, the tube wall is altogether of glass and is provided with inwardly extending projections 55 to which are welded narrow metallic rings 20 supporting the body 3. The rings 20 are preferably coated with glass. The glass portion 17a extending between two projections 55 is provided with a constriction for reasons later more fully explained. In this embodiment the metal rings 20 do not form part of the outside of the tube, but may be electrically connected with leading-out wires which are hermetically sealed into the portions 55.

Fig. 4 shows a further modification in which the tube wall consists of metal sleeves 21, the inside diameter of which is kept as small as permissible in view of the current density. The ends of the sleeves 21 are laterally and outwardly bent and the glass portions 22 insulating the sleeves 21 from each other extend perpendicularly to the axis of the tube, forming disc-shaped members of comparatively large diameter thus providing for a glass portion of considerable length between opposing ends of adjacent sleeves 21. The width of the glass disc however is kept small.

45 In Fig. 5 is shown a modification of the arrangement of Fig. 4 in which the glass portion 22 is provided with a reentrant portion 23 so as to further increase the length of the insulation.

While the embodiments of Figs. 4 and 5 are satisfactory in operation, such constructions are mechanically less suitable and result in a less desirable shape of the tube than the constructions shown in Figs. 2, 2a, and 3.

As has been stated previously, a construction in which the opposing ends of the metal bodies 3 (or equivalent members) is so close as to prevent a back discharge between such ends, is not altogether sufficient to prevent the occurrence of such a back discharge. Referring, for instance, to Fig. 2, it is geometrically possible to have longer paths than "a" between portions of the body 3, which paths would be sufficiently long to cause a back discharge between such portions. That such geometrically existing path becomes an actual discharge path is, however, prevented by making the diameter of the chamber 50 sufficiently small.

The explanation hereof is the following:

Applicants have taken into account that the mere geometrical possibility of having long discharge paths which by their length would be sufficient to cause a discharge, does not necessitate that a discharge actually takes place along such a path. In fact, they have made use of the fact that, although the electrons do not generally fol-

low the lines of force during gas ionization, the discharge is initiated by electrons substantially along the lines of force existing between adjacent bodies 3.

The lines of force, on the other hand, are not determined solely by geometrical considerations, but by the shape of the bodies, the existing voltage conditions and by the fact that the lines of force mutually affect each other.

For instance, for Figs. 2, 3 and 4, the lines of force are indicated by a number of dotted lines. It will be noted that of the lines indicated in Fig. 2 the one shown in the middle represents the longest line of force which remains confined within the discharge tube, whereas the longest line of force shown is intercepted by the glass wall 17 of the tube. If the distance "a" between the opposing ends of a body 3 and the diameter of the chamber 50 are kept sufficiently small, the longest discharge path within the tube will still be below the limit at which a back discharge between the metal bodies 3 can take place. Through the path defined by the longest line of force shown, no back discharge can take place as this line is intercepted by the glass wall 17.

The same considerations hold for the construction of Fig. 3, in which to further reduce the longest line of force confined within the tube, the tube wall 17a is provided with a constriction.

Similarly in a construction as shown in Fig. 4, it will be also noted that the longer lines of force are intercepted by the glass wall 22 and what has been stated in connection with the previous figures, also applies here.

If in a tube according to Figure 1 the rings 18 and the bushings 3 form separate members, they can be interconnected by various suitable means, for instance, by screw thread, bayonet joint, by closely fitting these members into each other, etc.

A simple and very convenient method of attachment is shown in Figs. 6 and 7.

For this purpose an expansion ring 25 shown in Fig. 7 is used which lies partly in an annular groove 26 provided in the periphery of the body 3 and partly in a corresponding recess 56 of the flange 27 of the ring 18. The flange 27 is also provided with an axially extending groove 28 which engages the end 29 of the ring 25. The end 29 of the ring is bent axially and slightly outwardly. The other end of the ring 30 is secured to the conducting body 3, in such a manner that it is fixed thereto in the tangential direction; this can be conveniently achieved, for instance, by bending the end 30 of the spring 25 into an inwardly extending hook and by locking it in a corresponding hole of the body 3.

To interconnect the body 3 with the ring 18, the body 3 is pushed into the ring 18, for instance, by means of a suitable tool which engages the inner-bore of the body 3. Thereby the bent end 29 of the spring 25 is in the lead and is inserted into the axial groove 28 of the flange 27. To prevent during the insertion, the ring 25 from extending beyond the outer surface of the body 3, the body 3 is slightly twisted into the direction shown by the arrow Fig. 7 so as to tension the spring 25 and cause it to recede in the annular groove 26. When the groove 26 has been brought into opposition with the recess 56, the body 3 is twisted back, which permits the spring to snap into the recess 56 thereby fixedly securing the body 3 to the ring 18.

It has been also found advantageous to reduce the inner diameter of the conducting body on its

side directed toward the anode, as shown for instance in Fig. 6.

To illustrate the advantages obtained by our invention a numerical example will be given.

For instance, a tube as shown in Fig. 1 designed for the rectification of alternating currents of the order of 1000 milliamperes and having to stand an inverse voltage of 125 kilovolts can be made not to exceed a total overall length "l" of 35 centimeters. The distance "a" between the opposing ends of adjacent electrodes is about 7 to 8 millimeters, whereas the length of the glass portions 17 is about 40 millimeters.

The inner diameter of the bushing 3 is approximately the same as the distance between the bushings, although it may be slightly larger and in the example given is 11 millimeters. The diameter of the chamber 50 is of the same order as the length of the wall 17, but may be slightly smaller and in the example given is about 30 millimeters.

The maximum voltage prevailing between two auxiliary electrodes is 25 kilovolts.

Such a tube is particularly adapted as a high voltage rectifying valve in X-ray installations, and with a mercury vapor filling having a pressure of .05 to .0005 millimeters of mercury, the potential drop of the tube is about 40 volts and this voltage drop is but little affected by variations of the load.

Such tubes of course can also be used for various other purposes, as for instance in radio or power transmission.

It will thus appear that according to our invention the voltage drop of a high voltage discharge tube is sub-divided by intermediate electrode members, and the distance of the opposing ends of adjacent electrodes is kept so small as to prevent a back discharge and considerably (for instance three times) smaller than the insulating lengths between such adjacent metal bodies on the tube wall and at the same time longer discharge paths within the tube at which a back discharge might occur are avoided, and that the discharge is confined to a smaller diameter and shielded in such a manner that it is outside of the influence of the electric charges prevailing on the glass portions of the tube wall.

The result is that according to our invention high voltage discharge tubes can be obtained in which the ignition voltage is low, the ignition is reliable, the danger of back discharge is eliminated and the overall dimensions of the tube are exceedingly small.

While we have described our invention in connection with specific embodiments and applications, we do not wish to be limited to such embodiments and applications, but desire the appended claims to be construed as broadly as permissible in view of the prior art.

What we claim is:

1. An electric discharge tube for high voltages comprising an envelope having insulating portions, an incandescible cathode, an anode, and a gaseous filling therein, a discharge path between said cathode and anode, and hollow conducting bodies spaced from each other and disposed between the cathode and anode to surround the discharge path, said bodies having portions sealed into an insulating portion of the envelope, the distance between the opposing ends of adjacent bodies being considerably smaller than the length of the insulating portion between the opposing ends of the sealed-in portion of said bodies.

2. A gas filled electric discharge tube for high

voltages comprising a tubular envelope having insulating portions, a gaseous filling therein, conductive bodies mounted in said envelope comprising an incandescible cathode, an anode spaced apart from the cathode to form a discharge path and a hollow conducting member between said cathode and anode and surrounding the discharge path, said member being secured to an insulating portion of the envelope, the diameter of said insulating portion being substantially larger than the inside diameter of said member and the length of said insulating portion being considerably longer than the distance between the opposing ends of adjacent bodies.

3. An electric discharge tube for high voltages comprising a tubular envelope having insulating portions, an incandescible cathode, an anode, and a gaseous filling therein, a discharge path between said cathode and anode, and hollow conducting bodies spaced from each other and disposed between the cathode and anode and surrounding the discharge path, the insulating portions of the envelope between two bodies having a diameter and a length which is considerably larger than the distance between the opposing ends of the bodies, these insulating portions enclosing spaces which are sufficiently small to prevent discharge paths between adjacent bodies of sufficient length to cause a back discharge.

4. An electric discharge tube for high voltages comprising a cylindrical envelope having insulating portions, an incandescible cathode, an anode and a gaseous filling therein, a discharge path between said cathode and anode, and hollow conducting bodies disposed between said cathode and anode and surrounding the discharge path, said conducting bodies being connected to the insulating portions of said envelopes, the distance between opposing ends of said conducting bodies being considerably smaller than the length of said conducting bodies and than the length of the insulating portions between two conducting bodies.

5. An electric discharge tube comprising an envelope having a gaseous filling, an incandescible cathode and an anode, said envelope having insulating portions, a discharge path between said cathode and anode, and hollow metallic bodies of small inner diameter confining the discharge path and having supporting flanges connecting said bodies to the respective insulating portions of the envelope, the ends of the adjoining bodies being closely spaced, the inner diameter of said bodies being small compared with the diameter of the insulating portions and said bodies being centrally disposed in said insulating portions of the envelope, whereby the discharge path is outside of the influence of the field of the electrostatic charge on the insulating portions of said envelope.

6. An electric discharge tube for high voltages, comprising an envelope of insulating material, an incandescible cathode and an anode, and a gaseous filling in said tube, a plurality of conducting bodies disposed within said envelope and spaced along the discharge path between the cathode and the anode, and a plurality of metallic members, one for each body and connected thereto, said members being sealed in said envelope, the insulating portion of the envelope between ends of adjacent members being considerably longer than the distance between the opposing ends of two adjacent bodies.

7. An electric rectifier tube for voltages above 10,000 volts, comprising a partly vitreous sealed envelope, a quantity of mercury therein, an in-

- candescible cathode disposed at one end of the tube and an anode disposed at the other end of the tube, a plurality of conducting sleeve members sealed in said envelope and a plurality of metal bodies each in electrical contact with a respective sleeve, said bodies surrounding the discharge path, the distance between the ends of adjoining sleeves being at least three times as large as the distance between opposing ends of adjoining bodies.
8. A discharge tube for high voltages, comprising a vitreous tubular envelope and a gaseous filling, said envelope forming a cathode chamber at one end of the tube and an anode chamber at the other end of the tube, an incandescible cathode disposed in said cathode chamber and an anode disposed in said anode chamber, a plurality of intermediate chambers and auxiliary electrodes within said tube, each said electrode extending in two adjoining chambers, said auxiliary electrodes forming hollow cylinders of relatively small inside diameter which surround the discharge path, the opposing ends of adjoining electrodes being considerably smaller than the diameter of the envelope.
9. An electrical discharge tube for high voltages, comprising a gaseous filling, an incandescible cathode and an anode therein, and a discharge path between said cathode and anode, a plurality of conducting sleeve members of small inner diameter forming wall portions of said discharge tube, disc-shaped glass portions extending perpendicular to the axis of the discharge path and sealed to opposing ends of two adjoining sleeves, the diameter of said glass discs being greatly in excess of the diameter of the metal sleeve members and the thickness of the discs being small compared to their diameter.
10. An electrical discharge tube for high voltages, comprising an envelope, a gaseous filling, an incandescible cathode and an anode therein, and a discharge path between said cathode and anode, a plurality of metallic sleeves forming wall portions of said envelope, glass members forming part of the envelope sealed between opposing ends of two adjoining sleeves, said glass members extending perpendicularly to the discharge path and being provided with an annular reentrant portion.
11. An electric discharge tube for high voltages comprising an envelope having vitreous portions, an incandescible cathode, an anode and a gaseous filling therein, said cathode and anode being provided at the two ends of the tube, and a discharge path between said cathode and anode, a plurality of conductive hollow cylinders disposed within said tube and surrounding said discharge path, and a plurality of metallic rings, each surrounding one of said cylinders and forming part of said envelope, the length of said rings being considerably less than of said cylinders, and a resilient connecting member interconnecting said cylinders and rings.
12. An electrical discharge tube comprising an envelope having a gaseous filling, a cathode and an anode therein, said cathode and anode forming a discharge path, a plurality of tubular metallic bodies surrounding the discharge path and being disposed with their opposing ends in close proximity to each other, the inside diameter of each of said bodies being smaller at its anode end than at its cathode end, and means supporting said bodies at spaced points along the length of the envelope, each of said means comprising a ring member connecting its body to the envelope.
13. A rectifier tube for voltages of the order of 100,000 volts having a cylindrical envelope comprising a mercury vapor filling having a pressure of .0005 to .05 millimeters mercury, an incandescible oxide coated cathode and an anode, said cathode and anode being disposed close to the two ends of the tube, a plurality of metallic cylindrical bodies defining a narrow discharge path, the distance between the ends of said bodies being less than 1 centimeter and the overall length of the tube being less than 35 centimeters.
- JOHANNES GIJSBERTUS WILHELM MULDER.  
ALFRED KUNTKE.

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