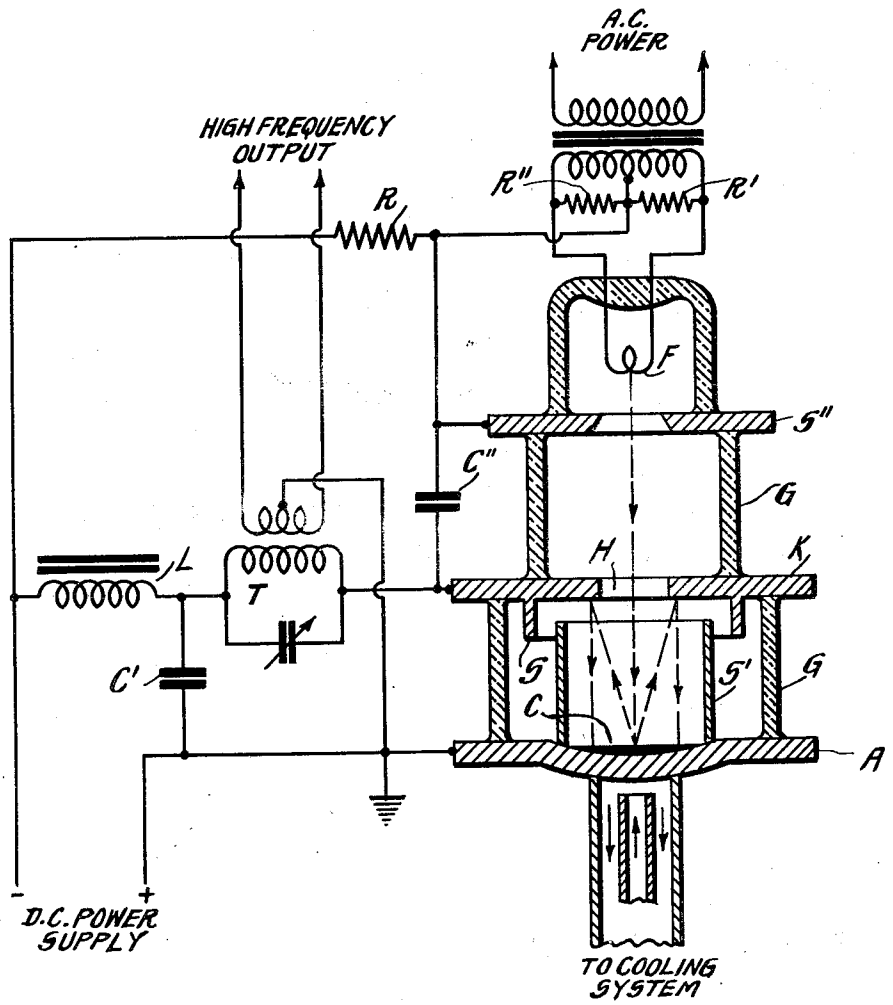
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VACUUM TUBE AND CIRCUIT THEREFOR

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VACUUM TUBE AND CIRCUIT THEREFOR

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This invention relates to oscillation generators.

An object of the invention is to produce a high power, high efficiency and high frequency oscillation generator.

Another object is to enable the conversion of D. C. power into A. C. power with high efficiency by utilizing controlled bursts of gas or vapor within an electron discharge device.

A further object is to provide a method of and means for operating a conventional high vacuum tube as a gaseous tube when it is desired to cause current to flow through the tube, to thereby obtain power conversion at high efficiencies.

One of the great difficulties experienced in operating conventional vacuum tube radio transmitters has been caused by internal arc-over within the tubes. From observation, I have come to the conclusion that this undesired arc-over is generally dependent upon operating conditions such that the internal surface of the tube anodes acquires a temperature less than that of other surfaces exposed to the vacuum. This often occurs in radio transmitters when cold cooling water is circulated through the water jackets of water cooled tubes. The resulting low anode temperature causes a continual accumulation on the anode of semivolatile materials always present even in the best vacuum tubes. These materials are likely to be impurities evaporated from the cathodes, and sometimes from the control electrodes. These impurities are likely to be sodium, potassium and aluminum, according to Dr. Lloyd P. Smith in his paper "The Emission of Positive Ions From Tungsten and Molybdenum" published in the Physical Review, February 15, 1930. However, it is possible that materials evaporated from cathodes and grids, including thorium and the base metals tungsten and molybdenum, etc., may also condense on the cold anode surface in a submicroscopic feathery or skeletonized layer, under some conditions of operation.

In the case of tubes with oxide cathodes the release of barium by electrolytic conduction in the cathode coating has provided so much semivolatile material in the tubes that for many years it was considered impractical to employ oxide cathodes in high voltage tubes and even now it is possible to use oxide cathodes in high voltage tubes only under special conditions which control the distribution of free barium over the internal tube surfaces.

In any case it is often observed, in most water cooled tubes, that after a long period of interruption of anode current, particularly when the cathodes are kept hot, resumption of anode current will result in an arc-over. I attribute this to an accumulation of a layer of the vaporized materials on the anode and control electrode which materials are easily sputtered off or evaporated due to increasing temperature by the first pulses of anode current which almost always strike the anode at a high potential. At any rate it has been found that when the same type of tubes are provided with air cooling for the anodes, and the cathodes are kept heated in such a manner that inactive surfaces (such as glass) exposed to the vacuum are coolest, then the flash-over phenomenon disappears or tends to vanish. If the semivolatile material condenses on the glass or other inactive surfaces which are the coolest part exposed to the vacuum, then there is nothing to cause the material from the inactive surfaces to be released in bursts of gas, because these inactive surfaces are not normally subjected to electron bombardment nor to such intense electric fields as anode surfaces. This suggests that a large part of the arc-over effect has been caused by condensation of vaporizable materials on the anode and transient re-evaporation of these materials under electron bombardment, resulting in a gaseous or arc discharge short circuit. In between times, the vacuum in the tubes remained high.

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According to the present invention I propose to make use of this previously very undesirable phenomenon by periodically bombarding a surface to release gas in momentary puffs or pulses a portion of which is ionized and through which very large discharge currents can pass in such a manner as to provide pulses of current for building up currents in a tuned circuit at the frequency of the pulses. Since the potential drop through the gas discharge may be quite small, on the order of perhaps 20 volts, and the D. C. power supply may range up to 20,000 volts, then the anode circuit conversion efficiency of such a device in accordance with the invention may range up to 99.9%.

In accordance with the invention, I propose a type of tube in which all surfaces exposed to the vacuum are kept relatively warm, except one portion which may be a portion of the surface of the anode, which is kept relatively very cold. Due to this temperature distribution, assuming a suitable range of temperatures, all volatile material in the tube accumulates rapidly on the cold spot where it remains until a portion of it is sputtered or evaporated off by a pulse of electrons impact-

ing upon the surface. The volatile material then, when in a gaseous state, allows a short circuit arc between the anode and a cathode. As soon as the arc has discharged the capacities connected between anode and cathode, the current automatically stops. Then the vapor quickly condenses over a large portion of the surfaces, active and inactive, exposed to the vacuum, leaving a relatively high vacuum which can support a large potential, as the output circuit oscillates up from nearly zero to about twice the D. C. power input potential. After this condensation, the vapor is slowly transferred by re-evaporation and condensation back to the cold anode.

A more detailed description of the invention follows in conjunction with a drawing, whose single figure illustrates a cross section of one embodiment of a self oscillator in accordance with the invention. This oscillator will operate at any frequency to which the tuned output circuit is adjusted, up to some limit of frequency determined by the rapidity of evaporation and recondensation of the vaporizable material.

In the drawing, the tube shown has an anode A, the central portion C of which is kept cold by means of a cold circulated liquid which may be refrigerated. Condensed on the central portion C is a vaporized alkali or alkaline earth material which I believe may be chosen in the following order of preference: cesium, rubidium, potassium, sodium, barium, lithium, lanthanum, strontium, and mercury. If cesium is used, the temperature of the cold central part C of the anode should preferably be no higher than 20 degrees C. which would tend to hold the cesium vapor pressure in the main body of the tube to less than 0.001 micron. Above the anode A is shown a cathode K in the form of a disc of metal with a hole H through its center. Both the cathode and anode are shown equipped with shield cylinders S, S1 respectively to restrict vapors so as to make them condense more quickly and so as to keep them from being evaporated to any large extent onto the glass insulating parts G of the tube.

Above the cathode is a flat shield electrode S'' in the form of a metal disc or cup, and above it is a hot electron emitting filament F. These are intended to be so proportioned that electron emission is not drawn from the filament through the shield electrode S'' except when the potential of the cathode K is nearly as positive as the anode. This will occur at the peaks of the radio frequency potential developed across tuned circuit T. For this condition, electrons leaving the filament F are accelerated through the shield electrode S'' and cathode K and impinge upon the cold spot C of the anode A at velocities corresponding to the D. C. power supply potential. This results in a burst of cesium vapor, ionization of a portion of the vapor and a short circuit arc between anode A and cathode K, tending to drive the tuned circuit T connected with the cathode to a maximum amplitude of oscillation.

R is a current limiting resistor provided to assist in the cut-off of electron flow between filament F and anode A, and for safety purposes, while resistors R', R'' serve to shunt the leakage reactance of the filament transformer to prevent accidental damage thereto.

To facilitate starting of oscillations I have shown a choke L and by-pass condenser C' in the power connection to the cathode K, which serves to delay rise of negative cathode potential when the D. C. power is first applied. This permits initial bombardment of the anode to get oscillations started.

When D. C. power is first applied, the cathode K and anode A tend to have more or less equal potentials which differ from the potential on the filament F and shield electrode S''. This potential difference causes a bombardment of the anode A by electrons from the filament F. After the first burst of gas (assuming that the time constants of choke L and by-pass condenser C' are such that a substantial potential has been built up on C' at the time of the burst) the momentary short circuit of anode A and cathode K through the burst of vapor, sets up an oscillation in tuned circuit T. At the time of the pulse of current between anode A and cathode K, the condenser in the parallel tuned circuit T will be charged by current flowing through the tube (between A and K) thus lowering the potential between A and K. At the same time a gas discharge current between cathode K, shield S'' and filament F lowers their potential differences, by a potential drop in resistance R, thereby stopping electron bombardment of anode A by high voltage electrons for a time sufficient to allow the arc to be extinguished at the same time that the burst of vapor condenses on the tube surfaces. Therefore, the circuit between anode A and cathode K is interrupted and stays interrupted while the tuned circuit T performs approximately a cycle of oscillation. Shortly before the end of the cycle, the instantaneous potential across tuned circuit T will be in a direction tending to make cathode K maximum positive with respect to filament F and shield S''. At this time high potential electrons from filament F are caused to impinge upon region C of anode A to produce another burst of vapor and a pulse of current so timed as to increase and maintain the amplitude of oscillations in circuit T.

It will thus be seen that during oscillation, the deposit of activating material on the central part of the anode is bombarded by high velocity electrons from the filament, when the cathode is near being least negative (most positive) and this results in transient evaporation of material and a short circuit between anode and cathode similar to an arc discharge in conventional high power tubes. As the arc discharge ceases due to bringing the anode-to-cathode potential down to a very low value, the activating material recondenses. The short circuit current, which flows in pulses timed to develop high frequency output power, can reach almost unlimited peak values and flows with a small potential drop.

Output from tuned circuit T will be a low radio frequency or audio frequency continuous oscillations.

Although I have not illustrated it in the figure I contemplate also using control of the high potential electron bombardment of the semivolatile coating on anode A by means of pulsed, or alternating current potentials applied between the filament and shield combination F, S'' and the other electrodes. Thus the device may be used as the equivalent of the well known class C conventional amplifier but will provide much higher power conversion efficiency.

The tube electrodes may be made of a base metal of suitable material to match the thermal expansion of the glass but this metal may be coated or plated, or inlaid with other materials to increase electrical conductivity. Also the cathode K may be inlaid with a refractory metal such as tungsten, molybdenum or tantalum to re-

duce destructive effects of ion bombardment. In operation, flow of anode-to-cathode current should preferably be through gas which momentarily is so dense as to hold the arc voltage drop below the sputtering point for the cathode material. The sputtering point may be of the order of 22 volts. This requires that the impinging electrons to cause evaporation from the volatile material on portion C of the anode A represent enough current at a high enough potential to provide adequate vapor density and ionization.

In practicing the invention, peak anode-to-cathode currents ranging up into thousands of amperes are possible, and the amount of charge which can be passed between anode and cathode per cycle of oscillation may be limited only by the density of energy dissipation and the cooling. By allowing the electric charges, representing the anode to cathode current, to flow in pulses of very high current value, it is possible to approach complete ionization of the vapor at each pulse and this is an aid to causing very rapid recondensation of the vapor.

By means of the invention, D. C. input currents of over 100 amperes at 10,000 volts or more from the D. C. power supply might be handled by a quite moderate sized tube, capable of dissipating 1 or 2 kilowatts of lost power, and providing 1,000 kilowatts of power output at audio or low radio frequencies.

As a further modification of the tube shown in the figure I may provide an additional electrode which is kept cold instead of anode A and which is thereby caused to accumulate semivolatile material, this material being periodically subjected to electron bombardment. By this means the circuits for controlling the bursts of vapor may be kept more nearly separated from the discharge path which carries the main power current.

What is claimed is:

1. The method of operating a vacuum tube one of whose electrodes has a surface of a vaporizable material exposed to the vacuum, which comprises cooling a portion of the surface of the electrode to be the coldest part exposed to the vacuum, bombarding said portion with electrons to cause transient evaporation of the vaporizable material condensed on said portion, thereby permitting an arc discharge, and repeating said bombardment at controllable equally spaced intervals whose repetition rate is dependent upon the desired output frequency and the rapidity of evaporation and recondensation of the vaporizable material, and deriving energy from said intermittent arc to provide alternating electrical current output power.

2. The method of operating a vacuum tube having a source of electrons, a vaporizable material, an anode, and a cathode in the form of an apertured shield interposed between said source of electrons and anode, which comprises cooling the anode to make it the coldest surface exposed to the vacuum, to thereby cause evaporated vaporizable material to condense thereon, resonating said shield at a predetermined frequency, to thereby cause pulses of electrons from said source to bombard said anode and produce bursts of vapor to cause flash-overs between said shield and anode at the resonating frequency.

3. The method of operating a vacuum tube having an electron gun, an anode, and an apertured cathode interposed between said gun and said anode, and a tuned circuit connected between said cathode and anode, said tube having

vaporizable material on its interior surfaces, which comprises cooling said anode to make it the coldest surface exposed to the vacuum to thereby cause the vaporizable material to condense predominantly thereon, varying the potential of said cathode relative to said anode at the frequency of said tuned circuit, to thereby cause pulses of electrons from said gun to bombard said anode and produce bursts of vapor between said cathode and anode at the frequency of said tuned circuit, as a result of which the vaporizable material condensed on said anode is temporarily evaporated off by each pulse of electrons impacting said anode, and deriving energy from said bursts to drive said tuned circuit.

4. An electron discharge device system comprising a filament, an anode and an apertured disc-like cathode located between said filament and anode, a parallel tuned circuit connected at one end to said cathode and at its other end through a by-pass condenser to said anode, a source of D. C. potential having its negative terminal connected through a choke coil to said last end of said tuned circuit and its positive terminal connected to said anode, a connection from said negative terminal to said filament, and means for maintaining at least a portion of said anode the coolest surface within said device.

5. An electron discharge device system comprising a filament, an anode and an apertured disc-like cathode located between said filament and anode, all located with an evacuated envelope, a parallel tuned circuit connected at one end to said cathode and at its other end through a by-pass condenser to said anode, a source of D. C. potential having its negative terminal connected through a choke coil to said last end of said tuned circuit and its positive terminal connected to said anode, a connection from said negative terminal to said filament, and means for maintaining at least a portion of said anode the coolest surface exposed to said vacuum.

6. An electron discharge device oscillation generator comprising in the order named, a filament, a flat apertured shield, a flat apertured cathode, and an anode, all located within an evacuated envelope, a parallel tuned circuit connected at one end to said cathode and at its other end through a by-pass condenser to said anode, a source of D. C. potential having its negative terminal connected through a choke coil to said last end of said tuned circuit and its positive terminal connected to said anode, a connection from said negative terminal to said filament, a current limiting resistor in said connection, a connection from said filament to said apertured shield, means for maintaining the central portion of said anode which is in a straight line with said filament at a temperature colder than any other surface exposed to the vacuum, and an output circuit coupled to said tuned circuit.

7. A system in accordance with claim 4 including a pair of spaced concentric metal cylinder shields between the central portions of said anode and cathode, one of said shields being connected to said anode, and the other of said shields being connected to said cathode.

8. A device for controlling electrical discharges comprising an envelope having therein a filament, an electrode and a vaporizable material, means for maintaining at least a portion of said electrode the coolest surface exposed to the interior of said envelope, means for periodic evaporation and ionization of said vaporizable material to provide a temporary low resistance path for the

electrical current, said last means including a tuned circuit coupled to said electrode and a source of potential for producing a potential difference between said filament and electrode.

9. A device for controlling electrical discharges comprising an evacuated envelope having therein a pair of spaced electrodes, and a vaporizable material on one of said electrodes, cooling means for maintaining at least a portion of said one electrode the coolest part exposed to the vacuum, and means including a tuned circuit and a source of potential coupled between said electrodes for periodically evaporating and ionizing said vaporizable material to cause bursts of vapor between said electrodes.

10. A device for controlling electrical discharges comprising an evacuated envelope having therein a pair of spaced electrodes, and a vaporizable material, cooling means for maintaining at least a portion of one of said electrodes the coolest part exposed to the vacuum, means including a tuned circuit coupled between said electrodes for periodically evaporating and ionizing said vaporizable material to cause bursts of vapor between said electrodes, and shield means for restricting the area of said vapor between said electrodes.

11. An electric discharge tube comprising a filament and a pair of spaced substantially parallel electrodes, all within an envelope, insulating material separating said filament and electrodes from one another, the inner electrode of said pair being apertured to enable electrons from said filament to pass therethrough, an alkaline earth metal activating material within the interior of said envelope, said material being capable of transient evaporation when bombarded by electrons from said filament, and means including a tuned circuit and a source of potential coupled between said pair of electrodes for causing periodic evaporation and ionization of said material to thereby provide a temporary low resistance path for electric currents.

12. An electric discharge tube comprising a filament and a pair of spaced substantially parallel electrodes, all within an envelope, insulating material separating said filament and electrodes from one another, the inner electrode of said pair being apertured to enable electrons from said filament to pass therethrough, an alkaline earth metal activating material within the interior of said envelope supported by one of said electrodes of said pair, said material being capable of transient evaporation when bombarded by electrons from said filament, means for cooling said one electrode to thereby maintain it cooler than said other electrode and said filament, a parallel tuned

circuit coupled between said pair of electrodes, and means including a source of potential coupled between said pair of electrodes for causing periodic evaporation and ionization of said material to thereby provide a temporary low resistance path for electric currents.

13. An electron discharge device oscillation generator comprising in the order named, a filament, an apertured shield, a flat apertured cathode, and an anode, all located within an evacuated envelope, a parallel tuned circuit connected at one end to said cathode and at its other end through a by-pass condenser to said anode, a source of unidirectional potential having its negative terminal connected through a choke coil to said last end of said tuned circuit and its positive terminal connected to said anode, a connection from said negative terminal to said filament, a current limiting resistor in said connection, a connection from said filament to said apertured shield, means for cooling the central portion of said anode which is in a straight line with said filament vacuum colder than any other surface exposed to the vacuum, a metal cylindrical shield surrounding the central portion of said anode and extending toward but not reaching said cathode, and an output circuit coupled to said tuned circuit.

14. An electron discharge device system comprising a filament, an anode and an apertured disc-like cathode located between said filament and anode, all located with an evacuated envelope, a parallel tuned circuit connected at one end to said cathode and at its other end through a by-pass condenser to said anode, a source of D. C. potential having its negative terminal connected through a choke coil to said last end of said tuned circuit and its positive terminal connected to said anode, a connection from said negative terminal to said filament, means for cooling at least a portion of said anode, and a vaporizable material located on said portion of said anode within said envelope.

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