April 26, 1949. C. G. SMITH 2,468,127

OSCILLATOR

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FIG. 1.

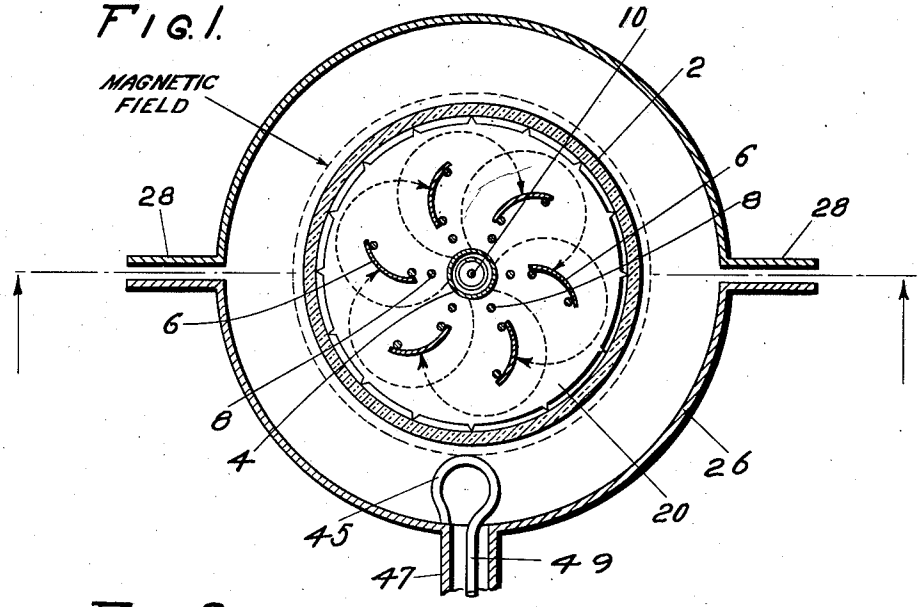
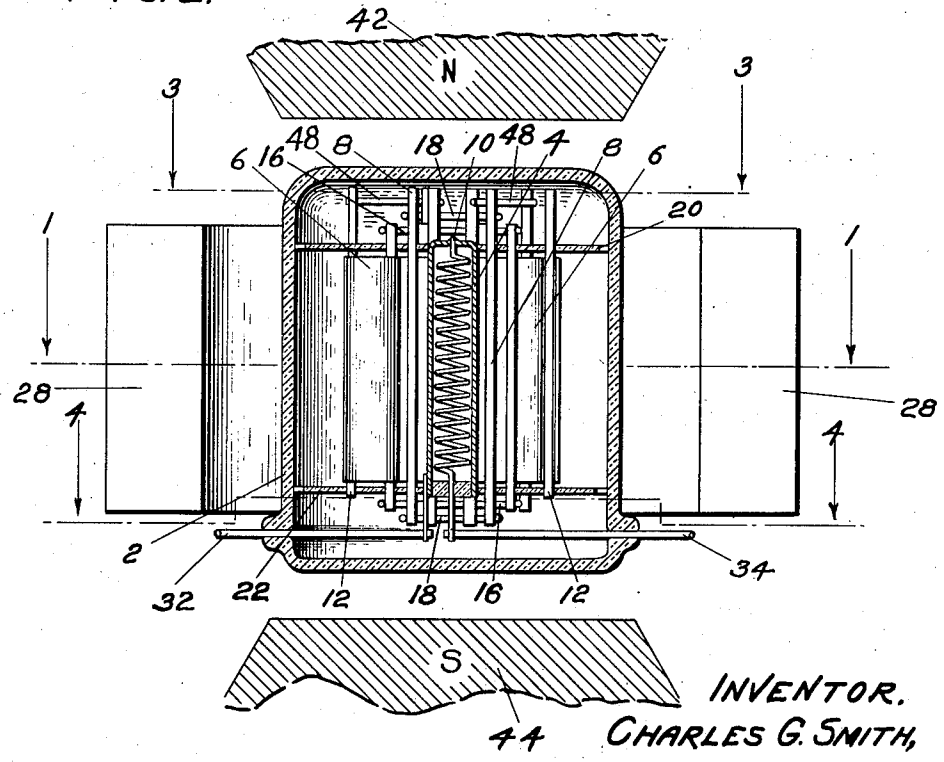


FIG. 2.



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FIG. 3.

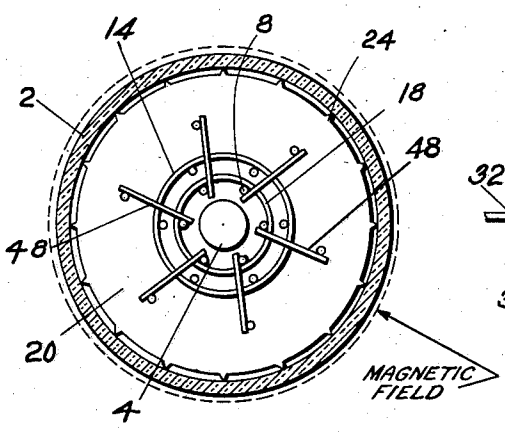


FIG. 4.

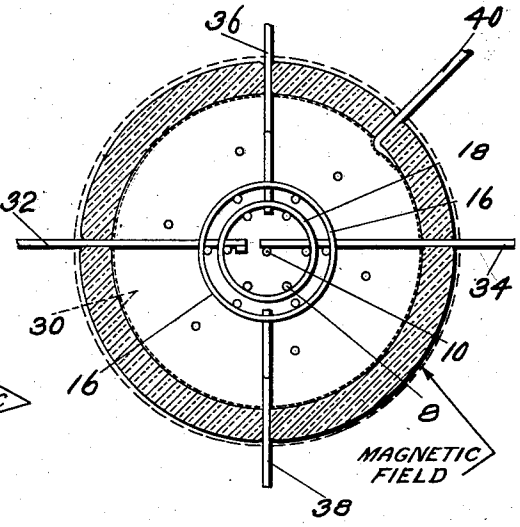


FIG. 5.

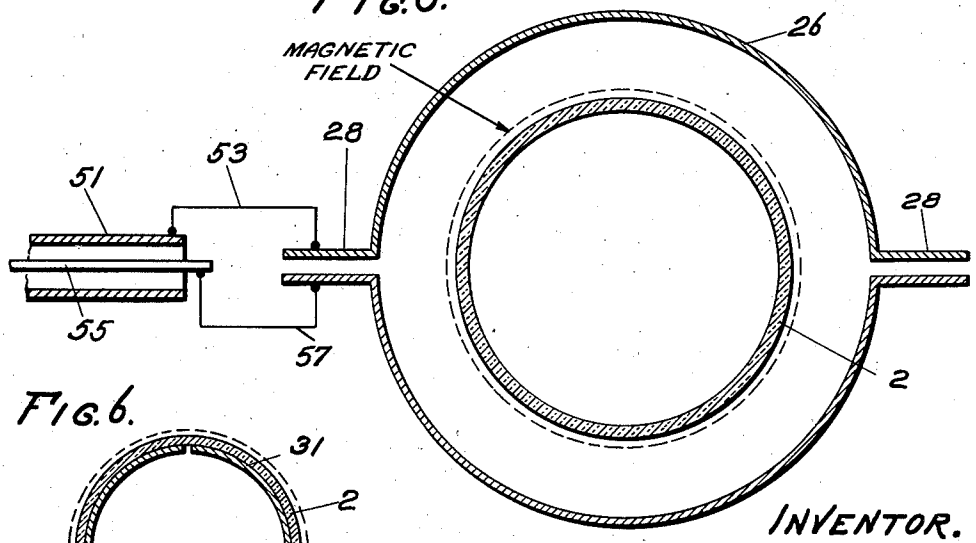
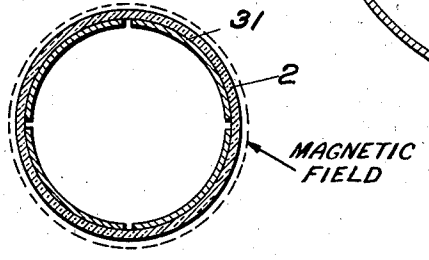


FIG. 6.



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FIG. 7

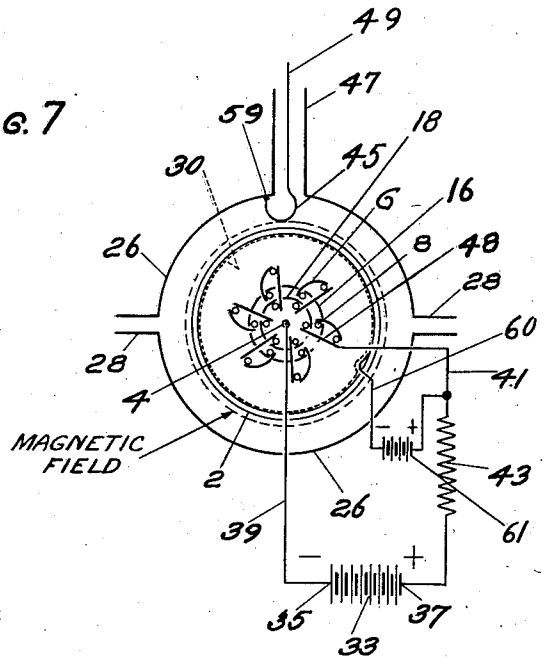
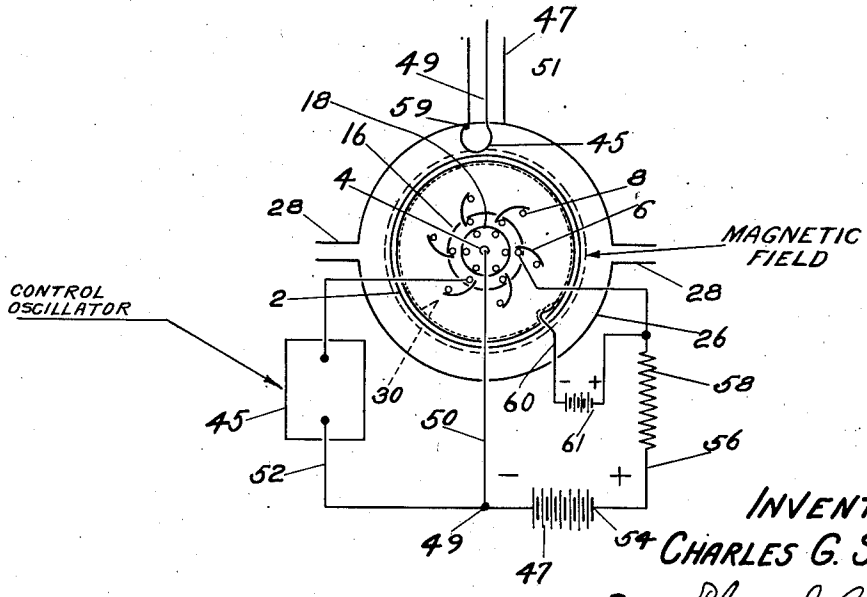


FIG. 8.



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UNITED STATES PATENT OFFICE

2,468,127

OSCILLATOR

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Application December 24, 1943, Serial No. 515,577

11 Claims. (Cl. 250—36)

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This invention relates to oscillators and more particularly to high frequency oscillators.

One of the objects of the present invention is to produce an oscillator in which practically the entire energy of the electron in flight is utilized.

Another object of the invention is to produce an oscillator in which the construction and arrangement are such that sharp pulsations of the grid voltage produce steady power pulsations in the induced oscillatory circuit.

Another object of the invention is to produce an oscillator in which electronic energy is coupled to an oscillating circuit by a magnetic coupling.

Another object of the invention is to produce an oscillator in which electronic energy is coupled to the oscillatory circuit by a magnetic coupling and through an insulating medium.

A further object of the invention is to produce a device in which very high frequency electric power can be fed advantageously through an insulating medium without overheating said medium.

These and such other aims and objects of the invention as may hereinafter appear will be readily understood from the following description, taken in connection with the accompanying drawing of one embodiment of the invention herein submitted for illustrative purposes.

In the drawing:

Fig. 1 is a horizontal cross-section on line 1—1 of Fig. 2 of one illustrative embodiment of the invention;

Fig. 2 is a vertical section on line 2—2 of Fig. 1;

Fig. 3 is a top plan view, partly in section, on line 3—3 of Fig. 2;

Fig. 4 is a bottom view, partly in section, on line 4—4 of Fig. 2;

Fig. 5 shows a modified output coupling;

Fig. 6 shows a broken partition for preventing electrostatic forces in the region of travel of the electrons;

Fig. 7 shows a circuit for a self-excited oscillator; and

Fig. 8 shows a circuit for an externally excited oscillator.

The illustrative embodiment of the invention shown in the drawing comprises an envelope 2 of any suitable material containing the electrode assembly including a cathode 4, a split anode, consisting of a plurality of transversely curved plates 6, and a grid 8 suitably mounted between said cathode and said anode plates. Herein said envelope 2 is made of glass and said cathode will preferably be cylindrical and contain a heater

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coil 10. The anode plates 6 are carried by electrically conductive rods 12 connected at top and bottom by circular conductors 14 and 16, (see Figs. 3 and 4), and one longitudinal edge of each anode plate 6 extends adjacent and parallel to the grid 8, the grid members of which are similarly electrically connected at top and bottom by circular conductors 18, (see Figs. 2, 3 and 4). The upper and lower ends of said rods 12 engage holes in top and bottom spacing members 20 and 22, respectively, of mica or other suitable insulating material, said spacing members being provided about their perimeters with a plurality of suitably spaced resilient tooth-like members 24 adapted yieldingly to engage the inner wall of said envelope 2. Means are herein provided constituting an oscillatory circuit, said means herein illustratively comprising a cylindrical structure 26 of copper or other suitable electrically-conductive material herein illustratively surrounding said envelope 2 and comprising two semi-cylindrical portions connected by condenser plates 28.

The average potential of said structure 26 is substantially that of the anode plates 6.

In accordance with the present invention means may be provided in some cases to render the region in which the electrons travel substantially free from superposed electrostatic forces such, for example, as might be produced by bombardment of the inner wall of said envelope by electrons. Such means might illustratively comprise a coating or film of a high resistance substance, such as carbon, on the inner surface of said envelope, as shown at 30 in Fig. 4, or a broken partition of non-magnetic conductive material 31, as shown in Fig. 6, near the inner surface of said envelope.

Referring to Fig. 4, the cathode heater coil 10 is connected to lead-in conductor 32 and conductor 34. Conductor 32 also supplies said cathode 4, and lead-in conductors 36 and 38 are joined, respectively, to lower circular conductor 18, connecting the grid members 8, and to the lower circular conductor 16, connecting the anode plates 6. A conductor 40 leads into said film of carbon 30, (see Fig. 4), or to said broken partion 31, as the case may be.

The invention contemplates the use of any suitable means for producing a moderate magnetic field substantially parallel to said cathode 4 within the apparatus. Said means herein illustratively comprises magnet pole pieces 42 and 44, suitably located one above and the other below said envelope 2, (see Fig. 2). In some cases

it may be desirable to make the field very slightly concave on the side toward the cathode, but the departure of said field from parallelism with the cathode is so very slight that substantial parallelism exists.

The high frequency energy developed by the apparatus is conveniently coupled directly to the output by any suitable means. In Figs. 1, 7 and 8 is shown a convenient coupling comprising a loop **45** magnetically coupled to the oscillating current and having one end connected to said oscillatory circuit **26** and the other to a rod **49** coaxial with a tubular wave guide **47** connected to the oscillatory circuit **26**.

In Fig. 5 is shown a modified coupling for this purpose, which comprises tubular wave guide **51**, connected by a conductor **53** to one of the condenser plates of condenser **28**, and a rod **55** coaxial with said wave guide, connected by a conductor **57** to the other plate of condenser **28**. The high frequency energy will thus be directly coupled to the output.

If the electrons are emitted in sharp pulsations from said cathode with proper frequency, the resultant electron current will induce oscillations in the oscillatory circuit comprising said cylindrical structure **26**, and it will be apparent that the longer the flight of the electrons, the longer will be their inductive action upon said oscillatory circuit and the stronger will be the oscillatory current induced in said circuit. The grid **8** provides a convenient means for securing such sharp pulses of electron emission. The cathode **4** is adapted to emit electrons continuously. Thus when no electron emission into the space beyond the grid is desired, a suitable negative voltage on the grid will prevent such electron emission. When a pulse of electrons is desired, the grid **8** is driven more positive by a suitable control voltage, and under these conditions the desired pulse of electrons will be emitted into the space beyond the grid. As pointed out above, to produce the oscillations it is necessary only that the electrons be emitted in sharp pulses. The period during which the grid permits electrons to pass through it, therefore only need be a small fraction of a half cycle of the oscillations produced in the outer oscillating circut.

The magnetic field created by said pole pieces **42** and **44** is availed of to divert the individual electrons of the electron stream emanating from the cathode **4** from their normal courses and to constrain them to follow curvilinear paths, substantially as indicated by dotted lines in Fig. 1. These individual curvilinear paths together form in effect a circulatory current of electrons within said envelope and the electrons in this current will thus travel longer paths than they normally would. In addition to this increase in the oscillatory current due to the prolongation of the flight of the electrons by the action of said magnetic field, their flight is still further prolonged owing to the fact that the oscillatory current induced in said oscillatory circuit, as it reacts upon said electron current by electro-magnetic induction, tends to retard their flight, thus still further prolonging their inductive action.

In accordance with the present invention the relative adjustment of the magnetic field and the voltage applied between the cathode and anode will preferably be such that the time of travel of an electron will substantially equal the time of a whole half cycle of the induced oscillatory current, so that by the time an electron reaches the anode it will have given up practically all its energy for the induction of said oscillatory current. Also with such an adjustment, the sharp, square wave impulses upon the grid, while they produce sharp impulses of electron current, that is to say at a predetermined frequency and lasting only during a minor portion of a half cycle of the oscillatory circuit, cause only steady, approximately sinusoidal impulses throughout substantially a whole half cycle of said oscillatory current. These factors make practicable the production of oscillatory power without a great amount of energy going into harmonics of the desired frequency, and add greatly to the efficiency and output of the apparatus and therefore to the practical value of the present invention. Wave lengths of the order of one meter are readily produced, so that single tubes of very large capacity appear possible by the use of applicant's invention.

The electronic space charge is equal to the plus charges on the anode plates and on other elements of the structure surrounding the electronic orbits. These can be made very large and therefore the electron current can be large. It follows that the present invention should make possible the production of oscillators of very great power and efficiency.

It will be noted that the present invention couples the electronic energy to radiation by the magnetic field created by the electrons in flight. This is a distinct advantage as it does away with certain objectionable features incidental to electrostatic couplings, such, for example, as heavy stresses and consequent dielectric losses. It will also be noted that the magnetic coupling can be effected through glass, without overheating the glass. Applicant's invention therefore teaches that very high frequency electric power can be fed advantageously through an insulating medium without overheating said medium. This is due chiefly to the absence of the heavy stresses above referred to.

From the above disclosure it would appear that the present tube is especially adapted to efficient generation of power over a considerable range of frequencies. It can be readily made in large sizes.

For some purposes the grid structure may be electrically connected to the anode plates through loops **48**. Such a connection is shown in Figs. 3 and 7. Voltages induced magnetically in these loops swing the grid through a desired voltage variation.

Fig. 7 shows an illustrative circuit for a self-excited oscillator embodying the present invention. The parts are shown only diagrammatically. A suitable source of voltage, a battery **33**, for example, has its negative pole **35** directly connected to the cathode **4** by conductor **39**, and its positive pole **37** connected to the anode plates **6** through the conductor **41** and circular conductor **16** connecting said plates. The anode plates are connected to the grid members **8** by the above-mentioned loops **48**. As above stated, voltages induced magnetically in these loops swing the grid through a desired voltage variation. A suitable controlling or restraining resistance **43** will preferably be inserted in the circuit.

Fig. 8 shows an illustrative circuit for an externally-excited oscillator embodying the present invention. In this circuit the loops **48**, connecting the grid members to the anode plates for swinging the grid through the desired voltage variation by the voltages magnetically induced therein, are omitted and an external control

oscillator, diagrammatically shown at 45, is substituted for that purpose. A suitable source of voltage, a battery 47, for example, has its negative pole 49 connected to the cathode 4 by conductor 50 and to the grid member 8 by conductor 52 through said control oscillator 45. The positive pole 54 of said battery is connected to the anode plates 6 by conductor 56 and the circular conductor 16 connecting said anodes. Said conductor 56 will preferably contain a controlling or restraining resistance 58.

In both Fig. 7 and Fig. 8 the grid members are interconnected by the circular conductor 18 and the anode plates 6 are interconnected by the circular conductor 16. The cylindrical structure 26 herein illustratively forming the oscillatory circuit comprising condenser plates 28 surrounds the envelope 2 containing the electrode assembly and is provided with a coupling for coupling the high frequency energy developed by the apparatus directly to the output. This coupling may be the same as that shown in Fig. 1 and comprises a loop 45 magnetically coupled to the electron current and having one end connected to the oscillatory circuit 26 at 59 and its other end connected to a conductor rod 49 coaxial with the tubular wave guide 47, coaxially surrounding said rod 49 and connected to said oscillatory circuit 26. A lead 60 connects the film 30 to the conductor 41 through a small battery 61. The broken partition 31, shown at Fig. 6, may be similarly connected.

Wherever the word "plurality" occurs in the specification and claims, said word is to be understood as meaning "two or more."

I am aware that the present invention can be embodied in other specific forms without departing from the spirit or essential attributes thereof, and therefore desire the present description to be considered in all respects as illustrative and not restrictive, reference being had to the appended claims rather than to the aforesaid description to indicate the scope of the invention.

What is claimed is:

1. The combination of a cathode adapted to emit electrons, a series of anode elements positioned circularly of said cathode, and means comprising a grid between said cathode and said anode elements to cause the electrons emitted by said cathode to flow toward said anode elements in pulsations, means for creating a magnetic field parallel to said cathode for diverting the electrons emitted from said cathode from normal rectilinear paths and causing them to flow in a circulatory stream and create a magnetic field substantially parallel with the axis of flow of said circulatory stream, and an oscillatory circuit magnetically coupled to said magnetic field created by said circulatory stream, to transfer energy from said electron stream to said oscillatory circuit.

2. In an electric oscillator, the combination of an envelope containing a cathode adapted to emit electrons, an anode assembly comprising a series of anode elements around said cathode, and a grid between said cathode and said anode assembly, means comprising said grid to cause the electrons emitted by said cathode to flow toward said anode assembly in pulsations, means to maintain a magnetic field within said envelope substantially parallel to said cathode for diverting the electrons emitted by said cathode from normal rectilinear paths and causing them to flow in a circulatory stream and create a magnetic field substantially parallel with the axis of flow of said circulatory stream, an oscillatory circuit magnetically coupled to said magnetic field thus created, to transfer energy from said electron stream to said oscillatory circuit, and means for rendering the regions in which the electrons travel free from superposed electrostatic forces.

3. In an electric oscillator, the combination of an envelope containing a cathode adapted to emit electrons, an anode assembly comprising a series of anode elements around said cathode, and a grid between said cathode and said anode assembly, means comprising said grid to cause the electrons emitted by said cathode to flow toward said anode assembly in pulsations, means for maintaining a magnetic field within said envelope substantially parallel to said cathode for diverting the electrons emitted by said cathode from normal rectilinear paths and causing them to flow in a circulatory stream and create a magnetic field substantially parallel with the axis of flow of said circulatory stream, an oscillatory circuit magnetically coupled to said magnetic field thus created, to transfer energy from said electron stream to said oscillatory circuit, and a high resistance coating upon the inner surface of said envelope to render the regions in which the electrons travel substantially free from superposed electrostatic forces.

4. In an electric oscillator, the combination of an envelope containing a cathode adapted to emit electrons, an anode assembly comprising a series of anode elements around said cathode, and a grid between said cathode and said anode assembly, means comprising said grid to cause the electrons emitted by said cathode to flow toward said anode assembly in pulsations, means for maintaining a magnetic field within said envelope substantially parallel to said cathode for diverting the electrons emitted by said cathode from normal rectilinear paths and causing them to flow in a circulatory stream and create a magnetic field substantially parallel with the axis of the flow of said circulatory stream, an oscillatory circuit magnetically coupled to said magnetic field thus created, to transfer energy from said electron stream to said oscillatory circuit, and a broken partition of non-magnetic conductive material adjacent the inner surface of said envelope to prevent bombardment of said surface by electrons.

5. In an electric oscillator, the combination of an envelope containing a cathode adapted to emit electrons, an anode assembly comprising a series of transversely curved anode elements suitably spaced around said cathode, and a grid between said cathode and said anode assembly, means comprising said grid to cause the electrons emitted from said cathode to flow toward said anode elements in pulsations, means for maintaining a magnetic field within said envelope substantially parallel to said cathode for diverting the electrons emitted by said cathode from normal rectilinear paths and causing them to flow in a circulatory stream and create a magnetic field substantially parallel with the axis of flow of said circulatory stream, and an oscillatory circuit magnetically coupled to said magnetic field thus created, to transfer energy from said electron stream to said oscillatory circuit.

6. In an electric oscillator, the combination of an envelope containing a cathode adapted to emit electrons, an anode assembly comprising a series of anode elements all transversely curved in the same direction and suitably spaced around said cathode, and a grid between said cathode and said anode assembly, means comprising said grid to

cause the electrons emitted by said cathode to flow toward said anode elements in pulsations, means for maintaining a magnetic field within said envelope substantially parallel to said cathode for diverting the electrons emitted from said cathode from normal rectilinear paths and causing them to flow in a circulatory stream and create a magnetic field substantially parallel with the axis of flow of said circulatory stream, and an oscillatory circuit magnetically coupled to said magnetic field thus created, to transfer energy from said electron stream to said oscillatory circuit.

7. In an electric oscillator, the combination of an envelope containing a cathode adapted to emit electrons, an anode assembly comprising a series of anode elements suitably spaced around said cathode, and a grid between said cathode and said anode assembly, means comprising said grid to cause the electrons emitted by said cathode to flow toward said anode elements in pulsations, means for maintaining a magnetic field within said envelope substantially parallel to said cathode for diverting the electrons emitted by said cathode from normal rectilinear paths and causing them to flow in a circulatory stream and create a magnetic field substantially parallel with the axis of flow of said circulatory stream, said anode elements being all transversely curved in the general direction of flow of said circulatory stream, and an oscillatory circuit magnetically coupled to said magnetic field thus created, to transfer energy from said electron stream to said oscillatory circuit.

8. The combination of a cathode adapted to emit electrons, an anode assembly adjacent said cathode, means to cause the electrons emitted by said cathode to flow toward said anode assembly in pulsations, means for diverting the electrons emitted by said cathode from normal rectilinear paths and causing them to flow in a circulatory stream and create a magnetic field substantially parallel with the axis of flow of said circulatory stream, an insulating medium, and an oscillatory circuit magnetically coupled to said magnetic field through said insulating medium, to transfer energy from said electron stream to said oscillatory circuit through said insulating medium.

9. The combination of a cathode adapted to emit electrons, an anode assembly comprising a series of transversely curved anode elements suitably spaced around said cathode, means to cause the electrons emitted by said cathode to flow toward said anode elements in pulsations, means for diverting the electrons emitted by said cathode from normal rectilinear paths and causing them to flow in a circulatory stream and create a magnetic field substantially parallel with the axis of flow of said circulatory stream, and an

oscillatory circuit magnetically coupled to said magnetic field thus created, to transfer energy from said electron stream to said oscillatory circuit.

10. The combination of a cathode adapted to emit electrons, an anode assembly comprising a series of anode elements suitably spaced around said cathode and transversely curved in the same direction, means to cause the electrons emitted from said cathode to flow toward said anode elements in pulsations, means for diverting the electrons emitted by said cathode from normal rectilinear paths and causing them to flow in a circulatory stream and create a magnetic field substantially parallel with the axis of the flow of said circulatory stream, and an oscillatory circuit magnetically coupled to said magnetic field thus created, to transfer energy from said electron stream to said oscillatory circuit.

11. The combination of a cathode adapted to emit electrons, an anode assembly comprising a series of anode elements suitably spaced around said cathode, means to cause the electrons emitted by said cathode to flow toward said anode elements in pulsations, means for diverting the electrons emitted by said cathode from normal rectilinear paths and causing them to flow in a circulatory stream and create a magnetic field substantially parallel with the axis of flow of said circulatory stream, said anode elements being all curved in the direction of flow of said stream, and an oscillatory circuit magnetically coupled to said magnetic field created by said circulatory stream, to transfer energy from said electron stream to said oscillatory circuit.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,219,961	Langmuir	Mar. 20, 1917
2,093,683	Lindenblad	Sept. 21, 1937
2,099,533	Prinz	Nov. 16, 1937
2,163,756	Llewellyn	June 27, 1939
2,178,056	Taylor	Oct. 31, 1939
2,196,392	Hansell	Apr. 9, 1940
2,233,263	Linder	Feb. 25, 1941
2,250,511	Varian	July 29, 1941
2,256,608	Braden	Sept. 23, 1941
2,259,690	Hansen	Oct. 21, 1941
2,264,858	Record	Dec. 2, 1941
2,272,165	Varian	Feb. 3, 1942
2,281,935	Hansen	May 5, 1942
2,289,319	Strobel	July 7, 1942
2,342,263	Fremlin	Feb. 22, 1944