Feb. 8, 1927. 1,617,175

C. G. SMITH

ELECTRICAL APPARATUS

Filed April 25, 1921

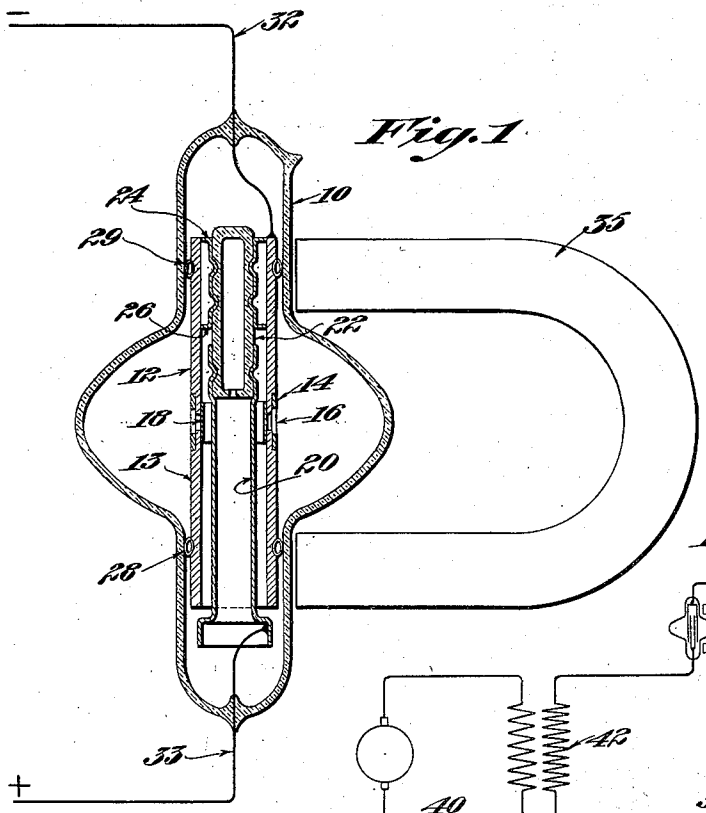

Fig. 1

Fig. 2

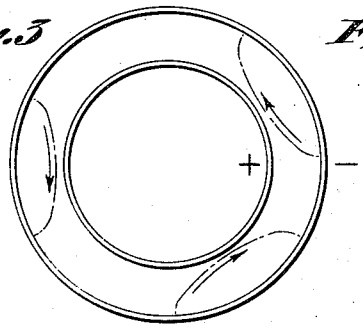

Fig. 3

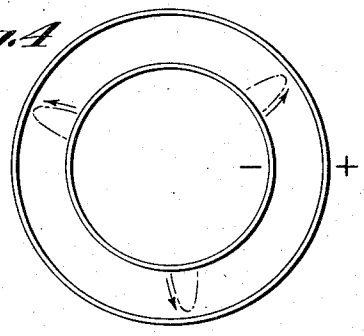

Fig. 4

Witness

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ELECTRICAL APPARATUS.

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The present invention relates to electrical apparatus and more particularly to apparatus of the type disclosed in the copending applications of Smith, Serial No. 415,536, filed October 8, 1920, and Serial No. 418,263, filed October 20, 1920.

As disclosed in the applications above referred to, it is possible to design and locate electrodes immersed in a gas in such a manner that gaseous conduction due to ionization of the gas may not take place even at high potential differences. This normal insulating state, however, may be changed to a conducting state by introducing a magnetic field in the space separating the electrodes. If the electrodes are in the form of cylinders immersed in a gas with a radial electric field between the cylinders and a magnetic field substantially parallel to the axes of the cylinders, then for a certain range of magnetic field strength the tube will freely conduct with the outer cylinder at a negative potential but will insulate against high potential differences when the inner cylinder is at a negative potential. It will be obvious to those skilled in the art that this form of tube is thus adapted for the rectification of alternating currents.

It has been discovered that the employment of a non-uniform or space varying magnetic field in a tube of this character having cylindrical electrodes positioned with their axes coincident markedly increases the rectifying properties of the tube and permits rectification to take place over a considerable range of magnetic field strength and a great range of gas pressures within the tube. Such a tube may be caused to rectify alternating currents with either the inner or outer electrodes negative providing that the magnetic field is non-uniform and strongest adjacent the negative electrode. In the preferred embodiment of the invention the tube is provided with concentric cylindrical electrodes and a space varying magnetic field with its strongest portion adjacent the outer electrode and its weakest portion adjacent the inner electrode. This type of tube will rectify with permissible variations of magnetic field strength and gas pressure approximating ten to one.

In its broadest conception the invention contemplates the employment of a non-uniform field introduced between any two electrode surfaces immersed in a gas and separated a distance apart approximating the order of magnitude of the mean free path of electrons in such a gas whether the electrode surfaces be plane or curved.

The theory underlying the action of such a tube is believed to be substantially as follows: In an apparatus of this character the separation of the active surfaces of the electrodes approximates the order of magnitude of the mean free path of the electrons, this path varying in accordance with the character of the gas employed and the pressure to which this gas is subjected. The employment of a magnetic field which is strongest at the outer cylindrical electrode and weakest at the inner electrode substantially lengthens the path of electrons leaving the outer electrode when the latter acts as a cathode and shortens and constricts the path of electrons leaving the inner electrode when this latter electrode is acting as a cathode. In this manner the paths of electrons leaving the outer cylinder are sufficiently lengthened to insure cumulative ionization and consequent gaseous conduction and, on the other hand, the paths of electrons leaving the cathode when the inner cylinder is negative are not sufficiently long to produce cumulative ionization and gaseous conduction in the opposite direction.

In the accompanying drawings illustrating the preferred form of the invention Fig. 1 represents a sectional elevation of a tube embodying the features of the invention; Fig. 2 is a simple circuit embodying the tube; and Figs. 3 and 4 are partially diagrammatic views illustrating the approximate path which it is believed the electrons follow when the tube is employed as a rectifier.

Referring to the illustrated embodiment of the invention it will be observed that the bulb or tube 10 contains steel cylinders 12 and 13 separated by a small air gap and connected together by a sleeve 14 of copper or other non-magnetic material having heat radiation openings 16 formed therein. The outer electrode comprises a short tube of molybdenum or other suitable electrode material gripped within the cylinders 12 and 13, as indicated, opposite the openings 16.

The inner electrode comprises a copper tube 20 which may be spun onto a piece 22 of silica glass which is in turn held in proper relation to the steel cylinder 12 by a copper spacing member 24 spun thereon and provided with annular flanges 26. The steel cylinders are retained within the opposite reduced ends of the bulb 10 by flexible holding rings 28 and 29. The inner and outer electrodes are respectively connected with leads 32 and 33 passing out of opposite ends of the tube, the lead 32 being connected to one end of the cylinder 12 and the lead 33 being connected within the enlarged mouth formed in the lower end of the inner electrode 20. The tube may be connected into appropriate form of circuit where it may be desired for example to rectify an alternating current of five hundred volts or more.

The magnetic field parallel to the axes of the electrodes may be conveniently introduced by a permanent magnet 35 positioned approximately as shown and operating in conjunction with the cylinders 12 and 13 of magnetic material to introduce a non-uniform magnetic field in the space separating the electrodes 18 and 20, this field being weakest adjacent the surface of the inner electrode 20 and becoming progressively stronger as the outer electrode is approached. Upon referrig to Fig. 2 a simple form of circuit embodying the tube as a rectifier is shown, this circuit conveniently comprising an input circuit indicated at 40 capable of delivering alternating current to the primary of a step-up transformer 42, the secondary of which is embodied in an output circuit containing the tube which rectifies the high voltage alternating current delivered thereto. This output circuit may be connected with any desired form of load circuit (not shown) to utilize the high voltage current so rectified.

Upon referring to Figs. 3 and 4 it will be observed that the electrons leaving the outer or negative terminal start in a region of strong magnetic field and their path is accordingly bent or curved quite rapidly. As they continue to move toward the inner electrode or anode, however, they pass into a region of less magnetic field and their path becomes straighter until it is substantially parallel to the plane of the anode, after which the electron moves over a comparatively long flat topped path adjacent the anode, which form of path is ideal for producing positive ions near the anode which drop to the cathode. On the other hand, with the same character of magnetic field and with the inner electrode negative, electrons leaving the cathode start off in a straight path toward the anode or outer electrode and then pass into a region of progressively stronger field where the electron is shortly bent back in a sharp curve and caused to return to the inner electrode or cathode from whence it started. Owing to the comparatively short distance which these electrons travel with respect to the length of travel of the electrons leaving the outer electrode it is a relatively simple matter to cause rectification over a wide range of pressures where the magnetic field is varying in space and strongest adjacent the outer electrode. As a matter of actual fact it has been observed that tubes of this character rectify successfully with gas pressures ranging from three-tenths of a millimeter to two-thousandths of a millimeter.

It should be understood by those skilled in the art that the characteristic properties of a magnetic field having its strongest portion adjacent one electrode and becoming progressively weaker as the opposite electrode is approached are capable of embodiment in a wide range of constructions employing cooperating electrodes immersed in a gas, this type of magnetic field causing a tube to conduct when the electrode in the region of strongest magnetic field acts as a cathode and to insulate when the electrode in the region of weakest magnetic field is acting as a cathode.

In a generic sense, the term "hollow cathode" includes a cathode whose active surface only partially surrounds a gaseous medium so that the medium immediately adjacent the active surface is more or less pocketed or confined.

A feature of the invention consists in that the field is stronger near the inner concave surface of cathode 13 than adjacent the outer convex surface of the anode 20.

I claim—

1. Gaseous conduction apparatus comprising a hollow cathode, an anode presented to the interior of the hollow cathode, means for creating an electric field between the surfaces of the electrodes, and means for introducing a non-uniform magnetic field in the space separating the electrodes which is strongest adjacent the cathode and becomes progressively weaker as the anode is approached.

2. Gaseous conduction apparatus comprising an electrode having a curved surface, a second electrode having a similarly curved surface on the convex side of the first electrode, means for creating an electric field in the space separating the curved surfaces of the electrodes, and means for introducing a magnetic field in the space separating the electrodes which is stronger near the inner surface of the concave electrode than adjacent the outer surface of the convex electrode.

3. An electrical apparatus comprising a gas filled tube, inner and outer cylindrical electrodes received within the tube and located with their axes substantially coinci-

dent, means for creating an electric field in the space separating the electrodes, means for introducing a magnetic field into the annular space separating the electrodes, and cylinders of magnetic material positioned concentric with the electrodes and arranged adjacent one of the electrodes to cause the magnetic field to be non-uniform between the electrodes.

4. An electrical apparatus comprising a gas filled tube, an inner electrode member, an outer electrode cylinder supported concentrically with the inner electrode member, cylinders of magnetic material arranged outside of the outer electrode, and means for creating a magnetic field which is introduced into the annular space between the electrodes by the cylinders of magnetic material, the field being strongest adjacent the outer electrode and becoming progressively weaker toward the other electrode.

5. An electrical apparatus comprising electrodes immersed in a gas and having opposing surfaces spaced apart a distance which is short and comparable to the mean free path of electrons in the gas, and means for introducing a non-uniform magnetic field between the electrodes.

6. An electrical apparatus comprising a gas filled receptacle, means for creating an electric field in a portion of the gaseous region which is limited in the direction of the electric field to a length comparable to the mean free path of electrons in the gas, and means for impressing a space varying magnetic field in the region.

7. An electrical apparatus comprising a gas filled receptacle, a pair of electrodes received therein and having opposing surfaces separated by a distance which is short and of the order of magnitude of the mean free path of electrons in the gas, means for impressing a magnetic field between the electrodes, and magnetic material placed adjacent one of the electrodes so that the magnetic field is strongest adjacent that electrode and becomes progressively weaker toward the other electrode.

8. Electrical apparatus comprising spaced electrodes with gas therebetween, the distance between the electrodes being of the order of the mean free path of electrons in the gas, and means for producing, in said space, a magnetic field which varies in intensity from one electrode toward the other electrode.

9. Electrical apparatus comprising inner and outer electrodes with an annular discharge space therebetween, containing gas, the distance between the electrodes being of the order of the mean free path of electrons in the gas, and means for producing a magnetic field which extends predominantly in the direction of the axis of said annular space and which varies in intensity radially of the annular space.

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