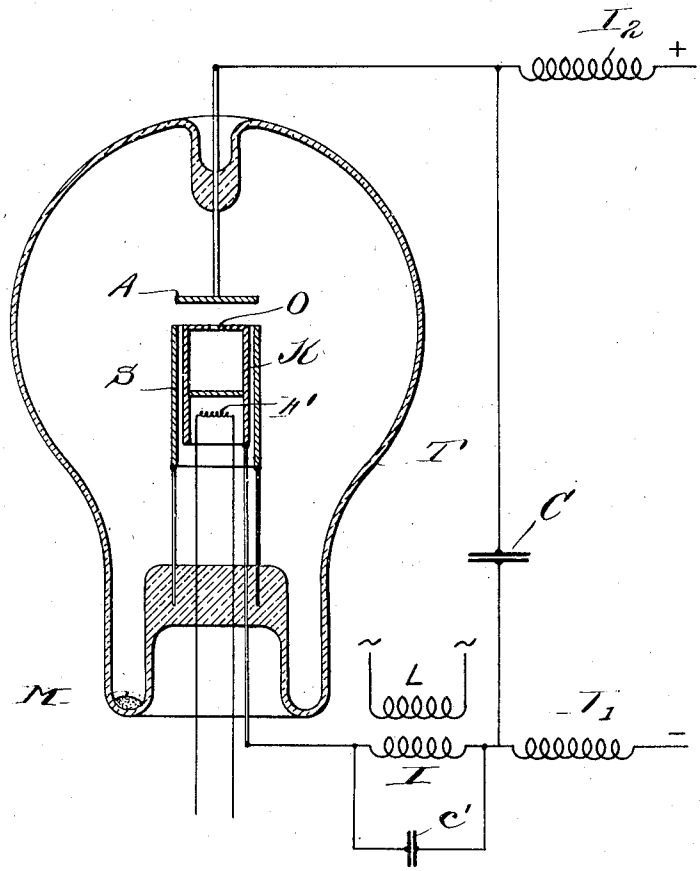
May 14, 1929. C. G. SMITH 1,713,356

PRODUCTION OF PULSATING CURRENT

Original Filed March 2, 1926



Inventor:
Charles G. Smith
by Roberts, Cushman & Woodberry
Attorneys.

Patented May 14, 1929. 1,713,356

UNITED STATES PATENT OFFICE.

CHARLES G. SMITH, OF MEDFORD, MASSACHUSETTS, ASSIGNOR TO RAYTHEON INC., OF CAMBRIDGE, MASSACHUSETTS, A CORPORATION OF MASSACHUSETTS.

PRODUCTION OF PULSATING CURRENT.

Application filed March 2, 1926, Serial No. 91,716. Renewed January 17, 1928.

This invention relates to gaseous conduction in rarefied gas and particularly to the production of oscillations or pulsations of current by rendering a gaseous medium periodically non-conducting at normal operating potentials. In one aspect this invention is a species of the genus described and claimed in prior application Serial No. 418,263, filed October 20, 1920 in that the characteristic curve (current abscissæ and potential ordinates) of the gaseous conduction device is discontinuous and the current abruptly drops in response to a change in the ioniation phenomenon accompanying the current flow. According to the prior disclosure the gaseous discharge between the electrodes is caused to pass through a restricted space subjected to the influence of a constant magnetic field such that the discharge is shut off after it has increased sufficiently to ionize the gas in the restricted space to a predetermined degree.

According to the present invention the magnetic field may be eliminated and by ionizing the gas in the restricted space approximately to the saturation point the space abruptly becomes con-conducting. By suitably proportioning the circuit impedances, size of said restricted space, gas pressure and other variable factors, the pulsations or oscillations may be produced at any desired frequency, theoretically up to or beyond the order of five hundred thousand per second. Powerful oscillations may be produced by this invention inasmuch as high voltages and large currents may be employed. The invention is particularly applicable to the conversion of direct current into alternating current inasmuch as the efficiency of tubes embodying this invention is much higher than tubes whose conductivity is more or less a sinusoidal function of time and which can never be more than fifty per cent efficient.

A cardinal feature of the invention consists in that a portion of the discharge path is rendered substantially non-conducting at normal potentials by ionizing the gas substantially to the saturation point. When the gas is thus ionized it becomes susceptible to the electrostatic forces between the cathode and anode and is, I believe, substantially expelled from said path by such forces, thereby rendering the path non-conducting until non-ionized gas or gas only partially ionized from the surrounding region can replace the expelled gas.

For the purpose of illustration one concrete embodiment is shown in the accompanying drawing in which a tube having the requisite characteristics is connected in a suitable oscillating circuit.

In the particular embodiment chosen for illustration, T represents a suitable tube which may be formed of glass, K a hollow cathode of nickel, steel, tungsten, molybdenum or other suitable material which is preferably cylindrical in transverse contour and closed except for the restricted discharge opening O, to which is presented the anode A which may be in the form of a molybdenum disk, S is a shield surrounding the cathode to restrict radiation and thereby maintain the cathode at a high temperature (say 700° C.) with less loss of energy, this shield being desirable but not essential, and F is a heating filament disposed within a skirt on the bottom of the cathode for heating the hollow cathode to facilitate starting the discharge and preferably to assist in maintaining the aforesaid radiation during operation. Either or both of the top and bottom of the cathode, which are preferably formed separately and welded to the cylindrical portion of the cathode, may be formed of different material or materials from that of the cylindrical portion. For example, the cylindrical part may be formed of nickel and the top containing opening O may be formed of molybdenum. The material surrounding the opening O is preferably metallic. Inasmuch as mercury vapor is a suitable gas for use within the tube a drop of mercury is shown at M. While the pressure of the mercury vapor may different for different purposes and indeed may vary considerably during operation, a typical example is 0.01 mm. Mercury vapor is particularly suitable for producing lower frequencies because its molecules are heavy and move more slowly.

For converting direct current into alternating current as illustrated in the drawing, the connections may comprise a positive lead connected to the anode through an inductance I_2, a negative lead connected to the cathode through inductances I and I_1, a condenser C of large capacity connected across the two leads, and a load transformer L having its primary connected in parallel with a smaller capacity C^1 to supply alternating current to the load circuit.

When employing the invention to convert direct current into alternating current in a

circuit such as illustrated, the tube readily conducts up to a high intensity of discharge in the restricted opening and then suddenly becomes non-conducting. After a brief period of stoppage the current again builds up and shuts off, thereby producing pulsations or oscillations of predetermined frequency depending upon the characteristics of the tube and circuit.

While the phenomenon is obscure I believe the abrupt stoppage of current at recurrent intervals is due to physical removal of the ionized gas from the retricted opening O by the electrostatic forces between cathode and anode when the gas in this space becomes substantially completely ionized. For example, in a particular case where the vapor pressure was .02 mm. the current density in the restricted opening was 4000 amperes per sq. cm., and theoretically the gas would be ionized substantially to the saturation point at this density.

By confining the active cathode surface in a restricted space, as by locating it inside a hollow cathode, the radiation in the restricted space is intense and largely aids the discharge between electrodes in ionizing the gas in the adjacent opening, this effect being enhanced by the greater density of luminous gas inside the cathode due to electric pumping effects as disclosed in my prior application Serial No. 55,262, filed September 9, 1925.

A theoretically perfect oscillator would alternate between conditions of no current flow and no potential drop. This invention approaches the ideal more closely than prior oscillators in that it has an abnormally low voltage drop during the recurrent periods of conduction, it shuts off abruptly instead of gradually as in sinusoidal rectifiers, and the flow of current during the shut-off periods is practically nil.

I claim:

1. The method of operating a gaseous conductor at an intensity of ionization approximating the saturation value which comprises producing ions by electron collision with molecules and concomitantly by subjecting the gas to intense ionizing radiation from a near by body of gas at a higher pressure than that of the saturated region.

2. The method of producing pulsating current with a gaseous discharge tube which comprises recurrently bringing the ionization in the path of the discharge substantially to saturation value, characterized in that the collision ionization is supplemented by intense radiation.

3. The method of producing pulsating current with a gaseous discharge tube which comprises recurrently bringing the ionization in the path of the discharge substantially to saturation value, characterized in that the collision ionization is supplemented by intense radiation from a nearby body of gas at a higher pressure than that of the saturated region.

4. The method of operating a gaseous discharge tube which comprises producing an intense discharge between electrodes in a rarefied gas and confining a portion of the path of the discharge sufficiently to ionize the gas therein substantially to the saturation point.

5. The method of producing alternating current which comprises impressing upon electrodes spaced apart in a gas with a restricted discharge opening therebetween, a potential capable of producing a discharge through said opening of sufficient intensity thoroughly to ionize the gas in the opening, and expelling the ionized gas from the opening by the electrostatic forces between said electrodes until the opening becomes momentarily non-conducting.

6. In the art of electronic discharge through gas, the method of producing pulsating current which comprises restricting the discharge to a zone small in cross-sectional area and with an intense discharge, ionizing the gas in said zone sufficiently to cause the ionized gas to be expelled from the zone by electrostatic forces to such extent as to render the zone momentarily non-conducting.

7. In a gaseous discharge tube having cathode and anode surfaces with a restricted discharge opening therebetween, the method of producing pulsations of current which comprises increasing the discharge through said opening until the space in the opening suddenly becomes non-conducting solely in response to gas ionization and electrostatic action on the ionized gas.

Signed by me at Cambridge, Massachusetts, this sixteenth day of February, 1926.

CHARLES G. SMITH.