

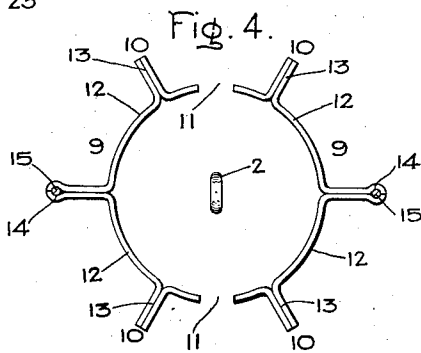
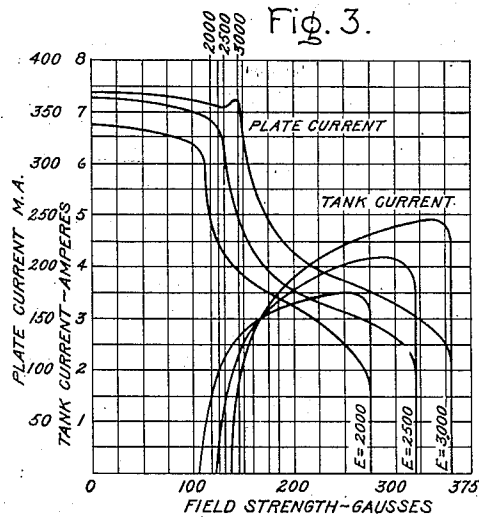
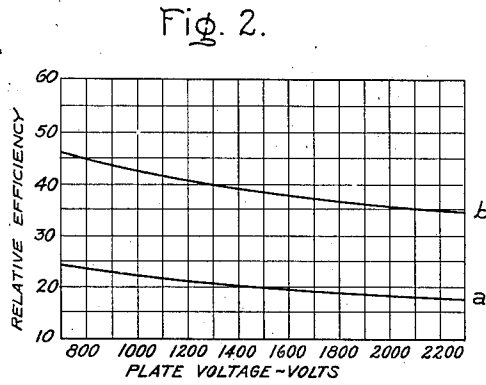
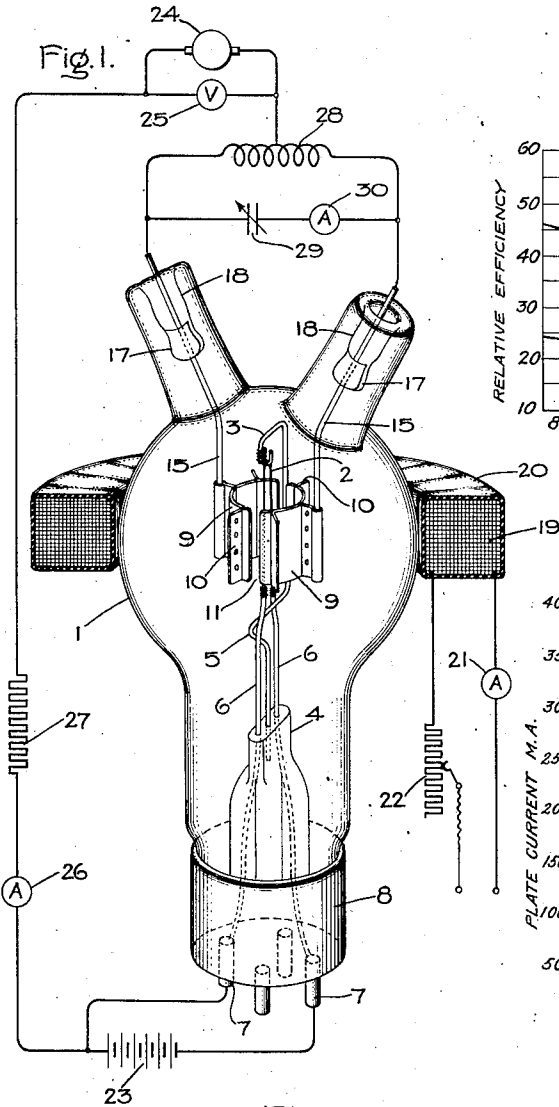
Nov. 29, 1932.

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1,889,595

ELECTRON DISCHARGE APPARATUS

Filed Oct. 8, 1929



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UNITED STATES PATENT OFFICE

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ELECTRON DISCHARGE APPARATUS

Application filed October 8, 1929. Serial No. 398,249.

The present invention relates to the construction and operation of electron discharge apparatus and more particularly to devices in which the direction and flow of electrons are controlled by combined magnetic and electrostatic fields in such a manner as to produce a negative resistance characteristic, indicative of the ability to produce amplification or oscillations when connected in appropriate circuits.

Apparatus of this character may comprise a source of electrons and one or more pairs of symmetrically arranged electron receiving surfaces, the travel of electrons being directed by a suitably applied electrostatic field and a supplementary magnetic field. The electron receiving surfaces constitute anodes which usually take the form of segments of a cylinder, while the source of electrons consists of a filament disposed in the longitudinal axis of the cylinder. A device of this sort may be termed, for convenience, a "split anode magnetron" and examples of such construction are described by H. Yagi in an article entitled "Beam transmission of ultra short waves" appearing in Proc. of the I. R. E. vol. 16, June 1928, pp. 735-6, and by K. Okabe in an article entitled "On short wave limit of magnetron oscillations" appearing in the Proc. of the I. R. E., vol 17, April 1929, pp. 652-659 inclusive. It is stated in these disclosures that the split anode magnetron offers an advantage over electrostatically controlled electron discharge devices in that the interelectrode capacity is comparatively small and hence when the device is connected in suitable circuits, oscillations of short wave lengths and of considerable amplitude may be generated.

In the usual form of split anode magnetron, the filament constitutes a single leg of substantially the same length as the anode and when it is desired to increase the filament emission for higher power output, a hairpin or spiral may be used in order to maintain the proper length of filament. The present invention is directed more particularly to the manner in which a filament of the hairpin type may be mounted.

An object of the invention is to arrange

a filament of an unsymmetrical shape and more especially of the hairpin type, in a novel and in the most advantageous position with respect to the cooperating anodes in a split anode magnetron with a view toward increasing the efficiency of the device.

The invention will be better understood when reference is made to the drawing in which Fig. 1 shows in elevation an improved form of magnetron with a solenoid in cross section and a schematic diagram of circuits which may be employed therewith; Figs. 2 and 3 are graphs depicting certain operating characteristics of the magnetron; while Fig. 4 is a top plan view of the electrode organization.

Referring to Fig. 1, numeral 1 designates a highly evacuated envelope containing a cathode in the form of a longitudinally disposed hairpin filament 2 supported on the upper end by a hook-shaped member 3 which overhangs the filament and extends vertically downward to the press 4. The upright portion of the member 3 is provided with a transversely extending loop 5 in order to offer flexibility to the member, thereby to maintain the filament 2 taut. The lower ends of the filament are bound to a pair of upright wires 6, 6 sealed in the press and extended to a pair of contact pins 7, 7 secured in the base 8.

The anodes 9, 9 constitute segments of a cylinder and are provided with heat radiating fins 10, the anodes being arranged in an approximate symmetrical manner about the filament 2, leaving a slot or opening 11 on both sides of the filament as shown more clearly in Fig. 4. The anodes may be fabricated in any suitable manner but I have found it convenient to form these members of a plurality of segments 12 each provided with radially extending flanges 13 which may be riveted together to constitute the heat radiating fin 10. The juxtaposed flanges at the middle of each anode are extended to form an eyelet 14 through which is passed a rod 15 for positioning each electrode in the envelope. The rods are fused in presses 17, which terminate in a pair of reentrant stems 18 and are extended through the envelope to con-

nect with external circuits. Supported in any suitable manner about the envelope 1, there is a cylindrical coil or solenoid 19 composed of many turns of wire having an outside layer 20 of insulating material such as tape. The coil may be energized by a source of direct current (not shown) through an ammeter 21 and a variable resistor 22. A source of direct current 23 is provided for supplying current to the filament while the anode current may be obtained from a relatively high voltage direct current source 24 shown for convenience in the form of a generator. The anode circuit also includes a volt meter 25 connected across the generator, an ammeter 26 and a current limiting resistance 27 connected in series. Across the anodes 9, 9 there is connected a high frequency oscillation circuit commonly called the "tank circuit" and consisting of an inductance 28 and an adjustable condenser 29 with an ammeter 30 for measuring tank or load current. The positive side of the source 24 is connected to the inductance, preferably at the mid-tap as shown.

It is apparent that the magnetic lines of force produced by the solenoid 19 thread the space between each anode and the filament in a direction parallel to the latter and it can be shown by operation that when potentials of proper magnitude are impressed on the electrodes and solenoid, oscillations may be produced in the circuit 28, 29, the frequency of which is determined by the electrical constants of the circuit. This frequency may be very high so that the magnetron will generate oscillations of exceedingly short wave lengths, for example of the order of a few meters or even less than a meter.

Fig. 3 is a graph which depicts exemplary static and dynamic characteristics of the split anode type of magnetron. In this figure the ordinates represent the values of plate current as measured by the milli-ammeter 26 and also the values of tank or oscillatory current as indicated by the ammeter 30, while the abscissas represent the values of the field strength of the solenoid 19 which may be controlled by the variable resistance 22. A curve is plotted against each of the two ordinates and the common abscissa for three typical voltages, 2000, 2500 and 3000 applied between the mid-tap of the inductance 28 and the cathode, if the voltage drop in resistance 27 is neglected. In other words, there is a pair of curves for each direct current voltage applied to the anodes, one of the curves showing the relation between the plate current and field strength and the other of the pair showing the relation between the tank current and the field strength. It will be noted from the graph that no tank or oscillatory current is generated in the device until the field strength is increased practically to the theoretical "cut-off" value so-called, which

in the case of the 2000 volt curve is in the neighborhood of 115 gauss, in the 2500 volt curve is approximately 130 gauss and in the 3000 volt curve is 145 gauss. The tank current starts to flow just before the theoretical cut-off value is reached and increases very rapidly at first, then somewhat slower until a maximum is reached, after which the oscillations suddenly cease.

During the generation of oscillations, the operation of the circuits is such that each of the electrodes 9 constitute a predominantly positive member for a portion of the time in an alternate manner and if the greatest tube efficiency is desired it is desirable to constrain the electron stream as a body to impinge, first on one electrode and then on the other depending on which is operating for the moment as the anode proper. It has been found in accordance with my invention that when hairpin filaments are utilized as a source of electrons in magnetrons of this type, there is a decided difference in efficiency as to the manner in which the filament is mounted with respect to the position of the anodes. It appears that when the plane of the filament is in line with the anodes, i. e. so that a straight line passing through each of the legs of the hairpin intersects with a portion of the oppositely disposed anodes, the leg of the filament remote from the predominantly positive member contributes little or no electrons to such member. The electrons from this filament leg tend to be attracted to the nearest and less positive electrode, hence are lost insofar as useful current is concerned. I have discovered the most advantageous position of a hairpin filament in order to offset this deleterious effect to be directly opposite the slots or openings between the anodes as clearly shown in Fig. 4, i. e. displaced 90° from the position in line with the middle portions of the anodes. It is apparent that under these conditions both filament legs are at substantially the same distance from each anode and the predominantly positive electrode tends to draw electrons from all portions of the filament. When the filament is positioned in accordance with my invention, the electron stream travels more nearly as a complete body toward the electrode momentarily operating as the anode thus allowing the maximum amount of current to flow first to one anode and then to the other anode. Fig. 2 graphically shows the advantage of placing the hairpin in line with the slots over the position of being in line with the anodes. In this figure, curve *a* which is plotted against tube efficiency as an ordinate, i. e.

Output in watts
Input in watts

and various values of direct current voltage applied by the source 24 as abscissas, shows that in a typical magnetron in which a hair-

pin filament is disposed in line with the anodes the maximum efficiency obtainable at a plate voltage of 700 is approximately 24% and at a voltage of 2300 in the neighborhood of 15%. On the other hand, when the hairpin is turned 90° from this position so as to lie in line with the anode slots in accordance with the present invention, the efficiency at 700 volts increases to approximately 46% and at 2300 volts to 35% with corresponding increases throughout the useful range of plate voltages, an increase in efficiency of more than twice.

While I have explained my invention more particularly with reference to a hairpin type of filament, it is obvious that the advantages of the discovery apply to all forms of cathodes which are normally unsymmetrical and in which one portion of the filament would ordinarily be in closer proximity to one of the anodes than to the other. The teachings of the present invention clearly show that it is advantageous to present a line of symmetry for the cathode construction through the slots positioned between the anodes.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a device for generating oscillations, an evacuated envelope containing a cathode, a plurality of curvilinear anodes separated by oppositely disposed slots and arranged about the cathode, an oscillating circuit connected between the anodes and cathode, means for producing a magnetic field which threads the space between the anodes and cathode, means for supplying energy to the cathode and to said circuit, said cathode being constituted of a filament having a plurality of legs arranged substantially in line with the slots between the anodes.

2. In electron discharge apparatus, an elongated evacuated envelope containing a cathode disposed longitudinally of the envelope, a plurality of anodes separated by oppositely disposed slots and arranged about the cathode, said anodes comprising segments of a cylinder, a translating circuit connected between the anodes and the cathode, said anodes being constituted of segments and provided with heat radiating fins, means for producing a magnetic field which threads the space between the anodes and the cathode, means for supplying energy to the cathode, to said circuit and to the magnetic field means, said cathode being constituted in the form of a hairpin, the legs of which are arranged substantially in line with the slots between the anodes.

3. In an electron discharge device, an evacuated envelope containing a filamentary member, a plurality of curvilinear electrodes separated by oppositely disposed slots and arranged about the said member, the filament being constituted of a plurality of legs ar-

anged substantially in line with the slots and adapted to cooperate with the said electrodes, means for producing a magnetic field which threads the space between the electrodes and the filament, and means for energizing the said electrodes and filament.

4. In an electron discharge device, adapted to produce oscillations, an evacuated envelope containing a filamentary member, a plurality of electrodes separated by oppositely disposed slots and arranged about the said member, said electrodes comprising segments of a cylinder, the filament being constituted of a plurality of legs arranged substantially in line with the slots and adapted to cooperate with the said electrodes, an oscillating circuit connected between said electrodes and the filament, means for producing a magnetic field which threads the space between the electrodes and the filament, and means for energizing the filament and the electrodes.

5. An electron discharge device comprising an evacuated envelope containing a pair of anodes, each of which is of substantially semi-cylindrical form, a solenoid surrounding said device, said anodes being arranged to form a hollow cylinder having a pair of diametrically opposite longitudinal openings, a cathode located within said cylinder and comprising a plurality of filament legs arranged substantially in line with said openings, an oscillating circuit connected between said electrodes and the filament, and separate leading-in conductors for each of said anodes sealed into said envelope.

In witness whereof, I have hereunto set my hand this 7th day of October, 1929.

KENNETH C. DE WALT.