Oct. 15, 1929. H. P. DONLE 1,731,889

GASEOUS CONDUCTION DEVICE

Filed June 26, 1922

Fig. 1.

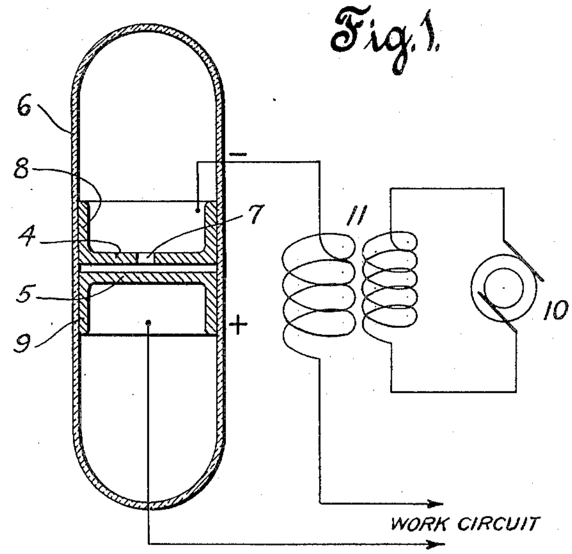


Fig. 2.

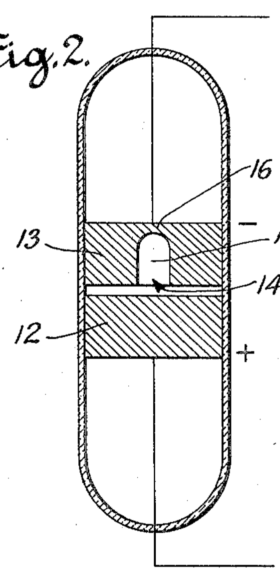
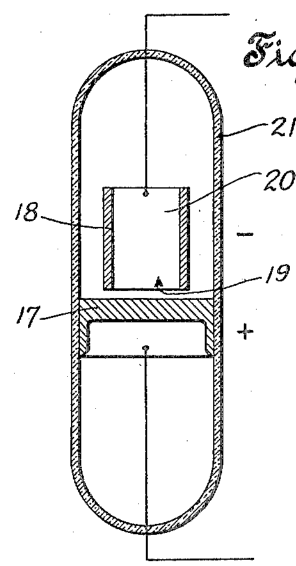


Fig. 3.



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Patented Oct. 15, 1929 1,731,889

UNITED STATES PATENT OFFICE

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GASEOUS CONDUCTION DEVICE

Application filed June 26, 1922. Serial No. 570,975.

The main object of my invention is to provide a simple, inexpensive but efficient type of rectifier for alternating currents.

This application is a partial continuation from #474,006 filed by me May 31, 1921, now Patent 1,420,824, dated June 27, 1922.

In its preferred form the invention utilizes two cold electrodes within a vacuum tube. I make use of the fact that negative particles tending to leave an electrode or move away from its vicinity will move in lines substantially at right angles to the electrode surface. By suitably forming and locating the electrodes I have found that I can secure predominating one-way transmission and consequently rectification.

I have been able to obtain rectification in this way with several different constructions.

Figure 1 illustrates one form of apparatus involving my invention for half wave rectification, the tube being shown in longitudinal section and the circuit being shown diagrammatically.

Figs. 2 and 3 are longitudinal sectional views of tubes with modified electrode construction.

The electrodes 4 and 5 are of suitable conducting material enclosed in an envelope or vessel such as the tube 6. This tube may be of ordinary glass and should be exhausted or evacuated to a suitable degree. I have found a pressure of approximately a millimeter of mercury to be satisfactory. An inert gas may be present in the tube at a corresponding pressure.

The electrode 4 is provided with an orifice or hole 7 in the approximate center of its face opposite the active surface of the electrode 5. These electrodes are placed with their faces so close together as to prevent or minimize ionization between the adjacent surfaces. The electrode 4 has a cylindrical part 8 which forms a wall spaced radially from the axis of the orifice 7. The other electrode 5 may also have a cylindrical extension 9.

Figure 1 shows a circuit with an alternating current generator 10 and a transformer 11. When the tube is connected as shown a pulsating direct current flows in the work circuit from the imperforate electrode 5 to the perforate electrode 4. When this type of tube is in operation an ionization glow very nearly fills the central part of the perforate cathode electrode 4. This glow is separated from the walls of the cathode by a narrow dark space. Projecting from the anode 5 through the orifice 7, a small conical column of very intense light will be seen. It is impossible while watching the device in operation, to distinguish the exact junction between the general glow throughout the interior of the cathode and this brilliant column emanating from the anode.

For the purpose of further explaining what I understand to be the action of this device I may state my belief as to its theory of operation. When the perforate electrode 4 is subjected to the negative potential of the A. C. wave to be rectified thus making the imperforate electrode 5 the anode and the perforate electrode 4 the cathode, all negative particles within the cathode will be repelled from its walls toward its center and literally forced through the hole 7 to the anode 5. The particles moving from the cathode to the anode under normal conditions in a tube having a cathode of approximately $1\frac{1}{4}''$ diameter will collide with gas molecules after traveling about $\frac{3}{16}$ of an inch. The electrons resulting from such collisions will pass axially of the tube and through the hole 7 to the anode 5. The small bright cone-shaped discharge indicates the position of violent collisions, inasmuch as the particles which move through a comparatively restricted zone attain relatively high velocity. The result of such numerous and violent collisions is to produce substantial conductivity in the device when the positive potential is applied to the anode 5 and thus to permit a relatively large current to pass during the corresponding half wave of the alternating potential to be rectified.

On the other hand, when the alternating potential reverses, so making the electrode 4 temporarily positive, the few negative particles which may pass through the hole 7 or may otherwise be within the walls of the electrode 4 encounter only a weak electrostatic field which does not tend to draw them strongly in any particular direction. Consequently, they do not attain sufficient velocity to produce substantial ionization. Other negative particles or electrons which are located between the opposing surfaces of the two electrodes but which do not pass through the orifice 7 will travel directly to the electrode 4 (now positively charged) without attaining sufficient velocity to cause ionization. Consequently, no current or only a small current can pass through the tube when the alternating potential to be rectified is applied in this inverse direction.

In the construction shown in Figure 2 the imperforate electrode 12 is of a substantially larger mass than the electrode 5. The electrode 13 in this case is provided with an orifice 14 leading to a chamber 15 which is closed at 16 at the top. In some cases the larger mass is desirable in order to provide additional thermal capacity. The closed end 16 of the chamber serves to shield the tube from the secondary axial bombardment which passes through the orifice 14. This end portion 16 also serves to supplement the electrostatic field tending to drive electrons through the orifice when the electrode 13 is the cathode. I wish it understood that the relative size and proportions of the various parts may be modified within the scope of my invention, but in any case the space between the adjacent faces of the electrodes should be less than the free mean path required for ionization.

For high voltages the electrodes should be as close together as possible, to eliminate a two-way discharge between the faces. The electrodes may be initially placed or adjusted farther apart for lower voltages where the electrons will necessarily be required to traverse a longer distance in order to absorb sufficient energy to ionize the gaseous atoms. With higher potentials the electrons start out at high velocities and acquire sufficient energy a very short distance from their starting points. In such cases the electrodes must be very close together.

In any case the electrodes should be of sufficient area and mass to avoid overheating under the conditions for which the tube is designed.

The theory of operation above set forth as to the device of Figure 1 also applies to that of Figure 2. When the electrode 13 becomes negative electrons are vigorously repelled from the walls of the chamber 15 toward its center and through the orifice 14 axially toward the anode 12. In this movement they set up extensive ionization and consequently the device becomes a good conductor for the negative half-wave of potential applied to the electrode 13. On the other hand, when the electrode 12 is negatively charged the electrons repelled from it to the adjacent face of the electrode 13 travel so short a distance that ionization is absent or negligible. Such of them as are in the orifice 14 or as are propelled into it are not strongly attracted by the walls of the chamber 15 in any particular direction and they therefore cause little, if any, ionization. Consequently for the half wave which makes the electrode 12 temporarily a cathode, the conductivity of the tube is negligible.

I have referred to the tube as being evacuated or exhausted to a suitable degree. It will be understood from this that I consider it necessary that a tube contain some gas in order that ionization can take place. Various gases may be employed, but, of course, the gas should be inert with respect to the electrodes so that no deleterious effect is produced. Nitrogen, helium, neon, argon and even hydrogen are generally considered inert with respect to various conductors commonly employed as electrodes in vacuum tube devices, and I have found them satisfactory in this case. Some gases may be more desirable than others with certain electrodes. It is desirable that the electrodes be designed so that the rectifier may operate continuously without overheating. It is, of course, well understood that some electrodes within a vacuum tube device absorb some gases and during the operation of the tube gradually give up part of the absorbed gases when operated for any length of time. This absorption and release of gas depends quantitatively upon the particular gas and electrode material utilized. To produce a tube of long life and stability it is therefore desirable to take this into account so that the released gas may be utilized to aid in maintaining the desired pressure within the vacuum tube.

In order to determine whether or not the electrodes in any particular device are properly located, i.e. so closely spaced as to minimize ionization in the inverse current flow direction, one may apply across the terminals of the device under test a direct current potential of the order of the alternating current potential to be rectified. When the imperforate electrode is made positive the tube will ionize as above described and considerable current will flow. However, when the imperforate electrode is made negative there will be substantially no ionization and negligible or no current will flow, if the spacing between the electrodes is sufficiently small for proper operation of my rectifier.

In the construction shown in Figure 3 the anode 17 is supported directly by the glass of the tube 21 and the cathode 18 is supported in any suitable manner away from the inner wall of the tube. In this case the cathode has a comparatively thin wall extending parallel to the axis of the orifice 19 and forms the chamber 20 in which the ionization takes place. In some cases it may be desirable to space the cathode away from the wall of the tube for instance to avoid the effect of inequalities of manufacture in dimensions and the effect of possible expansion of the electrodes or contraction of the tube. The end of the cathode adjacent the anode constitutes the face corresponding to the faces of the other forms of cathodes. Although the construction differs mechanically and in detail from the other forms herein shown, the same theory of operation appears to apply.

In my former application referred to, I have specifically claimed the full wave rectification form of device having two anodes. While such form of tube is perhaps more efficient than two single anode tubes as herein shown and claimed, nevertheless, the single anode tube device has advantages in simplicity and cheapness of construction and avoids the necessity of a comparatively wide separation of two anodes within a single tube. Two of the single anode tubes may be connected in the divided transformer circuit where full wave rectification is desired.

From the foregoing it will be evident that in Figs. 1 and 2 the insulating wall of the tube 6 bridges the space between the anode and cathode around the discharge opening in the cathode to which the anode is presented, thereby obstructing discharge between the anode and the exterior of the cathode as well as accurately positioning the electrodes relatively to each other. It will also be apparent that the bottom 4 of the member 8 in Fig. 1 constitutes an obstruction and by virtue of the surrounding insulation 6, all the current must flow through the opening 7 in the obstruction, the active cathode surface being confined to the interior surface of member 9.

I claim:

1. A rectifier comprising an envelope containing a rare inert gas, two flat faced disk electrodes mounted in said container with their adjacent faces so close together as to minimize ionization under one direction of applied potential, one of said electrodes having a passage opposite the face of the other to provide an ionizing path.

2. A gaseous discharge device comprising a hollow cathode having an interior active surface which is solid at operating temperatures, an anode presented to the interior of said hollow cathode from the exterior thereof, insulating material disposed around the outer surfaces of said electrodes to maintain them in desired position and restrict the discharge to the interior of said cathode.

3. A gaseous discharge device comprising a hollow electrode having an opening in one side, another electrode presented to said opening and spaced therefrom a distance of the order of magnitude of the mean free path of the electrons present in the gas, insulating material surrounding both of said electrodes to maintain them in desired relationship to each other and contacting with the outer surfaces only of the electrodes.

HAROLD POTTER DONLE.