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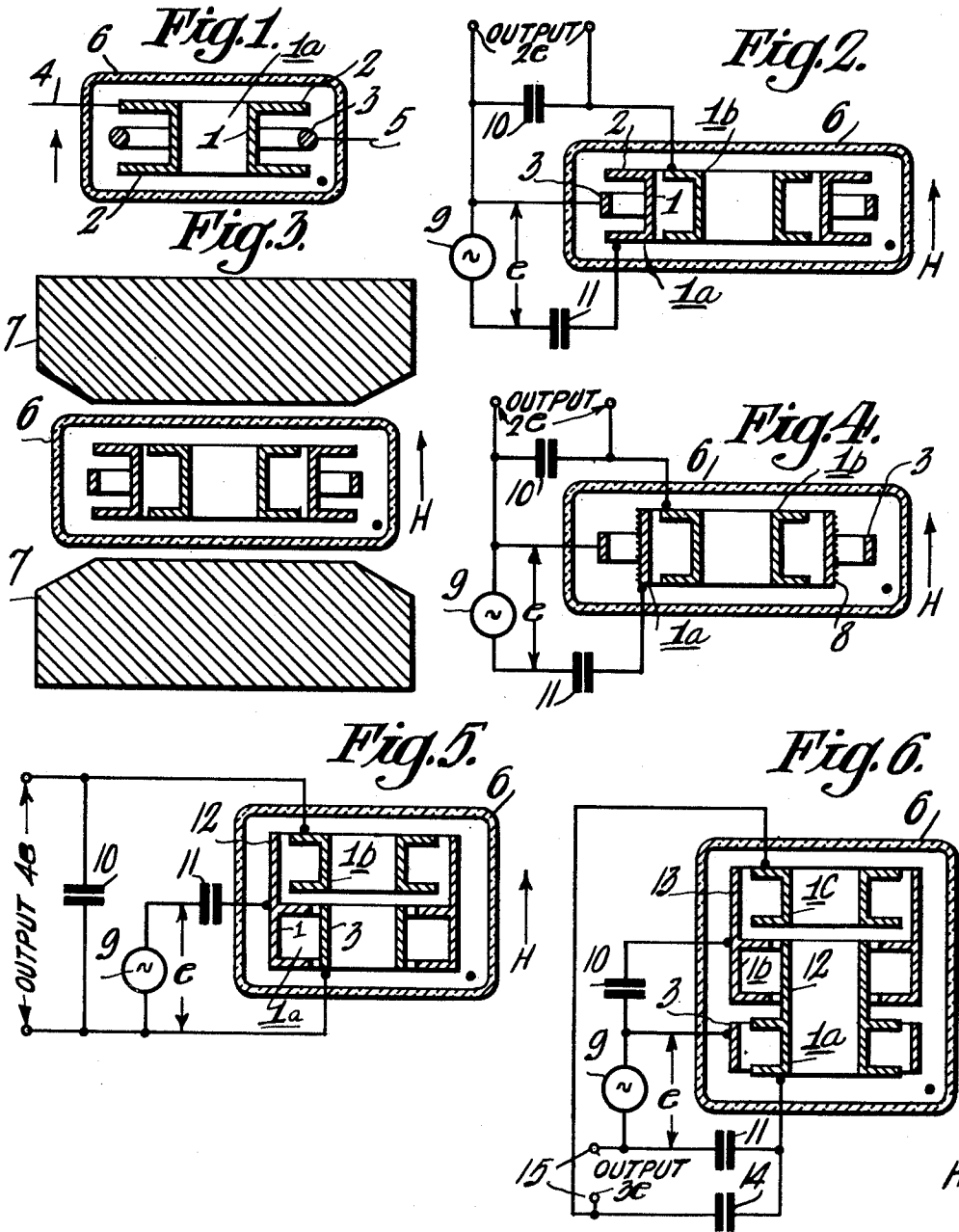
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MAGNETIC CONTROLLED GAS RECTIFIER TUBE

Filed June 30, 1949.

2 SHEETS—SHEET 1



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2 SHEETS--SHEET 2

Fig. 7.

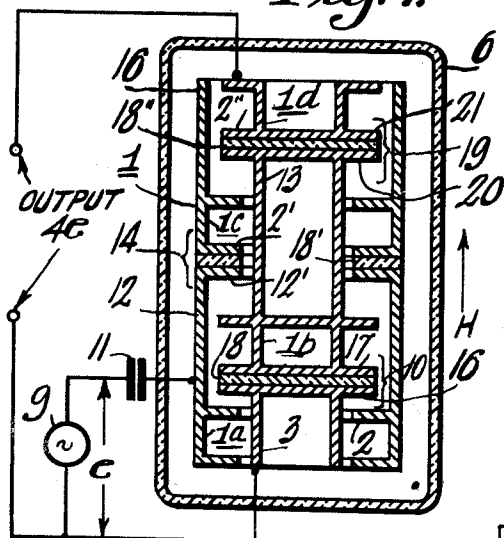


Fig. 8.

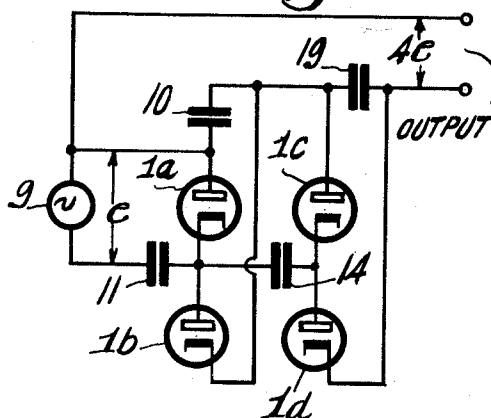
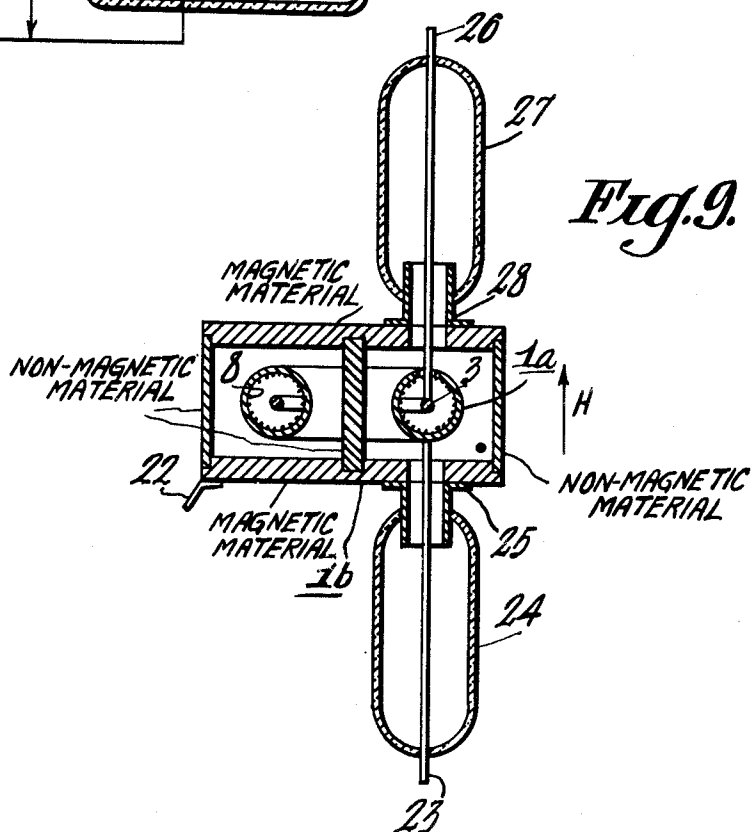


Fig. 9.



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27 Claims. (Cl. 313-162)

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This invention relates generally to multidiodes and particularly to such multidiodes that operate on the magnetic gas principle.

In my copending application Serial No. 93,324, entitled Gas Rectifier Tube Employing Magnetic Field, and filed on May 14, 1949, there is disclosed and claimed a magnetic gas rectifier tube which depends for its operation on the trapping of electrons within a confined space under the influence of a magnetic field.

The present invention extends the basic invention disclosed in said application into the field of multidiodes in which field the construction of the basic tube lends itself particularly to the voltage multiplier art in that one element of the tube is made to perform two functions, namely that of being an anode and a cathode. This permits the reduction in the number of tubes in such systems and thus a reduction in the number of electrical connections both within and outside the tubes.

Moreover, the basic tube is not limited in application simply to a voltage doubler, but it may be applied to voltage triplers and voltage quadruplers with the additional advantages that it is now possible to have the elements in such forms and separated by dielectrics forming capacitors within the tube, thus reducing the number of capacitors required in the circuits outside the tube.

Furthermore, the tubes of my invention do not require heating. This eliminates insulation problems of the heater windings usually energized by coils coupled to a high voltage transformer, such as in a television apparatus.

The total required magnetic flux is substantially reduced in the compound tube of the instant invention since the same field is, in effect, simultaneously applied to all of the tube elements, thereby obviating the necessity for separate magnetic fields for a plurality of separate tubes in a voltage multiplier network.

In the said copending application the electrodes are disclosed in such constructions and arrangements that with a magnetic field impressed upon the medium of the tube, the starting times for conduction and the diffusion times for the ions are such that heavy high frequency currents at high voltages may be rectified with negligible conduction on the inverse part of the operating cycles.

The principal object of the present invention is to provide a more simple multi-element tube in which a less number of elements are used than have previously been required.

Another object of the invention is to provide an improved tube in which an element of the tube performs the functions of both an anode and a cathode.

Another object of the invention is to provide

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an improved multi-stage voltage multiplier in which elements in one stage perform a function in a succeeding stage.

Another object of the invention is to provide an improved single tube multi-stage voltage multiplier in which dielectric materials are used to separate certain elements within the tube and thus provide capacitors within the structure of the tube that otherwise would require additional outside connections therefor.

A further object of the invention is to minimize the total required magnetic flux in a multi-tube voltage multiplying rectifier network employing magnetically biased gaseous tube components.

Other objects of the invention will be apparent from the description of the invention as set forth in detail in this specification and from the drawings made a part hereof in which:

Figure 1 is a line sketch of the rectifier tube disclosed and claimed in the referenced application;

Figure 2 is a line sketch in cross-section of a double diode;

Figure 3 is a sketch in cross-section of a typical tube according to the invention in combination with a pair of magnet poles providing a concentration of the magnetic field in the axes thereof;

Figure 4 is a line sketch in cross-section of a modified form of a double diode tube in which the inner cathode is in the form of a spool, the anode-cathode in the form of short cylinders one of which is electron emissive due to heating by bombardment of the other, and the outer anode in the form of a short cylinder;

Figure 5 is a line sketch in cross-section of a double diode tube the elements within the tube making up the individual diodes being displaced along the axis of the tube;

Figure 6 is triple multiplier similar to the arrangements shown in Figure 5;

Figure 7 is a quadruple multiplier similar to the arrangements shown in Figure 5, but with dielectric material between certain elements to form capacitors otherwise required in the circuits outside the tube;

Figure 8 is a schematic circuit diagram corresponding to the system of Figure 7; and

Figure 9 is an elevational cross-sectional view of a preferred embodiment of a voltage doubler tube according to the invention. Similar reference characters are applied to similar elements throughout the drawing.

Referring to Figure 1, numeral 1a represents the cathode of the tube comprising the basic diode structure disclosed in said application, which consists of a circular band or short cylinder 1 and flat discs 2 attached at the ends of the band and extending outward to form a rectangular cross-section, spool or U-shaped grooved or concave ring. In the horizontal axis of cathode

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1a is positioned anode 3, which is shown as a ring. Terminal leads 4 and 5 are connected to cathode 1a and anode 3, respectively, and pass through the ionizable gas filled envelope 6 of the tube.

It is, of course, understood that the shape of the electrodes are not limited to those shown in the drawings. A number of typical structures are disclosed in said copending application. For example, the cathode may be the inner half of a generated toroid and the anode may be in the form of a circular, flat, or other cross-section, band or ring.

In operation: When a positive voltage is applied to the anode in relation to the cathode, the free residual electrons in the tube are attracted to the anode. When a magnetic field H is applied to the medium of the tube, the electrons are trapped within the space between the cathode and the anode and the lengths of their paths are extended beyond the mean free path for collision of the molecules of the medium thereby causing cumulative ionization of the medium and the tube becomes conductive. When the polarity of the electrodes are reversed, as when an alternating voltage is applied to the tube, the electron trapping ceases and the electrons are swept out of the space.

Referring to Figure 2, there is disclosed therein a double diode enclosed within the ionizable gas-filled envelope 6 which consists of the ring anode 3 and concave ring cathode 1a and a second concave ring cathode 1b mounted concentrically within cathode 1a and similar in construction thereto. In this arrangement the inward side of 1a acts as the anode to the concave inner cathode 1b.

The operation of each of the two diodes is the same as previously described. However, as the radii of the elements of the inner diode are less than the radii of the outer diode, the intensity of the magnetic field H should be increased in the space occupied by the inner diode. This may be accomplished by shaping the poles of the magnet as indicated at 7 in Figure 3.

In Figure 4 is shown a modification of the double diode of Figure 2, in which the intermediate cathode-anode 1a consists of the band 1, having a cathode electron-emissive coating 8 deposited on the outer surface thereof. The device will operate without an auxiliary heater when the diode is allowed to conduct for a sufficient time to obtain thermionic electrons.

As a practical application of the device, there is shown in Figures 2 and 4 the circuits of a voltage multiplier. One terminal of the alternating voltage source 9 is connected to anode 3 and to the concave inner cathode 1b through a capacitor 10. The other terminal of the source 9 is connected to cathode 1a through capacitor 11. The voltage across capacitor 10 is twice that of the source 9, as is well known in the diode multiplier art described, for example, in *Radio Engineers' Handbook* by F. E. Terman (1943), at pages 592-593.

It has been found that the electrodes, as disclosed, may be reversed in their relative physical positions in the tube, that is, the band anode 3 may be placed within the intermediate cathode-anode 1a. The invention therefore is readily adaptable to the vertical axial displacement of the elements within the tube. Figures 5, 6 and 7 show such axially displaced elements.

In Figure 5, the base or bottom of the groove 1 of concave cathode 1a is extended vertically axially of the tube forming a band portion 12

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which becomes the anode for concave cathode 1b. A band anode 3 is positioned inside cathode 1a. In Figure 6, a triple voltage multiplier tube is shown in which the base of concave cathode 1a is extended to form a band 12 which becomes the anode of concave cathode 1b, the base of cathode 1b is extended to form a band 13 which becomes the anode of a third concave cathode 1c, and a band anode 3 surrounds cathode 1a. The connections to anode 3, cathodes 1a and 1b are the same as shown in Figure 5 with the addition of a capacitor 14 connected between cathodes 1a and 1c. The voltage across capacitors 10 and 14 is twice the voltage across source 9 and the voltage across the terminals 15, connected to source 9 and capacitor 14 is three times the voltage across the source 9.

Figures 7 and 8 comprise a voltage quadrupler multiplier tube network wherein three of the four required capacitors are within the envelope of the tube. One end of the band anode 3 is covered over by plate 16 which forms one electrode of the capacitor 10. The other electrode of the capacitor 10 is a plate 17 covering one end of cathode 1b. A high dielectric constant material 18 capable of withstanding suitably high voltage may be located between the plates 16, 17 to increase the capacitance therebetween.

The anode band 12 is bent inwardly and extended as shown, to form one electrode 12' of the capacitor 14, the other electrode of which is the disc 2' of cathode 1c. The band 1 of cathode 1c is extended to form the band 16 which acts as the anode for cathode 1d. Cathode 1d is capacitively coupled to band 13 of cathode 1b by the internal capacitor 19, one electrode of which is plate 20 covering the end of and a part of band 13. The other electrode of capacitor 19 is plate 21 which is the inner extension of disc 2' of cathode 1d. It is obvious that when a voltage is applied from source 9, the voltage between that source and the cathode 1d will be four times the voltage of source 9. Dielectric material 18', 18'' may be utilized in capacitors 14 and 19 to increase the capacitance thereof.

A preferred modification of the embodiment of the invention described heretofore by reference to Figures 2 and 4 is shown in Figure 9. This modification comprises a hollow rectangular or other cross-section toroid forming the outer cathode 1b and completely enclosing the other diode elements 1a and 3. A terminal 22 connected to the external surface of the toroidal cathode 1b is provided. The intermediate cathode-anode 1a comprises a smaller, circular or other cross-section toroid supported centrally within the rectangular cross-section toroidal cavity of the cathode 1b by a terminal 23 which is in turn supported by a glass insulator 24 sealed into the lower surface of the toroidal cathode element 1b by a Kovar eyelet 25. If desired, the inner surface of the intermediate cathode-anode 1a may include a coating 8 of electron emissive material. The anode 3 of the inner diode, which includes the inner surface of the intermediate toroid 1a, comprises a metallic ring which is supported by a terminal 26 which in turn is supported by a glass insulator 27 sealed into the upper surface of the outer toroidal cathode 1b by a Kovar eyelet 28. The apertures in the outer toroidal cathode 1b adjacent the Kovar eyelets 25 and 28, and in the upper surface of the cath-anode 1a, should be sufficiently large to provide the desired voltage breakdown characteristics for the terminals 23 and 25 passing

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therethrough. The toroids are filled with an ionizable gas, preferably in a saturated condition.

There is thus disclosed a magnetic multidiode which consists of a plurality of elements so arranged that one element acts as a cathode for an anode and an anode for a succeeding cathode thus reducing the number of elements required in the tube and thereby reducing the connections necessary to the elements within the tube and the connections necessary to pass through the envelope of the tube. The construction and arrangement of elements also permit parts of elements to form plates of capacitors and thus further decrease the connections required in circuits involving the use of a plurality of diodes and condensers, such as for example, in voltage multipliers. It further reduces the total magnetic flux required for controlling the ion paths within the several magnetic tube elements of the system.

What I claim is:

1. A magnetic gas rectifier tube comprising a first cathode having a concave active surface, a first anode in operative relation with said cathode and forming therewith a first diode element, said first anode having a portion providing a second cathode, a second anode in operable relation with said second cathode forming with said second cathode a second diode element, and means providing an envelope enclosing the space surrounding said anodes and cathodes, said envelope being filled with a low pressure ionizable gaseous medium.

2. Apparatus according to claim 1 including means for applying a common axial magnetic field to said diode elements.

3. A magnetic gas rectifier tube comprising a first cylindraceous cathode having a concave active surface, a first anode in operative relation to and coaxial with said cathode and forming therewith a first diode element, said first anode having a portion providing a second cathode, a second anode in operable relation and coaxial with second cathode forming with said second cathode a second diode element, and means providing an envelope enclosing the space surrounding said anodes and cathodes, said envelope being filled with a low pressure ionizable gaseous medium.

4. A magnetic gas rectifier tube comprising a first cylindraceous cathode having a concave active surface, a first anode in operative relation to and coaxial with said cathode and forming therewith a first diode element, said first anode having a portion substantially isolated from electron bombardment from said first cathode, said portion providing a second cathode, a second anode in operable relation and coaxial with said second cathode forming with said second cathode a second diode element, means providing an envelope enclosing the space surrounding said anodes and cathodes, said envelope being filled with a low pressure ionizable gaseous medium, and means for providing an axial magnetic field for said diode elements.

5. A magnetic multidiode comprising: an envelope containing a low pressure ionizable gaseous medium and enclosing a first anode consisting of a ring-like electrode mounted in the horizontal axis of said envelope, a first cathode consisting of a circular band electrode concentric with said first anode, and a second cathode consisting of a circular band electrode concentric with said first cathode, the said first cathode being the anode to said second cathode.

6. A magnetic multidiode comprising: an en-

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velope containing a low pressure ionizable gaseous medium and enclosing a first anode consisting of a ring-like electrode mounted in the horizontal axis of said envelope, a first cathode consisting of a circular band electrode concentric with said first anode, and a second cathode consisting of a circular band electrode concentric with said first cathode, the said first cathode being the anode to said second cathode, the diameter of said first cathode being approximately half that of said first anode.

7. A magnetic multidiode comprising: an envelope containing a low pressure ionizable gaseous medium and enclosing a first anode consisting of a ring-like electrode mounted in the horizontal axis of said envelope, a first cathode consisting of a circular band electrode concentric with said first anode, and a second cathode consisting of a circular band electrode concentric with said first cathode, the said first cathode being the anode to said second cathode, the diameter of said first cathode being approximately half that of said first anode, and the diameter of said second cathode being approximately half that of said first cathode.

8. A magnetic multidiode comprising: an envelope containing a low pressure ionizable gaseous medium and enclosing a first anode consisting of a ring-like electrode mounted in the horizontal axis of said envelope, a first cathode consisting of a circular band electrode concentric with said first anode, and having flat horizontal discs attached thereto forming with said band a concave ring, and a second cathode consisting of a circular band electrode concentric with said first cathode, and having flat horizontal discs attached thereto forming with said band a concave ring, the said band of said first cathode being the anode to said second cathode.

9. A magnetic multidiode comprising: an envelope containing a low pressure ionizable gaseous medium and enclosing a first anode consisting of a ring-like electrode mounted in the horizontal axis of said envelope, a first cathode consisting of a circular band electrode concentric with said first anode, and having flat horizontal discs attached thereto and extending toward said first anode forming with said band a concave ring, and a second cathode consisting of a circular band electrode concentric with said first cathode, and having flat horizontal discs attached thereto and extending toward said first anode forming with said band a concave ring, the said band of said first cathode being the anode to said second cathode.

10. A magnetic multidiode comprising: an envelope containing a low pressure ionizable gaseous medium and enclosing a first anode consisting of a ring-like electrode mounted in the horizontal axis of said envelope, a first cathode consisting of a circular band electrode concentric with and inside said first anode and having flat horizontal discs attached thereto forming with said band a concave ring, and a second cathode consisting of a circular band electrode concentric with and inside said first cathode, and having flat horizontal discs attached thereto forming with said band a concave ring, the said band of said first cathode being the anode to said second cathode.

11. A magnetic multidiode comprising: an envelope containing a low pressure ionizable gaseous medium and enclosing a ring-like anode mounted in the horizontal axis of said envelope, a first band ring cathode concentric with said

first anode, a concave ring second cathode concentric with said first cathode, the said first cathode being the anode to said second cathode.

12. A magnetic multidiode comprising: an envelope containing a low pressure ionizable gaseous medium and enclosing a ring-like anode mounted in the horizontal axis of said envelope, a first band ring cathode concentric with and inside said first anode, a concave ring second cathode concentric with and inside said first cathode, the said first cathode being the anode to said second cathode.

13. A magnetic multidiode comprising: an envelope containing a low pressure ionizable gaseous medium and enclosing a ring-like anode mounted in the horizontal axis of said envelope, a first concave ring cathode concentric with said anode, the concavity of said ring being perpendicular to the vertical axis of said envelope, and a second concave ring cathode concentric with said first cathode, the said first cathode being the anode to said second cathode.

14. A magnetic multidiode comprising: an envelope containing a low pressure ionizable gaseous medium and enclosing a ring-like anode mounted in the horizontal axis of said envelope, a first grooved ring cathode concentric with said anode, the bottom of said groove being parallel to the vertical axis of said envelope, the said bottom being extended beyond one of the sides of said groove, and a second grooved ring cathode concentric with said extended bottom, the said extended bottom being the anode to said second cathode.

15. A magnetic multidiode comprising: an envelope containing a low pressure ionizable gaseous medium and enclosing a ring-like anode mounted in the horizontal axis of said envelope, a first grooved ring cathode concentric with and outside said anode, the bottom of said groove being parallel to the vertical axis of said envelope, the said bottom being extended beyond one of the sides of said groove, and a second grooved ring cathode concentric with and inside said extended bottom, the said extended bottom being the anode to said second cathode.

16. In a magnetic multidiode: an envelope containing a low pressure ionizable gaseous medium and enclosing a plurality of grooved ring members, the base of the groove of each member being extended beyond one side of said groove, the said members being positioned in said envelope with the said bases and said extensions thereof being parallel to the vertical axis of said tube and in such relation to each other that the concave side of said groove of one member faces the base extension of another of said members.

17. The structure set forth in claim 16 wherein some of the members have juxtaposed surfaces forming capacitors therebetween.

18. In a magnetic multidiode: an envelope containing a low pressure ionizable gaseous medium and enclosing a plurality of grooved ring members, the base of the groove of each member being extended beyond one side of said groove, the said members being positioned in said envelope with the said bases and said extensions thereof being parallel to the vertical axis of said tube and in such relation to each other that the concave side of said groove of one member faces the base extension of another of said members, a circular electrode concentric with the groove of one of said members, and a grooved electrode concentric with the extended base of one of said members.

19. The structure set forth in claim 18 wherein one end of said circular electrode is covered by a plate and one side of said grooved electrode is extended to form a plate, the members and the circular electrode and the grooved electrode having juxtaposed surfaces forming a plurality of capacitors.

20. The structure set forth in claim 18 wherein one end of said circular electrode is covered by a plate, one side of said grooved electrode is extended to form a plate, and plates connected to the extended base of at least one of said members, some of the said electrodes and said members having juxtaposed surfaces forming a plurality of capacitors.

21. A gas rectifier tube according to claim 1, wherein some of the electrodes have juxtaposed surfaces forming a plurality of capacitors.

22. A gas rectifier tube according to claim 1, wherein some of the electrodes have juxtaposed surfaces forming at least one capacitor.

23. Apparatus according to claim 17 wherein said diodes and the capacitors provided therebetween are arranged to provide a voltage multiplying network, means for applying alternating potentials to said network, and means for deriving multiplied rectified potentials from said network.

24. A magnetic gas rectifier tube comprising a toroidal envelope filled with a low pressure ionizable gas and providing a first cathode having a concave inner active surface, a toroidal first anode supported within and in operative relation with said first cathode and forming therewith a first diode element, the inner surface of said first anode providing a second cathode, a ring second anode supported within and in operable relation with said second cathode forming with said second cathode a second diode element, and connections through said envelope to said inner anode electrodes.

25. Apparatus according to claim 24 including means for applying a common axial magnetic field to said diode elements.

26. A magnetic gas rectifier tube comprising a toroidal envelope of rectangular cross-section filled with a low pressure ionizable gas and providing a first cathode having a concave inner active surface, a circular cross-section toroidal first anode supported within and in operative relation with said first cathode and forming therewith a first diode element, the inner surface of said first anode providing a second cathode, a ring second anode supported within and in operable relation with said second cathode forming with said second cathode a second diode element, and connections through said envelope to said inner anode electrodes, said connections being insulatedly supported by said envelope and providing supports for said anode electrodes.

27. Apparatus according to claim 26 including means for applying a common axial magnetic field to said diode elements.

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