Oct. 21, 1952 J. H. COLEMAN 2,615,139

GAS RECTIFIER TUBE EMPLOYING MAGNETIC FIELD

Filed May 14, 1949

Fig. 1.

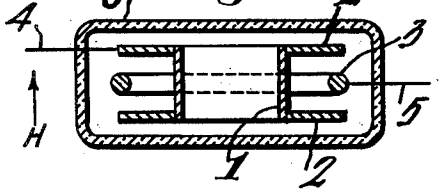


Fig. 2.

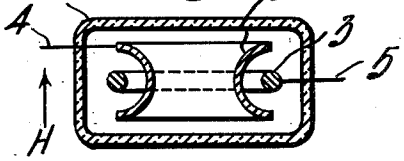


Fig. 3.

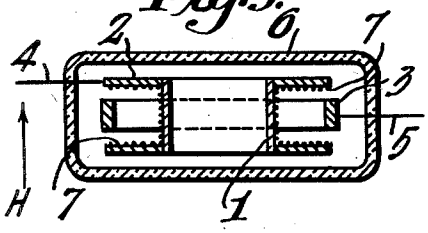


Fig. 4.

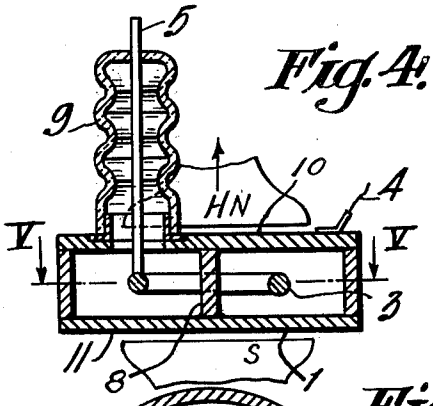


Fig. 6.

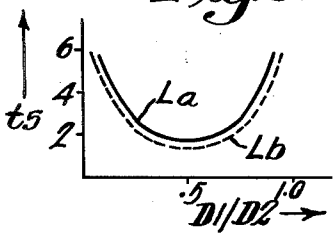


Fig. 5.

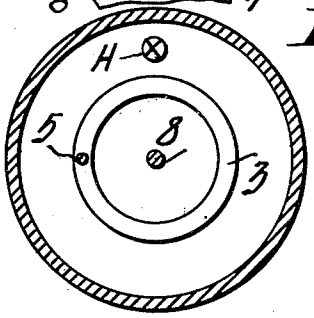


Fig. 7.

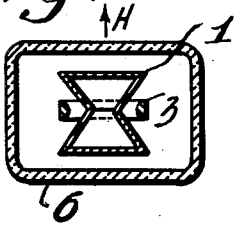


Fig. 8.

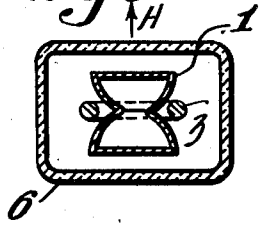


Fig. 9.

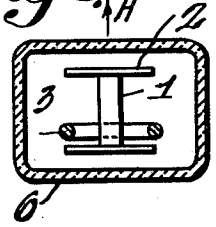
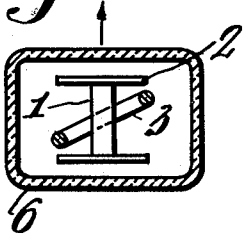


Fig. 10.



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GAS RECTIFIER TUBE EMPLOYING MAGNETIC FIELD

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18 Claims. (Cl. 313—103)

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This invention relates generally to high-voltage gas rectifiers and particularly to such rectifiers in which a magnetic field is impressed upon the medium of the tube to produce electron trapping.

In prior art gas rectifier tubes, a compromise has been made between the pressure of the medium in the tube and operating conditions with respect to voltage between the anode and the cathode and with respect to the frequencies of the currents to be rectified. In the point and plane type of gas rectifier tube it has been essential that there be a sufficient density of the gas to provide molecules for ionization, thus necessitating that the tube operate at relatively high gas pressure. Such tubes are limited to low operating frequencies because of the long diffusion time of the ions. Such tubes also have low inverse voltage ratings due to the short mean free paths between molecules of the medium which causes back-arcing even at low-operating voltages.

Another conventional prior art gas tube consists of a cathode in the form of a long cylinder which surrounds an anode consisting of a second concentric cylinder. A magnetic field is impressed axially of the tube. The inverse voltage rating of the latter tubes is so low that they have been recognized as not being suitable for operation at high voltage. Such tubes also are unsuitable for high frequency current rectification.

I have discovered that the reason for the limiting operation characteristics of such conventional types of gas rectifier tubes has been due to the structural arrangement of the elements of the tube. By reversing the relative positions of the cathode and the anode in the magnetic type tube, and by changing the form of the cathode from the long-cylinder to such a short cylinder that it approaches a modified toroid, or by changing the form of the anode from a long-cylinder to a concentrated ring positioned adjacent the cathode and by concentrating the ionization in a limited space in the medium, a magnetic gas rectifier tube will operate at low gas pressure and high frequencies and with high efficiency for rectifying heavy currents at high voltages.

In one embodiment of my invention, the cathode consists of a circular band-like cylinder with flat discs secured at each end, to form with the cylinder a circular spool. The anode is in the form of a ring and preferably is positioned midway axially of the tube between the two flanged ends of the cathode. The magnetic field is impressed coaxially with the tube axis. In a typical

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tube, as disclosed in greater detail hereinafter, no arc-back was experienced on the inverse part of the operating cycle up to 25,000 volts at frequencies of 100 kilocycles. On the useful half of the operating cycle, peak currents of 40 amperes at 2,000 volts are practicable in a tube of relatively small size.

In another embodiment of the invention, the cathode is in the form of an inner half-torus of any desired cross-section surrounded at its center point by a coaxially disposed ring anode.

In a third and preferred embodiment of the invention, the cathode comprises a hollow structure having a toroidal interior of rectangular, square, circular or elliptical or other cross-section enclosing a ring anode of desired cross-section, preferably at the center of the torus cross-section and including an aperture in the torus for a connection to the ring anode.

In all of the embodiments of the invention to be described in detail hereinafter, it is essential that the anode and cathode be so relatively spaced that electron trapping is effected without reducing the ability of the tube to withstand high inverse voltages, and wherein the relative spacing and shape of the electrodes is such as to permit satisfactory operation at relatively high operating frequencies. Also, in all of said embodiments, it is desirable that the cathode be concave facing the anode. The anode may be convex or flat facing the cathode and preferably but not necessarily positioned centrally and coaxially therewith.

The principal object of the invention is to provide a novel gas rectifier tube operable at high frequencies and at high voltages.

Another object of the invention is to provide a gas rectifier tube for high-frequency high-voltage operation with a high inverse voltage rating.

A further object is to provide a novel gas rectifier tube utilizing an applied magnetic field and employing ion trapping.

Another object of the invention is to provide a gas rectifier tube that is compact and generally flat in form and in which the ionization of the medium is concentrated in a small space due to an applied magnetic field and to the electrode conformation and arrangement.

Other objects of the invention will be apparent from the description of the invention set forth in detail hereinafter and from the drawing made a part hereof in which Figure 1 is a line sketch in cross-section of one embodiment of the invention; Figure 2 is a line sketch in cross-section

of a second embodiment of the invention; Figure 3 is a line sketch in cross-section of a modification of said second embodiment of the invention in which a secondary emission responsive material is applied to some of the surface of the cathode; Figure 4 is a cross-sectional view of a third embodiment of the invention; Figure 5 is a plan cross-sectional view taken along the section line V—V of Figure 4 of said third embodiment of the invention; Figure 6 is a plot of the relation of the starting time for conduction to the ratio of the diameter of the cathode to the diameter of the anode; and Figures 7, 8, 9 and 10 are illustrative of alternative electrode arrangements accordings to the invention.

Similar reference characters refer to similar elements of the invention throughout this specification and the drawings.

Referring to Figure 1 of the drawing, the cathode 1 comprises a short, preferably hollow, cylinder or spool, preferably of non-magnetic material. At the ends of the cathode 1 are secured discs or end plates 2, preferably of magnetic conductive material, which extend radially outwardly from the periphery of the tube.

The anode 3 may be in the form of a ring, the diameter of which is approximately the same as the diameter of the periphery of the end plates or discs 2. The anode 3 preferably is positioned coaxially with and midway the axial length of the cathode 1, and is preferably of some non-magnetic material having a smooth surface to reduce losses by field emission on the inverse part of the operating cycle. The form of the anode 3 is not limited to a ring of a circular cross-section; it may be in the form of a short, flat ring or cylinder. However, to prevent undesired electron trapping the ring cross-section should not have concave sides facing the cathode. Leads 4 and 5 from the cathode 1 and anode 3 respectively are brought out through the envelope 6 of the tube. The tube is saturated with a light gas, such as neon, mercury, or hydrogen, under pressure 10^{-3} to 10^{-5} mm. of Hg. A magnetic field is impressed upon the tube along the axis thereof, as shown by pole pieces N and S, as indicated by the arrow H. The nature of the gas will determine the conformation and relative proportions of the electrodes to permit sufficiently rapid ion diffusion before the beginning of the inverse half-cycle.

A second embodiment of the invention, illustrated in Figure 2, includes a cathode 1 in the form of the inner half of a hollow toroid, of circular, elliptical, or other cross-section, the central portion of the toroid being surrounded by a ring anode 3 having a diameter substantially equal to the largest or end diameter of the half toroid. The magnetic field is coaxial with the tube structure as indicated by the arrow H.

Figure 3 illustrates a modification of the first embodiment of the invention previously described by reference to Figure 1, wherein the outer surface of the spool-shaped cathode 1 is coated with secondary electron emissive material 7 such as aluminum. The ring anode 3 is shown as a ring of rectangular cross-section but may be of circular or other cross-section as desired.

A third embodiment of the invention, illustrated in Figures 4 and 5 of the drawing, employs a cathode 1 composed of a hollow cylindrical member 2 and a cylindrical central arm 8. The inner surfaces of the member 2 and the peripheral surface of the arm 8 define a toroidal cavity of rectangular cross-section in which a ring anode 3 of circular cross-section is centrally mounted. The hollow member 2 forms the tube envelope. The end plates 10 and 11 of member 2 preferably are of magnetic material whereby the applied field may be more readily concentrated in the trapping space. A connecting lead 5 brought out through a glass insulator 9 supports the anode ring 3 substantially at the center of the toroidal space within the cathode 1. It should be understood that the space within the cathode 1 may be of elliptical, circular, or of other cross-section instead of the rectangular cross-section illustrated.

If desired, any of the embodiments of the invention illustrated in Figures 1 through 5 may employ secondary electron emissive material as a coating on all or only a portion of the cathode structure opposite the adjacently disposed anode.

In all of the embodiments described herein, it should be understood that the anode need not necessarily be coaxial with and centrally disposed with respect to the cathode, since obviously it could be located closer to one end of the cathode than the other end, or it could be tilted with respect thereto.

In operation: It has been found that as the potential on the anode begins to become positive in relation to the cathode, at the beginning of the forward part of the cycle, there is sufficient residual ionization in the gas for free electrons to be attracted towards the anode. These electrons are trapped within the space between the electrodes under the influence of the magnetic field H until their paths are lengthened beyond the mean free path for ionization of the molecules of the medium. Upon collision of these electrons with the molecules of the medium, other electrons are freed which under the effect of electric field are attracted toward the anode, causing cumulative ionization. Likewise, the ionized molecules or ions are attracted toward the cathode and, when they strike the secondary emission responsive material on the cathode, further electrons are freed.

On the inverse part of the cycle the free electrons and the ions are swept out of the ionized space.

The operating efficiency of the tube is affected by the starting time for conduction (*ts*) after the positive voltage has been applied to the anode and by the diffusion time for the ions (*td*) which, if too long, would cause arc-backs on the inverse part of the cycle. It was found that when light gases are used as the medium of the tube, the effects of the diffusion time were negligible.

The starting time of conduction (*ts*) is affected by the geometry of the cathode and anode. It has been found that the starting time for conduction bears a direct relation to the ratio of the diameter (D1) of the cathode 1 to the diameter (D2) of the anode 2. There are plotted in Figure 6, two curves each of which show the observed relation for two tubes of different cathode lengths (L*a* (solid line) and L*b* (dotted line)). In Figure 6, the ordinates are plotted in microseconds and the abscissa for ratios of D1 to D2 from 0.0 to 1.0. It will be noted that for both values of the length of the cathode 1, the optimum starting time for conduction occurred when D1/D2 approaches 0.5.

Other geometries that affect the operation of the tube include the form of the cathodes and anodes. It is believed that trapping cut-off conditions are determined by the shortest distance

in the equatorial plane between the two electrodes.

As an example of a practical application of the invention to rectification of high frequency currents, a tube of the invention, such as disclosed in Figure 1 was placed in the circuit of a television set to rectify the output of the horizontal output transformer that supplies the kinescope with a D. C. voltage. The voltage pulses occur at a 15,700 cycles per second repetition rate with approximately 0.1 duty cycle. Oscillographs showed satisfactory rectification with negligible arc-back in a standard television receiver power supply. While the cathode has been described primarily as a band-like cylinder 1, the discs 2 actually form a part of the "cathode spool" as used in its generic or general sense.

It will thus be seen that in some embodiments a novel rectifier tube is had by forming the cathode in the shape of a short hollow cylinder with flat end discs projecting radially from the axis of the tube and the anode in the form of a ring approximately twice the diameter of the cathode, the anode being positioned midway the axial length of the cathode, the anode and cathode being mounted in a gaseous medium and subjected to a magnetic field axially the tube.

It has been found that the embodiments of the invention described by reference to Figures 1 to 3 of the drawing have the disadvantage that conductive material is more readily deposited on the high-voltage insulators thereby deteriorating the high back-voltage characteristics of the device with aging. The structure described by reference to Figures 4 and 5 of the drawing has been found under test to be substantially free of deleterious aging characteristics and to maintain relatively high inverse voltage characteristics after many hours of operation at high current and high voltage. Also due to the mechanical arrangement of the electrodes, the structure described by reference to Figures 4 and 5 provides better heat dissipation and more convenient mechanical structure from the standpoint of production. However, the structures disclosed by reference to Figures 1 to 3 may be preferred for some applications.

I claim as my invention:

1. A gas rectifier tube comprising a ring-shaped anode, a cathode having a central portion and end portions, said central portion being of smaller diameter than and extending through the anode and having an active emitter surface which faces the inside thereof, said end portions being positioned with at least a portion of said anode between them, whereby a discharge space is formed between the anode and the structure of said cathode which is concave toward said anode, an envelope enclosing at least said discharge space, and a low pressure ionizable gaseous medium within said envelope.

2. A tube according to claim 1 including means for establishing in said space a magnetic field coaxial with said cathode for providing electron trapping in said space.

3. A gas rectifier tube comprising a ring-shaped anode having inward and outward radially facing side surfaces and axially facing end surfaces, a cathode concentric with said anode and having an annular surface facing the inward facing side surface of the anode and both of its end surfaces, an envelope surrounding the space between the anode and the cathode and a low pressure gaseous medium within the envelope.

4. A tube according to claim 3 including secondary electron emissive material coating at least a portion of said cathode facing said anode.

5. A tube according to claim 3 including means for establishing in said space a magnetic field coaxial with said cathode for providing electron trapping in said space.

6. A tube according to claim 3 wherein said gaseous medium is mercury vapor in a saturated condition.

7. A gas rectifier tube comprising: a cylindraceous cathode, a disc secured to each end respectively of said cathode the outer portions of which discs extend beyond the said cathode and form with said cathode a continuous circular spool, an anode consisting of a ring the diameter of which is greater than the diameter of the cathode, the said ring being positioned midway along the axis of said cylinder, and an envelope surrounding the space between said cathode and said anode, the said envelope being filled with a low pressure gaseous medium.

8. A tube according to claim 7 including means for establishing in said space a magnetic field coaxial with said cathode for providing electron trapping in said space.

9. A gas rectifier tube comprising: a cathode consisting of a continuous narrow band of non-magnetic metal having the form of a short cylinder, a disc of non-magnetic material secured to each end respectively of said cylinder the outer portions of which discs extend beyond the said cylinder and form with said cylinder a continuous circular spool, an anode consisting of a ring of non-magnetic material the diameter of which is substantially that of the outer rims of said discs, the said ring being positioned midway along the axis of said cylinder, and an envelope surrounding the space between said cathode and said anode, the said envelope being filled with an ionizable gaseous medium at a pressure of the order of 10^{-3} to 10^{-5} mm. of Hg.

10. A gas rectifier tube comprising: a cathode consisting of a continuous band of metal having the form of a cylinder, a disc secured to each end respectively of said cylinder the outer portions of which discs extend beyond the said cylinder and form with said cylinder a continuous circular spool, an anode consisting of a ring the diameter of which is substantially that of the outer rims of said discs, the said ring being positioned midway along the axis of said cylinder, and an envelope surrounding the space between said cathode and said anode, the said envelope being filled with a light ionizable gaseous medium.

11. A gas rectifier tube comprising: a cathode consisting of a continuous band of metal having the form of a cylinder, a disc secured to each end respectively of said cylinder the outer portions of which discs extend beyond the said cylinder and form with said cylinder a continuous circular spool, a secondary emission responsive material lining said spool, an anode consisting of a ring the diameter of which is substantially that of the outer rims of said discs, the said ring being positioned midway along and coaxial with the axis of said cylinder, and an envelope surrounding the space between said cathode and said anode, the said envelope being filled with an ionizable low pressure gaseous medium.

12. A gas rectifier tube comprising: a cathode consisting of a continuous band of metal having the form of a cylinder, a disc secured to each end respectively of said cylinder the outer portions of which discs extend beyond the said cylinder and form with said cylinder a continuous

circular groove, an anode consisting of a ring the diameter of which is substantially that of the outer rims of said discs, the said ring being positioned midway along and coaxial with the axis of said cylinder, and the diameter of which ring is substantially twice that of said cylinder, and an envelope surrounding the space between said cathode and said anode, the said envelope being filled with an ionizable gaseous medium.

13. A gas rectifier tube comprising: a cathode having a shape like the inner half of a hollow toroid, such as would be generated by rotation about a central axis of a semicircle which is concave away from said axis, whereby said cathode includes a continuous outwardly-facing circular groove, an anode consisting of a ring the diameter of which is substantially that of the outer rims of said groove, the said ring being positioned midway between said rims and coaxial therewith, and an envelope surrounding the space between said cathode and said anode, the said envelope being filled with an ionizable gaseous medium.

14. A gas rectifier tube comprising a hollow cylindrical cathode of non-magnetic conductive material forming a gas tight enclosure, a ring-shaped anode electrode supported within the space within said hollow cathode and concentric therewith, and an ionizable gas at low pressure confined within said space.

15. A tube according to claim 14 including means for establishing in said space a magnetic field coaxial with said cathode for providing electron trapping in said space.

16. A tube according to claim 14 wherein the space within the hollow cathode has rectangular cross-sections in axial planes.

17. A gas rectifier tube, comprising a hollow cathode forming a gas tight enclosure, said cathode comprising an elongated rod, a pair of discs one connected to each end of said rod and extending beyond the same, means joining the ends of said discs in gas tight relation; a ring shaped anode within said hollow cathode and surrounding said rod, and a support for said anode sealed through said cathode and insulated therefrom.

18. A gas rectifier tube, comprising a hollow cathode forming a gas tight enclosure, said cathode including a pair of spaced apart discs and a conductive member extending between said discs and connected thereto, said conductive member being substantially centrally located with respect to the edges of said discs, a ring shaped anode electrode within the space within said hollow cathode and a lead-in support member connected to said anode and sealed through one of said discs and insulated therefrom.

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