June 16, 1931. S. RUBEN 1,809,912

GASEOUS DISCHARGE DEVICE

Filed July 2, 1927

Fig. 1.

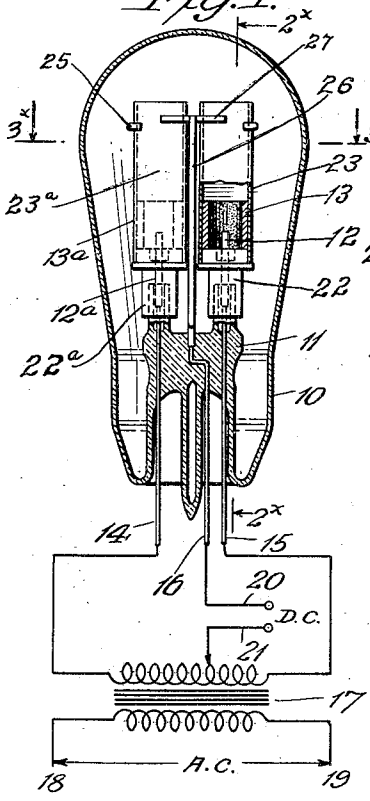


Fig. 2.

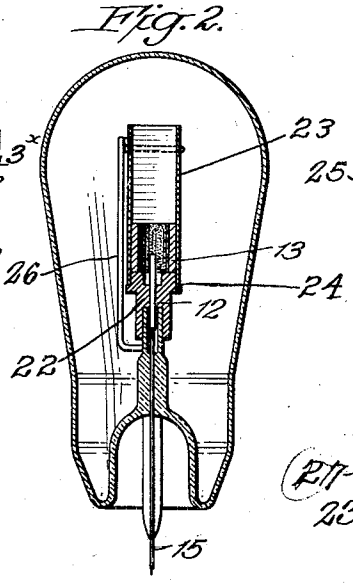


Fig. 3.

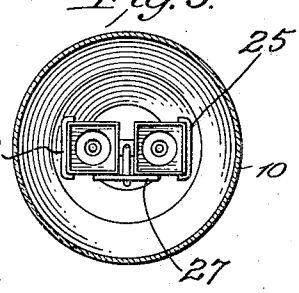


Fig. 4.

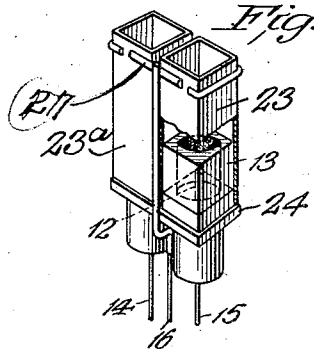


Fig. 8.

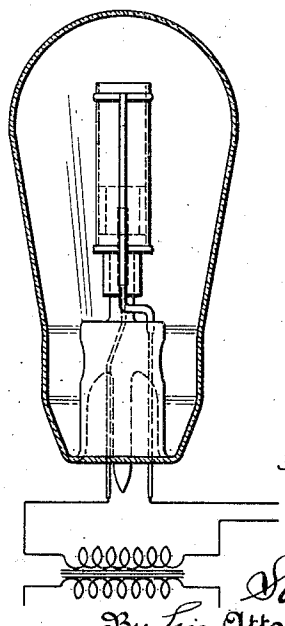


Fig. 6.

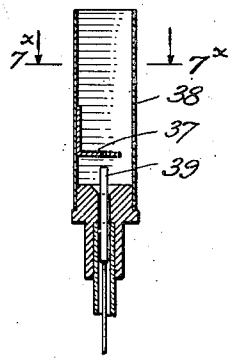


Fig. 5.

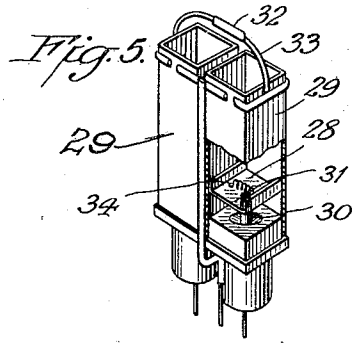
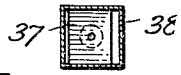


Fig. 7.



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UNITED STATES PATENT OFFICE

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GASEOUS DISCHARGE DEVICE

Application filed July 2, 1927. Serial No. 203,035.

This invention relates to gaseous discharge devices and more particularly to the use of such devices in the rectification of alternating currents.

It has for an object the provision of a rectifying device employing a low pressure gaseous discharge which possesses a low initial discharge or breakdown potential, a low impedance during operation and long life.

Another object is to materially increase the efficient current output capacity of an ionic rectifying device without necessitating an increase in size of parts.

Briefly these objects are accomplished by the provision of a cathode, which comprises substantially a reacting surface composed of highly electro-positive and readily volatile metal applied to a base of metallic material which will react with compounds of the surface metal to cause their reduction and thus maintain the surface metal in a pure state. With the use of such a cathode, there is produced a device which possesses a particularly low operating impedance and high current capacity resulting from the concentrated field of metallic vapor surrounding the electrodes and produced by volatilization of the cathode surface metal under the influence of the heat generated at the electrodes and the electrode bombardment by gas particles and also from the photo-electric action at the surface metal producing electron emission. Furthermore, such a device also possesses a low ionization or discharge potential, a low cathode drop of potential, and long life resulting from the maintenance of greater gas purity and from the reduction of the gas losses such as result from chemical absorption and physical adsorption or both.

Another feature is that of supplying the low pressure initially conductive gas at a pressure somewhat in excess of that value giving minimum impedance to thereby extend the life of the device over a longer period, as the reductions in pressure attendant upon operation of the device will then lower the pressure to a value approaching that of minimum impedance and thus actually lower the impedance, in contrast to the increased impedance which results from the decreased pressure caused by gas loss when the initial pressure value is equal to that corresponding to minimum impedance. Since these losses occur principally early in the life of the device, the latter will thus possess a minimum operating impedance during the greater portion of its life.

A further feature of the invention comprises the use of an auxiliary electron-emissive filament in combination with the usual cathode element and placed transverse to and within the leakage current path between the electrode pairs of a full-wave rectifier. With such an arrangement the leakage current heats the auxiliary emissive filament, causing it to emit an electron stream tending to cause greater ionization of the conducting gas particles and thereby materially increase the current output or load which the device will carry and appreciably decrease the internal impedance and dependence of the operating characteristics of the device upon the gas pressure.

To these and other ends, the invention consists in further features all of which will be more fully described and thoroughly understood with the aid of the description to be given in connection with the accompanying drawings, the novel features being particularly set forth in the appended claims.

In the drawings:

Fig. 1 is a vertical sectional view of a full wave rectifying device comprising two pairs of electrodes constructed in accordance with the invention and shown connected in circuit with a transformer for securing full-wave rectification;

Fig. 2 is a vertical sectional view taken along the line 2^x—2^x of Fig. 1;

Fig. 3 is a horizontal sectional view taken along the line 3^x—3^x of Fig. 1;

Fig. 4 is a perspective view, partly broken away of the preferred electrode arrangement;

Fig. 5 is a perspective view, partly broken away, of a modified form of electrode;

Fig. 6 is a vertical sectional view of another alternate form of electrode;

Fig. 7 is a horizontal section taken along the line 7^x—7^x of Fig. 6; and

Fig. 8 is a vertical sectional view of a half-wave rectifying device embodying the principles of the invention.

In the drawings the same reference characters have been used to denote similar parts.

Referring to the drawings, I have shown in Figs. 1 to 4 inclusive a commercial form of device embodying the features of my invention and illustrating an arrangement of parts adapted for use in effecting complete or full-wave rectification of alternating currents. The particular device illustrated and described hereinafter is one showing the adaptation of the invention to a rectifying device especially suited for use in supplying the necessary rectification in the filter circuits in so-called "B" battery eliminators used in conjunction with radio apparatus. Generally, such a device comprises a suitable glass bulb or envelope 10 containing a readily ionizable gaseous atmosphere at low pressure and having an inner upright glass post 11 formed integral therewith and serving as a support for two similar sets of associated anodes 12, 12*a* and cathodes 13, 13*a*. The anodes are provided with separate lead-in wires 14 and 15 while the cathodes are joined internally and provided with a common lead-in wire 16, all lead-in wires 14, 15 and 16 being sealed in the post 11 and joined as by spot welding to the ends of their respective electrodes. With this arrangement, complete or full-wave rectification is then obtained by connecting the anode leads 14 and 15 to the ends of the secondary of a suitable transformer 17 whose primary is connected across the incoming alternating current lines 18 and 19, the direct current being taken off through leads 20 and 21 connected respectively to the central point of the secondary and the cathode lead-in wire 16. Thus, the cathodes are at all times negative to one of the anodes and positive to the other, this designation or relation changing at the end of each half-cycle, so that current flows alternately through each pair of electrodes producing a continuous uni-directional current in the direct current leads 20 and 21.

Rectification in this form of device is obtained principally by the use of spaced electrodes of dissimilar surface areas, producing thereby asymmetrically conductive electrode gaps and resulting in a greater flow of positive current from the smaller to the larger surfaced electrode and the amount of rectification is substantially dependent upon the ratio between these surface areas. To this end, the electrodes employed are preferably so designed that this ratio is made as large as possible. Furthermore, the construction and arrangement of the electrodes are so chosen that high thermal radiation and a uniform distribution of current over the electrode surface are obtained to thereby reduce both sputtering at the electrodes and the resultant occlusion of gases.

Electrode combinations of various designs may be employed to provide the desired surface area ratio but I have found the use of a short tubular member having a cylindrical cavity and open at at least one end in combination with a rod positioned in axial alinement therewith with one end projecting within the open end of the former to give especially satisfactory results. With this arrangement asymmetrical conductivity, giving rectification, is produced and is dependent upon the size of the electrodes or in other words, their diameters, and upon the length of the rod electrode protruding within the cylindrical electrode. Since the greater positive current flows from the smaller to the larger electrode (a larger flow of negatively charged particles taking place in the reverse direction), the cylindrical electrode may be appropriately termed the cathode and the smaller or rod electrode the anode, as when the polarity relation between the electrodes changes from this designation, there is no appreciable flow of current between them.

In the device illustrated, the rod anodes 12, 12*a* are suitably secured, as by sealing, with their axes vertical to the glass post 11 and are enclosed within suitable refractory insulating jackets 22, 22*a* as a baked lava product, so as to leave active only a small portion of their surfaces adjacent the cathodes and thereby suppress the ionic discharge from the anodes and thus obtain the desired surface area ratio between anode and cathode. By forming the refractory jackets 22, 22*a* with flat upper surfaces and of similar cross-section to that of the tubular cathodes 13, 13*a*, the latter may be conveniently supported on the former. In order to restrict the ionic discharge to the desired paths and reduce leakage, the cathodes are preferably enclosed with suitable metallic tubes 23, 23*a* extending beyond the upper ends of the cathodes and these tubes are conveniently supported on external lateral annular shoulders 24 provided on refractory jackets 22, 22*a* just below their upper ends. Semi-rectangular braces 25 are welded to the tubes 23, 23*a* to add stiffness and a further support is provided in the form of a vertical metallic rod 26 having its lower end sealed into the glass post 11 and its upper end connected as by welding to a cross-piece 27 joining the two cathode tubes 23, 23*a*. By securing the cathode lead-in wire 16 to the end of this support 26, the cathodes are suitably connected in circuit.

The operating characteristics of an ionic discharge rectifying device are substantially dependent upon the discharge potential, or the potential required to start the discharge when the circuit is closed, and the impedance of the device, the device being constructed

and designed as to make both these factors a minimum. The initial discharge potential is dependent upon the ease with which the conducting medium may be ionized while the operating impedance is substantially dependent upon the conductivity of the medium after initial ionization. The impedance is also dependent upon the pressure of the gaseous conducting medium, the cathode drop of potential (a property of the cathode surface metal), and the purity of the gas and electrode surfaces.

Certain of the factors thus noted are not constant but show a tendency to so change with time as to increase the impedance and the life of the device is thus decreased since it is substantially determined by the rate of increase of the impedance. The presence of impurities in the tube not only adds to the initial impedance value but also causes an increase in the same by interacting with other elements to form new compounds and also with the conducting medium per se to decrease its conductivity. Sputtering at the electrode surfaces, which occurs when the latter become heated under impact of the gas molecules, causes occlusion or absorption of the gaseous medium, results in reduction of gas pressure with the consequent increase in impedance, and also causes destruction of the electrodes per se.

In accordance with a feature of my invention, I have overcome the above noted difficulties by forming the cathode reacting surface of a readily volatile highly electro-positive metal and employing an easily ionizable and preferably inert gas as the conductive gaseous medium. With this combination of features the inert gas will serve as the initial conducting medium by means of which the discharge is started, providing the device thereby with a low discharge potential, and under such operation the readily volatile metal is vaporized, forming an atmosphere of especially high conductivity which will serve to carry the load during the balance of the operation, thus materially reducing the impedance during operation. Furthermore with such a cathode surface of an electro-positive metal the cathode drop of potential is reduced to a minimum and similarly sputtering with absorption of gases and consequent reduction of gas pressure and increase in impedance is also reduced to a minimum. Also by using such an alkali metallic vapor as the load carrying conductive medium, the device is less dependent upon the pressure of the inert gas (since the operation is no longer dependent purely upon the gas ionization under the direct influence of the applied potential) and small changes in the gas pressure will consequently not materially affect the opearting characteristics and life of the device. I have also found that the use of electro-positive metal surfaced cathodes provides an additional source of electrons by virtue of the photo-electric effects produced by gas discharge and electrode bombardment thus creating a greater ionization of the gaseous atmosphere and consequently increasing the efficiency and output capacity.

A cathode surface of highly electro-positive metal may be supplied in various ways, but I have found that the usual difficulties incident to the handling and working of such metals (due to their highly active chemical nature) are satisfactorily overcome by forming the cathodes 13, 13*a* of a metallic material which will react readily with compounds of the desired surface metal to cause their reduction, coating such a base prior to exhaustion of the device with the surface metal in the form of one of its suitable stable compounds, and heating the coated base after exhaustion and prior to filling, as inductively, to cause the reduction of the compound, leaving the base coated with a regular uniform surface of the desired highly electro-positive metal in the free state. In this manner, any compounds of the electro-positive metal formed during operation by its interaction with impurities are quickly reduced and the surface at all times maintained in a pure state. Magnesium has been found to be a particularly satisfactory metal for use as a cathode base, since it possesses a ready tendency to cause reduction of other metals and furthermore in the instant application, it serves the additional function of serving in place of the usual "getter" to purify the gaseous atmosphere. The electro-positive metal employed is preferably that possessing the lowest practicable atomic number and the properties desired are possessed by the alkali metals of the first group of the periodic system of elements which include cæsium, rubidium, potassium, sodium and lithium, the arrangement being in their order of preference from the operating characteristic viewpoint. When cæsium or rubidium is employed, for example, the surface is suitably obtained by coating a magnesium base 13, 13*a* with a layer of cæsium or rubidium chloride and heating to reduce the latter and form the pure metal, cæsium or rubidium, as the case may be. The amount of cæsium or rubidium provided may be varied within wide limits but I have found that a coating or approximately 0.1 mms. depth to give excellent results.

In ionic discharge devices, the impedance is directly dependent upon the gas pressure and even small variations in either direction from a certain definite pressure corresponding to minimum impedance produce comparatively large increases in the impedance and discharge or ionization potential characteristics. It is customary therefore, to accurately control the pressure within the tube so as to obtain a pressure giving minimum

impedance. On the other hand, however, I have found that reductions in the gas content, accompanied by corresponding increases in impedance, occur during the operation of the device, such losses being caused principally by sputtering at the electrode surfaces, causing occlusion of the gases.

In order to counter-balance these undesirable characteristics and thereby extend the life of the device, I supply the inert gas at a pressure somewhat in excess of that corresponding to minimum impedance, so that should reduction of the active gas content occur (as by occlusion or absorption due to sputtering at the electrodes) the pressure will be lowered to the desired minimum impedance value. The life of the device is thereby materially extended, since a greater decrease in pressure due to this occulsion occurs during the early stages of the operation, the rate of loss being smaller thereafter, and by employing an initial pressure above the desired minimum impedance value this initial drop will cause a decrease in pressure to a value approximating the minimum impedance value instead of a decrease to a value below the minimum impedance value. Consequently the device will possess during the greater portion of its life an impedance value more nearly approximating that of the desired minimum impedance value and as a result thereof, the life will be appreciably extended.

The particular value of gas pressure employed will depend upon the allowable leakage current which may exist, since the use of a higher pressure results in increased leakage. As a general rule, however, I have found that the leakage current will be maintained within suitable limits, if the gas pressure employed is not greater than ten per cent above the minimum impedance value.

The choice of gas to be employed as the initial conducting medium will be determined by a consideration of the operating characteristics of a given gas together with the commercial and economic feasibility of its use. The various characteristics which such a gas should preferably possess comprise:

1. Stability under the operating conditions of the device.

2. A substantially inert or non-reactive character relative to the other elements present in the device.

3. Low ionization potential, or in other words high electrical conductivity, to provide the device with a low discharge potential and low impedance.

4. Low atonic weight to decrease the bombardment effects on the electrode.

Those gases which I have found to be best suited for general use in ionic discharge devices are the monatomic gases, neon, helium, argon, all of which are stable and substantially chemically inert, and of these neon and helium are the more preferable for use in such circuits as "B" battery eliminator circuits for radio installations, the choice between these latter being obtained by a study of comparative operating data together with costs of materials. Helium, for example, is the lighter gas and will therefore result in a smaller bombardment effect on the electrodes, thus diminishing sputtering and gas absorption at the electrode surfaces. Neon, on the other hand, is appreciably more conductive than helium and is less critical with respect to the relation between the gas pressure and impedance of the device, thus making possible the use of a greater excess of gas, to offset sputtering and occlusion losses, without appreciably affecting the impedance.

In Fig. 5, I have shown a modified arrangement of the electrodes in accordance with my invention and in which the cathodes comprise flat plate electrodes 28 of a metal having a low cathode drop of potential, as nickel or aluminum, supported on the shields 29 perpendicular to the axis of the rod anodes 30 and provided with a small central opening 31 disposed in axial alinement with the anode and serving to equalize or balance the discharge between the electrodes. The alkali vapor conducting medium is provided in this form of the invention by depositing the metal upon the interior parts of the device in such a manner that it will be vaporized under the influence of the heat conveyed to it by radiation and convection from the electrodes. As in the case of the vapor produced from the coated cathode, the metallic vapor here produced will serve to carry the load during operation, thus providing the device with a low operating impedance. The metallic vapor constituent is preferably deposited within the device as the last step in its production so that loss of the vapor during the earlier steps of baking and evacuation is obviated. I accomplish this end by using the metal in the form of a compound mixed with a reducing agent which will liberate the metal upon the application of heat and placing such a mixture in a suitable container, as a metallic capsule 32 carried on suitable wire supports 33 above the electrodes. With this construction the other steps in the production of the device may be carried out without volatilizing the metal and then the metal deposited, as the final step, on the interior parts of the device by heating the capsule, as inductively, to a temperature sufficiently high to cause reduction of the desired metal containing compound and volatilization of the reduced metal. When cæsium is employed as the conductive vapor, for example, I employ a powdered mixture of cæsium chloride and metallic magnesium in the capsule 32, and upon heating such a mixture, the interaction of these materials produces magnesium chloride and cæsium which latter then vola-

tilizes and upon cooling condensers upon the solid portions of the tube and particularly in the field of discharge of the device such as on the walls of the cathode and the cathode shield. In this way a concentrated field of the vapor is obtained in the immediate areas of the electrodes.

To increase the output of an ionic discharge device has been the object of a further feature of the invention and in accordance with this feature, I have found that the current capacity may be greatly increased and at the same time the over-all efficiency, even at low current values, greatly increased by employing a thermionically active element or filament 34 (Fig. 5) in circuit with the cathode and positioned transverse to and within the leakage current path which normally exists between the electrodes of a full-wave rectifying device employing two pairs of electrodes for rectification of both sides of each wave. I have found that this leakage current is of such intensity that articles placed transverse to and within its path become readily and quickly heated to a temperature which decreases with the distance away from the electrode, and is sufficient to create a bright red heat in close proximity to the electrode. With such a thermionic element as an auxiliary cathode, the leakage current thus causes it to become heated, resulting in an emission of electrons which are attracted along to the anode and cause ionization of the gaseous molecules, thereby appreciably increasing the current carrying capacity of the device. Furthermore since there is thus supplied an auxiliary source of electrons for gas ionization, the device is considerably less dependent upon the inert gas pressure. When the current reverses during the other half of each cycle the filament becomes positive with respect to the rod anode and no current flows as the emitted electrons, being negatively charged, will be repelled by the negatively charged anode. Furthermore, by changing the position of the auxiliary thermionic cathode 34 in the leakage path so as to vary its distance from the anode, the amount of emission may be readily controlled since the emission is dependent upon the temperature of the filament which in turn varies with its distance from the anode. When such an auxiliary cathode is included, the leakage current set up will quickly heat the filament 34, causing emission therefrom and emitted electrons will in turn cause an increased ionization of the gas particles.

In addition the cathode and anode drops of potential are also materially reduced and particularly as a result of these effects the impedance is greatly lowered. Thus the use of a thermionically active filamentary cathode in an ionic discharge device increases the current carrying capacity of the device and with lower capacities materially increases the efficiency. In addition, the life of the device is materially increased.

In the electrode arrangement illustrated, I have shown the thermionic auxiliary cathodes as short coiled thermionically active wires 34, supported as by spot welding on the upper surfaces of the plate cathodes 28, over the openings 31 therein. These openings 31 in this form of electrode in which an auxiliary thermionic element is employed afford convenient and direct passages for the emitted electrons to the anode. Various materials may be employed to provide the thermionically active element, but I have found that the use of conductive cores coated with thermionically active materials such as the oxides of the alkali earths (barium, calcium and strontium,) or mixtures of them with each other or with other materials to be especially satisfactory.

In Fig. 8, I have shown the adaptation of the arrangement of Figs. 1, 2, 3 and 4 to a one way rectifying device, containing but one electrode pair, together with suitable circuit connections for its use.

A modification of the preferred electrode structure is shown in Figs. 6 and 7, the cathode being shown as a plate 37 provided on one edge with a lateral flange by means of which it is secured to and supported within the shield 38 in spaced relation to the rod anode 39.

In assembling the various elements in the production of the device, care should be taken to insure purity and cleanliness of all parts and elements since the ionization potential and impedance are increased by the presence of impurities whose action might be either to raise the ionization or break down potential, to increase the anode and cathode drops of potential and therefore the impedance, due to chemical reaction at the surfaces of the electrodes, or it might be a combination of both these effects. The gas purity may be readily controlled either prior to the filling of the tube by the insertion of a hot magnesium electrode or "getter" in the path of the inflowing gas or after filling by including such a "getter" in the arrangement of the device. When the alkali vapor conduction feature, however, is employed, the alkali metal will, in sputtering and during volatilization, tend to purify the gas, obviating the necessity of employing a "getter."

Since the discharges take place upon the surfaces of the electrodes and volatilization of the alkali metal is effected from all parts or surfaces within the device, these parts should be thoroughly cleaned before use.

What I claim is:—

1. An ionic discharge rectifying device comprising two pairs of spaced asymmetrically conducting electrodes of opposite polarity, and an electron emissive filament in direct electrical contact with a cathode elec-

trode and positioned in the leakage path of the device to be heated by the leakage current.

2. An ionic discharge rectifying device comprising two pairs of spaced conducting electrodes of opposite polarity, and an electron emissive filament in direct electrical contact with a cathode electrode and positioned in the leakage path of the device at predetermined distance from the anode electrode, said filament to be heated by the leakage current.

3. An ionic discharge rectifying device comprising an enclosing envelope, two pairs of opposed electrodes to provide full-wave rectification, the members of each pair being spaced apart relative to each other, leads for the electrodes, and an electron-emissive electrode in direct electrical contact with a cathode member and disposed in the leakage path between the electrode pairs to be heated by the leakage current.

This specification signed and witnessed this 28th day of June, 1927.

SAMUEL RUBEN.