This invention relates to electronic oscillators, and particularly to oscillators wherein the electron flow is derived, substantially in its entirety, from so-called "secondary electrons" liberated from solid conductors by bombardment.

The primary object of this invention is to provide a new type of electronic oscillator. Among the other objects are: To provide an oscillator which will convert direct current energy at extremely high efficiencies; to provide an oscillator which is substantially free from frequency limitations, and is particularly adapted to the generation of oscillations at frequencies above 30 megacycles; to provide a type of oscillator which is equally well adapted for the generation of either very small or very large amounts of power; to provide an oscillator wherein the electrical circuits are symmetrical, so that the neutral point of the circuit may be grounded without introducing difficulties or complications; to provide an oscillator of the high vacuum type, which is independent of ionization phenomena and is not subject to the instabilities and inconsistencies which such phenomena introduce; to provide an oscillator which is easily "triggered off"; and to provide an oscillator having no heated electrode of the thermionic type, and which is correspondingly free of the difficulties and complications introduced by cathode heating circuits.

Other objects of my invention will be apparent or will be specifically pointed out in the description forming a part of this specification, but I do not limit myself to the embodiment of the invention herein described, as various forms may be adopted within the scope of the claims.

Referring to the drawings:

Figure 1 is a schematic diagram showing one form of the oscillator of my invention, including the oscillating tube and its associated circuits.

Figure 2 is a diagram showing a modification of the form of oscillator shown in Figure 1, wherein the amplitude of oscillation is self-limiting.

Figure 3 is a cross sectional view showing an oscillating tube surrounded by a permanent magnet guiding-field structure.

Figure 4 is a cross sectional view of a modified form of the tube which will generate oscillations without the use of a guiding or focusing field.

Figure 5 is a circuit diagram illustrating a tube of the type shown in Figure 4 with a different type of oscillating circuit from that shown in Figure 1.

Figure 6 is a schematic diagram showing a modified form of my invention wherein an asymmetrical tube and circuit are employed.

Figure 7 is a graph showing the characteristic form of a secondary emission curve.

In my copending application, Serial Number 622,585, filed October 7, 1933, I have described an electron multiplying device wherein, by utilizing the phenomena of secondary electron emission, extremely small currents may be multiplied to give very large final outputs. The initial current necessary in this apparatus may be so small as to be immeasurable by any ordinary method, e.g., the photoelectric current emitted from nickel by light in the visible spectrum. I have there pointed out the regenerative nature of the multiplication, stating that by back coupling the output of this device into its input, self-sustaining oscillations can be produced. This application specifically relates to the production of such self-sustaining oscillations by the method therein indicated.

Considered in its broad aspect, the essential features of the invention comprise a pair of electrodes defining an electron path. A cloud of electrons oscillated along this path by potentials applied to the electrodes, and striking one of them, which may be termed cathode, with sufficient velocity to release secondary electrons at a ratio greater than unity as compared with the impacting primary electrons, causes a current flow from a d-c source of potential included in a circuit with the electrodes. A potential drop due to this current is applied in phase to apply the necessary impacting velocity to the oscillating cloud of electrons, and thus the oscillation becomes self-sustaining and relatively large amounts of oscillating power may be withdrawn from the circuit. The energy for maintaining the oscillation is, of course, derived from the d-c source, which must be sufficiently high in potential to release the secondary electrons at the required ratio.

For the oscillations to be self-starting as well as self-sustaining, the requirements are somewhat more rigorous. If an exciting oscillation of sufficiently high voltage be applied initially, there will be enough casual electrons present in the space between the electrodes to build up the secondary emission currents of the value required to produce the necessary voltage drop with almost any electrode material, provided the electrons are sufficiently accurately guided along their path so that there is little probability of their being collected before they strike the cathode. In order that the oscillations be self-starting, however, the work function of the cathode surface should be
as low as possible, and for this reason it is preferred to provide the cathodes with surfaces of photoelectric material, such as the alkali metals, potassium hydride, or the extremely sensitive caesium silver oxide surfaces which have proved the best of those that have yet been tried in the laboratory for this purpose. With such a surface it has been found that almost any shock to the operation, even under the most unfavorable conditions. After the device has been operating a time and the electrodes become warm, it becomes more difficult to prevent oscillations than it is to start them.

Considering the invention now in greater detail.

Fig. 1 shows a form of my invention which is one of the simplest and most readily constructed and operated. The vacuum tube which forms the heart of the apparatus is of the type described in my prior application above referred to, and comprises an evacuated envelope 1 of cylindrical form, having cathodes 2, 2' mounted in the opposite ends thereof. The cathodes are supported by lead wires 4, which are sealed through the walls of the envelope, and comprise discs of pure silver whose surfaces have been oxidized and coated with caesium in a manner well known for the formation of photoelectric cells. An anode 5, comprising a ring fitting snugly the walls of the tube is mounted midway between the two cathodes, connection being made to the anode through a lead 6 sealed through the wall of the tube. The connection between the two cathodes is an oscillating circuit comprising an inductor 7 in parallel with a variable condenser 9. A central tap 10 on the inductor connects through a potential source 11 to the anode, preferably through radio frequency chokes 13 and 14, which, although not strictly necessary, improve the performance of the apparatus and increase its oscillating output.

A secondary coil 15, coupled to the inductor 7 may be used to withdraw power from the circuit, this method of coupling being shown as typical of numerous well known methods of withdrawing energy from any oscillating circuit.

Surrounding the tube is a solenoid 16, which is supplied with direct current from a source 17, the current being accurately adjustable by means of the rheostat 18.

Consider the circuit in the non-oscillatory state.

and that electrons are released from approximately the center of the cathode 2 with zero velocity. Such electrons would be accelerated toward the anode 5, and, in the absence of the focusing field due to the solenoid 16, would probably strike the anode and be removed from the inter-electrode space. If, however, the focusing coil be excited to the proper value, its field will guide the electrons past the anode to a point on the opposite cathode 2' corresponding to the cathode 2 from which they were originally liberated. During their flight they are accelerating up to the time they reach the median plane of the anode, while from this point on they are decelerated by the electrostatic field supplied by the source 11, and, under the conditions mentioned, will arrive at the opposite cathode with zero velocity, having occupied in flight a time determined by the potential of the source 11 and the distance between the two cathodes.

If the resonant circuit comprising coil 7 and variable condenser 9 be tuned to a frequency whose half period is approximately equal to the time of flight of the electrons, the original liberation of the electrons from the cathode 2 will cause a current to flow from the source through one-half of the inductor 7 to the cathode 2. This provides a potential drop which appears on the two cathodes in such phase as to accelerate the flight of the electrons causing them to impact the second cathode 2' with a finite velocity. If this velocity be sufficient to release electrons from the second cathode at a ratio greater than unity, the difference between the number of impacting primary electrons and emitted secondary electrons forms a current which is supplied to the other branch of the inductor 7, causing a voltage drop in opposite phase, which accelerates the space current through the tube in the opposite direction. The secondary electrons emitted therefore impact the first cathode in increased numbers and with increased velocity, and the oscillation quickly builds up to a point where it is limited either by space charge effects within the tube, by loss of energy to the output circuit, or by some other extraneously introduced factor.

The factors which determine how readily such an oscillation will start are the dimensions of the tube, the voltage of the source 11, the focusing current, and the material of the cathode surface. The dimension of the tube determines the gradient between the two cathodes. The velocity with which any electron strikes the opposing cathode is determined almost entirely by the integrated effect of the oscillating potential during its time of flight. It will, therefore, have maximum velocity of impact if its entire flight is accomplished during one-half cycle of oscillating potential, i. e., during a portion of the cycle wherein the potential of the cathode from which it was emitted is always positive with respect to the opposite cathode. Whether this be the condition for maximum emission upon impact or not, depends upon the portion of the secondary emission curve upon which the tube is operating. The curves of nearly all materials are of substantially the shape shown in Figure 7, but the coordinate values vary greatly for different materials. If the voltages are such that impact occurs with a velocity corresponding to the ascending branch of the curve, an increase in velocity will result in a corresponding increase in number of secondary electrons emitted at each impact. If, however, the voltage is applied to the crest of the curve there will be no increase in the number of secondaries per impact with increased voltage, while if the voltage increases to the point where the descending branch of the curve is in use, an increased potential will result in a decreased number of secondaries.

The effect of the focusing field upon the oscillation is dependent upon the number of electrons which it permits to be collected by the anode. When oscillations are first started all of the available electrons are necessary to create the new secondaries, and therefore, under starting conditions, the focus should be quite critically adjusted. When equilibrium is reached, however, it is obvious that all electrons in excess of the number of impacting primary electrons must be collected in each half cycle. With a very plentiful supply of primaries, and a high secondary-primary ratio, the focusing becomes very much less critical as soon as the oscillation has started, and decrease of the intensity of light will, in general, actually cause a large increase of oscillating power. Experience has shown that the oscillations will continue with approximately one-tenth of the focusing field required to start them.

The effect of the material of the cathode sur-
faces upon the action of the device is obvious. With the caesium surfaces here described, one of the reasons why starting oscillation is by flashing a light upon one of the cathodes. The oxide caesium surfaces, moreover, have an extremely low work function, and secondary ratios as high as 4 or 5 are readily obtainable. This obviously leads to quick build-up of circulating current in the oscillatory circuit and consequent quick and easy starting.

To give some actual values, and thus indicate the order of magnitude of the circuit constants involved, a tube of the character described having a spacing of 5.5 centimeters between the cathodes, was operated at frequencies varying between 30 megacycles and something over 100 megacycles. The corresponding voltages of the d-c source required to give the necessary corresponding times of flight varied between 350 volts for the lower frequency and 800 volts for the higher one.

Under these conditions it was found that oscillation could be started by flashing a light on one cathode as mentioned above, by a sudden closing of the circuit to the source 11, or even by suddenly closing the focusing field circuit. After the circuit has been in operation for a few moments, permitting the cathodes to become warm, and the effective energy which must be derived from an impacting electron in order to cause secondary emission, such shocks became unnecessary, and oscillation would occur without any appreciable electrical shocks to start them.

It should be noted that although the order of the period of the tuned circuit should be approximately twice the time of flight of electrons under the d-c field component, this value is not critical. For each value of accelerating voltage there is a fairly wide range of tuning over which the circuit will oscillate. Within this range the resonant frequency of the tuned circuit is a primary factor in determining the frequency of oscillation. Minor factors are the accelerating voltage and the amplitude, since this latter factor involves the velocity of the electrons and hence affects the mean time of flight. The value of the focusing field, due to its effect upon amplitude, and upon the length of the electron path, also affects frequency to a slight extent.

Once oscillation has started in the system, it continues to build up in amplitude until the number of electrons collected by the anode in each half cycle is equal to the excess of secondary over primary electrons. If the proportion of the total electron cloud collected were independent of the density of the cloud, the amplitude of the oscillation might continue to build up almost indefinitely, for it will be seen that in the device of my invention there is no fixed limit to the electron emission as there is in the ordinary thermionic tube.

In actual operation, however, the greater the density of the cloud the greater will be the proportion collected, since the increased space charge with high densities repels the peripheral electrons with greater force and tends to drive electrons to the anode. This sets a limit to the amplitude of oscillation, but it is very easy to construct tubes where this limit is so high that the tube will be destroyed before it is reached. It may therefore be necessary in certain instances to reduce the focusing current as soon as the oscillation is started, in order to prevent destruction of the tube by overheating.

If the voltage builds up to a point where the secondary emission curve is operating upon its descending branch, this also makes the amplitude of oscillation self-limiting, the voltage increasing until the proportion of secondaries to primaries falls to a point where the excess of electrons is equal to the number collected. It will be recognized that the load withdrawn from the oscillating circuit also has an effect in limiting the amplitude, in that this load acts effectively to decrease the voltage drop produced in the oscillating circuit by a current of definite amount, and hence affects the primary-secondary ratio. With certain types of load it may be highly desirable to operate the tube upon the descending branch of the curve, since in this case an increased load, by decreasing the accelerating voltage, increases the number of electrons emitted. This, in turn, increases the voltage drop, and causes equilibrium to reestablish itself at a point corresponding to the changed load.

The relation between the tuning of the resonant system to the time of flight of the electrons as determined by the accelerating voltage may also limit the amplitude of oscillation.

Analytical solution of the effect of varying the oscillatory component of the accelerating potential upon the time of flight, and hence upon the tuning of the resonant circuit for maximum output, is extremely difficult, and at the date of this application for patent is only partially complete. In general, the time of flight varies with the phase of emission, with the amplitude of the oscillating potential, and with the shape of the electrostatic fields and the portion thereof through which the electron falls. There will, for any amplitude of oscillation, be only one or at most two phases of emission for which the time of flight is exactly one-half cycle, and it follows that there will usually be a difference in phase between the flight of any group of impacting electrons and that of the secondaries which are released thereby. This phase shift may be either increased or decreased by an increase in amplitude of oscillation. If increased, it serves to set a limit to amplitude. For if it be such that the highest emission ratio occurs at a phase where the emitted electrons never reach the opposite cathode, or reach it with insufficient velocity to cause further emission, the oscillation will tend to die out. It is for this reason that the half period of the tuned circuit should be of the same order of magnitude as the time of flight. Within this limit it is easy to find a frequency whereat oscillation will start, and once started, to find the conditions of optimum operation. Theoretically, with the tube of Figure 1, oscillation may occur where the time of flight is the time of any odd number of half cycles, but starting such oscillations is difficult where the time is greater than that of one-half cycle.

Another mode of limiting the amplitude of oscillation is shown in Figure 2. With the exception noted hereafter, the circuit of Figure 1 is duplicated in this arrangement, and the various elements thereof are identified by similar reference numbers. The exception is that the direct current component supplied by the source 11 is passed through a solenoid 20 which surrounds the tube. In the usual case, where a decrease of focusing current increases the intensity of oscillation, the solenoid is so connected as to "boost" the main focusing field, thus imposing a condition less favorable to oscillation and limiting output.
It is by no means necessary that a solenoid be used to provide the guiding field. Figure 3 indicates a method of mounting the tube within a permanent magnetic structure, which will produce a similar effect. The tube is mounted between pole-pieces 22, which concentrate and direct the magnetic field established by permanent magnets 24.

Electrostatic methods of guiding the electron cloud may be utilized as well as electromagnetic ones. In the tube shown in Figures 1, 2, and 3, the electrostatic fields are strongly curved, and the electromagnetic focusing fields are necessary in order to guide the electrons between the cathodes. In the tube of Figure 4, however, the lines of force in the electrostatic fields are substantially straight within the electron path, and it may therefore be operated without the use of electromagnetic focusing. This tube comprises an envelope 25 within which are mounted the opposed cathodes 28, preferably slightly concave, substantially as within the tubes already described. Midway between the cathodes is a conducting band 27, fitted snugly within the walls of the envelope and connected with a lead 29 sealed through the wall of the tube. Projecting inwardly from the center of the band is an annular diaphragm 30, and secured across the opening is a diaphragm or a cage or grid 31, preferably formed of extremely fine wire of open mesh so that the actual area which it offers to the electron stream is extremely small as compared with the total area of the aperture.

With this structure the lines of force between the edges of the cathode and the anode are somewhat curved, but those passing down the center of the tube are almost straight. The chance that an electron liberated from the central portion of either cathode will be collected by the anode is very small, the travel being in nearly straight lines. This tube will be found to be somewhat more difficult to set into oscillation than those utilizing the magnetic guiding field, but it is none-the-less operative, and it offers the advantage that no extraneous focusing equipment is necessary.

While the tube of Figure 4 may be utilized in the same circuit as the one first described, the fact that the anode forms an electrostatic shield also permits its use in a circuit of somewhat different type as shown in Figure 5. In this case the two cathodes are connected together, and the oscillating circuit comprising the inductor 35 and condenser 36 is connected between the junction of the two cathodes and the anode through the accelerating potential source 37. The negative end of the source is shown as connected to ground, as is the second terminal of the parallel resonant circuit. The resonant circuit is tuned to a frequency whose whole period is approximately equal to the time of flight of the electrons between the cathodes.

An electron released from either cathode will be attracted to the anode and will require approximately one-half cycle to reach this point. If the phase of the potential developed in the oscillating circuit by the electron flow from the cathode is correct, this potential will reverse after the electrons pass through the grid 31, so that this potential will still be effective to accelerate the electrons during the remainder of the journey down the tube and will cause the secondary electrons to be emitted by impact with the cathode as before. With this form of circuit there will, in general, be two electron clouds oscillating through the tube in opposite directions, and passing through each other at approximately the plane of the anode. The circuit is less readily oscillatory than the previously described, that it derives energy from the d-c source but once in each cycle instead of twice as in the cases previously described. It has, however, the characteristic that capacity between the cathodes and anode is less for the same frequency of operation, and hence when especially high frequencies are desirable it may offer certain advantages.

Figure 6 shows a form of the device in which but a single secondary emissive cathode is used. This cathode 40 is mounted in one end of the evacuated envelope 41. Near the other end of the envelope is an anode 42 of the same type as that described in connection with the tube of Figure 4, and immediately behind this anode is positioned an auxiliary cathode 44, which need not have a photo-emissive surface. A focusing coil 45 is shown as supplied by a battery 46 and rheostat 47, but it is to be understood that any means of guiding the electron cloud, either electromagnetic or electrostatic, may be used.

A parallel oscillating circuit 49 is connected in series with the cathode 40 and anode 42 through the accelerating potential source 50. A connection 51 leads from the negative end of the source 50 through a biasing potential source 52 to the auxiliary cathode 44, the potential of the source 52 being sufficient to maintain the auxiliary cathode always negative to the cathode 40.

In this case the action of the device is substantially the same as that of one-half of the tube of Figure 5. Electrons released from the cathode 40 reach the anode in approximately one-half cycle. Passing through the anode they are immediately reversed in direction by the field between the anode and auxiliary cathode, and return through the anode at the same velocity which they had attained on first reaching it. By this time, however, the oscillating potential between anode and cathode has reversed, so that approximately one full cycle after being released from the cathode 40 there again impact it with a velocity due to the integrated effect of the oscillating voltage during their time of flight. The release of additional secondary electrons and repetition of the cycle occurs as before.

The circuit of Figure 6 has the same disadvantages compared with that of Figures 1 and 2 as does the circuit of Figure 5, with the additional disadvantage that a certain number of the electrons will be collected each time the cloud passes through the anode 42. After the oscillation has become stabilized this is no material disadvantage, but it does render the oscillation more difficult to start. On the other hand, the anode-cathode capacity which is effectively shunted across the oscillating circuit is only one-half that of the already small capacity contributed by the structure of Figure 5. Thus the use of this arrangement may be justified in certain circumstances, even though an auxiliary oscillator, later removed, may be necessary to start it in oscillation.

It should be recognized that the action of the oscillators here described is complex, that many factors enter into the final result, and that, owing to the interaction of these factors, a change in some one condition may, in certain instances, produce directly, the opposite effect from what might generally be expected. Thus imposing a load on the oscillator will usually change the phase as well as the magnitude of the...
potentials in the oscillating circuit, and for many conditions of tuning and accelerating voltage will likely occur the intensity of oscillation even though the tube be operating on the rising
branch of the secondary emission curve. Similarly special conditions may be found where increase of focusing field increases oscillation intensity, instead of decreasing it, as is the usual case. Anomalies of this character are probably
more apt to occur as limiting conditions for self-oscillation are approached, for under these circumstances a minor or secondary effect, operating in conjunction with the limiting factor, may overshadow the effect which ordinarily dom-
inates.

A somewhat similar state of affairs may exist as regards the optimum degree of vacuum in the oscillating tube. All of the earlier experiments with the device were made with as high a degree
of vacuum as could be secured—much higher than that in the ordinary three element tube or in the old style, gaseous discharge type of X-ray tube. Collision ionization phenomena within the tube are undesirable. Nevertheless, there is consi-
dererable evidence that small amounts of adsorbed gases on the electrodes themselves are advantageous where high secondary emission ratios are desired, and it is therefore highly prob-
able that operation of the device will be facilitated by the presence within the tube of small quantities of inert gas, such as helium, neon, or others of the same group, as long as the mean free path of electrons within the tube is longer than the inter-electrode distances.

1. Claim:
1. An oscillation generator comprising an evacuated envelope, a plurality of electrodes within said envelope including an anode and a cathode capable of emitting secondary electrons at a ratio to primary electrons greater than unity upon impact by such primary electrons, a potential source sufficient to accelerate electrons to a velocity causing emission from said cathode at said ratio, means including circuitual connections between said electrodes for producing traversing and retraversal of the space between said electrodes by the secondary electrons emitted from said cathode to produce self-oscillation within said circuitual connections.

2. An oscillation generator comprising an evacuated envelope, a plurality of electrodes within said envelope including an anode and a cathode capable of emitting secondary electrons at a ratio to primary electrons greater than unity upon impact by such primary electrons, a potential source sufficient to accelerate electrons to a velocity causing emission from said cathode at said ratio, and means for applying electrical potential to said electrodes, means for cyclically modifying said potential by current flow to cause a cloud of electrons in a space path therebetween to oscillate back and forth along said path and periodically to impact said cathode with sufficient velocity to maintain said cloud of electrons at undiminished density independently of accretions thereon by other than secondary electrons.

3. An oscillation generator comprising an evacuated envelope, a plurality of electrodes within said envelope including an anode and a cathode capable of emitting secondary electrons at a ratio to primary electrons greater than unity upon impact by such primary electrons, a potential source sufficient to accelerate electrons to a velocity causing emission from said cathode at said ratio, and means including a resonant circuit for modifying the potential from said source to cause the electron cloud developed by the impacting primary electrons to traverse and retraverse the space between said electrodes in response to the oscillating potential developed in said resonant circuit by the movement of said electron cloud.

4. An oscillation generator comprising an evacuated envelope containing a pair of opposed cathodes having surfaces adapted to emit electrons by impact and an anode positioned therebetween, means for imparting velocities to electrons emitted from said cathodes toward the opposed cathodes past said anode, an impedance connected to cause secondary electrons liberated from one of said cathodes to flow therethrough, and means for applying the voltage drop caused by electron flow in said impedance to impart sufficient additional velocity to the liberated secondary electrons to cause release of additional secondary electrons by impact with the other cathode.

5. An oscillation generator comprising a pair of opposed surfaces capable of emitting by impact a number of secondary electrons greater than the number of impacting primary electrons, an anode positioned to collect a portion of said secondary electrons, means for guiding a portion of said secondary electrons at least as great as the number of primary electrons from either cathode toward the other in avoidance of said anode, a current source for supplying the deficiency of electrons caused by the secondary emission from said cathodes, and circuitual connections including said cathodes and said source for applying a voltage drop caused by the flow of secondary electrons from one of said cathodes to accelerate said electrons toward the other cathode to a velocity sufficient to cause secondary emission of electrons therefrom at a ratio greater than unity.

6. An oscillation generator comprising a pair of opposed cathodes capable of emitting secondary electrons by impact in excess of the number of impacting primary electrons, a source of potential great enough to impart sufficient electron velocity to cause emission of secondary electrons in said amount of impact with said cathodes, and means including said source of potential and a resonant circuit for applying potential from said source to cause electrons liberated by impact from said cathodes alternately to impact the opposing cathode.

7. An oscillation generator comprising a pair of opposed cathodes adapted to emit secondary electrons by impact, an anode positioned between said cathodes, means for guiding a portion of secondary electrons emitted from either of said cathodes past said anode toward the other cathode, a parallel resonant circuit connected to said cathodes, and a source of potential connected to apply a voltage between said cathodes and said anode great enough to accelerate electrons to a velocity sufficient to cause emission of secondary electrons from said cathodes at a ratio greater than unity.

8. An oscillation generator comprising an evacuated envelope, a pair of opposed cathodes positioned within said envelope, an anode so positioned between said cathodes as to permit the greater portion of a space current passing between said cathodes to pass uncollected by said anode, a parallel resonant circuit connecting said cathodes, and a source of potential connected to...
apply a voltage between said cathodes and said anode great enough to accelerate electrons to a velocity sufficient to cause emission of secondary electrons from said cathodes at a ratio greater than unity.

9. An oscillation generator comprising an evacuated envelope, a pair of opposed cathodes positioned within said envelope and having surfaces of photoelectric material, an anode so positioned between said cathodes as to permit the greater portion of a space current passing between said cathodes to pass uncollected by said anode, a parallel resonant circuit connecting said cathodes, and a source of potential connected to apply a voltage between said cathodes and said anode great enough to accelerate electrons to a velocity sufficient to cause emission of secondary electrons from said cathodes at a ratio greater than unity.

10. An oscillation generator comprising a pair of opposed cathodes adapted to emit secondary electrons by impact, an anode positioned between said cathodes, means for guiding a portion of secondary electrons emitted from either of said cathodes past said anode toward the other cathode, a parallel resonant circuit connecting said cathodes, and a source of potential sufficiently great to excite secondary emission from said cathodes at a ratio greater than unity connected between said anode and a point intermediate the terminals of said parallel resonant circuit.

11. An oscillation generator comprising an evacuated envelope containing a pair of opposed cathodes and an annular anode surrounding the path therebetween, means for establishing a magnetic field longitudinal of said path to guide electrons therealong between said cathodes, a source of potential sufficient to excite secondary emission from said cathodes at a ratio greater than unity, and circuit connections between said anode, cathodes and source for applying a voltage drop resulting from emission from either of said cathodes in a direction to accelerate the emitted electrons toward the other cathode.

12. An oscillation generator comprising an evacuated envelope, a pair of opposed cathodes within said envelope spaced to provide a free electron path therebetween, a cooperating anode positioned to collect electrons deviating from said path, means for guiding electrons from either of said cathodes along said path, a source of potential great enough to cause secondary emission of electrons from said cathodes at a ratio to impact against the other cathode sufficient to cause further secondary emission.

13. An oscillation generator comprising an evacuated envelope, a pair of opposed cathodes within said envelope spaced to provide a free electron path therebetween, a cooperating anode positioned to collect electrons deviating from said path, means for guiding electrons from either of said cathodes along said path, a source of potential great enough to cause secondary emission of electrons from said cathodes at a ratio to impact against the other cathode sufficient to cause further secondary emission.

14. An oscillation generator comprising an evacuated envelope, a pair of opposed cathodes within said envelope spaced to provide a free electron path therebetween, a cooperating anode positioned to collect electrons deviating from said path, means for guiding electrons from either of said cathodes along said path, a source of potential great enough to cause secondary emission of electrons from said cathodes at a ratio to impact against the other cathode sufficient to cause further secondary emission.

15. An oscillation generator comprising an evacuated envelope, a pair of opposed cathodes within said envelope spaced to provide a free electron path therebetween, a cooperating anode positioned to collect electrons deviating from said path, means for guiding electrons from either of said cathodes along said path, a source of potential great enough to cause secondary emission of electrons from said cathodes at a ratio to impact against the other cathode sufficient to cause further secondary emission.

16. An oscillation generator comprising an evacuated envelope, a pair of parallel opposed cathodes spaced within said envelope and defining an electron path therebetween, an annular anode surrounding said path, a source of potential sufficiently great to impart an electron velocity which will excite secondary emission from said cathodes at a ratio greater than unity connected to said anode, and a resonant circuit tuned to a frequency whose half period is of the order of magnitude of the time of flight of an electron between said cathodes under the influence of said potential source connected between said cathodes and having an intermediate terminal connected through said source to said anode.

17. An oscillation generator comprising an evacuated envelope, a pair of parallel opposed cathodes spaced within said envelope and defining an electron path therebetween, an anode grid intermediate said cathodes comprising an electrostatic shield of small actual area, to permit the passage therethrough of a relatively large number of infalling electrons, a source of potential sufficient to cause secondary emission of electrons from said cathodes at a ratio greater than unity connected to said anode, a connection between said cathodes, and an oscillating circuit connecting said anode and said cathodes tuned to a frequency whose period is of the order of magnitude of the time of flight of an electron between said cathodes under the influence of the potential of said source.

18. The method of generating self-sustaining oscillations by means of secondary emitting surfaces which comprises the steps of causing an electron flow to impact such a surface at sufficient velocity to cause an emission of secondary electrons therefrom at a ratio greater than unity,
causing a flow of current consequent to said emission to produce a voltage drop, and applying said voltage drop to accelerate said electrons to a like impact with another such surface.

19. The method of generating electrical oscillations which comprises forming a cloud of electrons, oscillating said cloud along a path by applying accelerating potentials thereto, maintaining said cloud by causing the release of secondary electrons by impact at the end of said path, and deriving the potentials for causing said impacts from the currents comprising said secondary electrons.

20. The method of generating electrical oscillations which comprises forming a cloud of electrons, oscillating said cloud along a path by applying accelerating potentials thereto, withdrawing a portion of the electrons from said cloud at each oscillation thereof to supply useful power, causing said cloud to generate by impacts at the ends of said path sufficient electrons to maintain said cloud and supply those withdrawn therefrom, and deriving the potentials for causing said impacts from the currents comprising said secondary electrons.

21. An oscillation generator comprising a pair of opposed cathodes, means for causing a cloud of electrons to oscillate between said cathodes and impact thereon with velocity sufficient to maintain the density of said cloud by the secondary electrons emitted by said impacts, and means for deriving from the current flow comprising said secondary electrons the energy required to give to said cloud the impacting velocity.

22. An oscillation generator comprising an evacuated envelope containing an anode and cathode structure including opposed surface portions capable of emitting secondary electrons at a ratio to impacting primary electrons greater than unity, means including said anode for directing the flow of a portion of the electrons from one of said surface portions toward the other without impacting said anode, means for causing a current flow resultant upon the emission of electrons from said cathode structure to produce a potential on said anode so phased in relation to the time of emission of said electrons as to cause them to impact said cathode structure with sufficient velocity to cause the emission of further secondary electrons.

23. An oscillation generator comprising an evacuated envelope containing an anode and a cathode structure capable of emitting secondary electrons at a ratio to impacting primary electrons greater than unity, means including said anode for directing electrons emitted by said cathode structure in a path avoiding said anode and returning to said cathode structure, and means connecting said cathode structure and said anode for applying potentials due to current flow resultant upon emission of electrons from said cathode structure to said electrons during their traversal of said path to impart thereto a final velocity sufficient to cause them to impact said cathode structure and release further secondary electrons thereby.

24. An oscillation generator comprising an evacuated envelope containing an anode and cathode structure, means including said anode for directing electrons liberated from said cathode in paths terminating in said cathode structure, and means for causing electrons traversing said paths to develop potentials between said anode and said cathode structure sufficient to cause impact of said electrons with said structure causing emission of a greater number of secondary electrons than impacting primary electrons.

25. The method of generating self-sustaining oscillations which comprises the steps of generating a cloud of electrons, subjecting said electrons to an electrostatic field directed towards a common center of oscillation from a plurality of directions whereby electrons component of said cloud released on one side of said center will tend to oscillate about said center, withdrawing energy from certain of said oscillating electrons to damp the oscillations thereof to bring them to rest at said center of oscillation, applying a portion of the energy thus withdrawn to other electrons component of the cloud to increase their net energy, and utilizing the additional energy of said last named electrons to cause them to release further electrons within said field.

26. The method of generating self-sustaining oscillations which comprises the steps of establishing an electrostatic field releasing electrons in said field, causing said electrons to oscillate about a center of oscillation within said field, causing the oscillation of said electrons to so modify said field as to transfer energy from certain of said electrons to others, and using the excess energy transferred to electrons whose energy is increased to release further electrons in said field.

27. The method of generating self-sustaining oscillations by means of secondary electron-emitting surfaces, which comprises the steps of generating an electrostatic field between a pair of such surfaces directed toward a common center, releasing electrons within said field to oscillate about said center, generating an oscillating potential from the motion of said electrons, and applying said potential to modify said field in such phase as to cause certain of said electrons to impact said surfaces with sufficient energy to release additional electrons within said field.

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