Fig. 1a

CATHODE END SHIELD

COOLING WATER OUT

COOLING WATER IN

CATHODE COATING

FIELD COIL

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The present invention relates to electron discharge device circuits which employ an electron discharge device having a cold cathode capable of emitting secondary electrons. An object of the invention is to provide apparatus for efficiently converting low frequency or direct current energy to audio or radio frequency energy.

Another object is to provide a simple and rugged vacuum tube structure and circuit capable of handling power levels ranging up to hundreds of kilowatts, with relatively high efficiency.

A further object is to provide a high power evacuated electron discharge device which requires no great concentration of electron emission.

A still further object is to provide a magnetron type of generator having a cold cathode and whose individual elements have relatively large surface areas as a result of which the effects of temperature are minimized.

A still further object is to provide a magnetron type of oscillation generator for use in communication, in which the tube employs a cold secondary emissive cathode lying in the axis of a cavity resonator constituting an anode for the tube.

In one embodiment of the invention, the electron discharge device is a vacuum tube which employs a relatively cold tubular cathode. This cathode is cooled in suitable manner and is so arranged as to produce copious secondary electrons when bombarded. Means are provided to produce a magnetic field in a direction parallel to the axis of the cathode. A cavity resonator in which appears a periodically reversing electromagnetic field surrounds the cathode. This cavity resonator is in the form of a metallic cylinder closed at both ends. A hollow cathode passes through these ends but is insulated therefrom by suitable seals, such as glass. In effect, the cavity resonator serves also as an anode, and this anode is supplied with a power from a source of controllable direct or low frequency potential and current. A source of relatively high frequency power is utilized to excite the tube to produce oscillations. The anode-to-cathode potential is periodically increased above and reduced below what would be the cut-off potential value in the absence of oscillations, but at a frequency lower than the excitation frequency. As a result of this circuit arrangement, electron current flows between anode and cathode in the form of pulses of a frequency related to the periodic rise and fall of the anode-to-cathode potential.

The generator circuit of the invention may have wide industrial uses, such as for example in the induction heating field. If desired, the invention can be used for communication purposes on frequencies ranging from a relatively low value up to perhaps 100 megacycles or more, provided the excitation frequency is properly chosen in relation to the output frequency. If employed for communication purposes, the system of the invention can be modulated in a manner described hereinafter.

A more detailed description of the invention follows in conjunction with the drawings, wherein:

Figs. 1 and 2 illustrate two embodiments of cold cathode oscillators, in accordance with the present invention;

Fig. 1a illustrates a cross-sectional view of the magnetron of Fig. 1 and shows the end walls and fluid cooling arrangement in more detail;

Figs. 3 and 3a are graphs given to explain the operation of the present invention; and

Fig. 4 shows an embodiment of the invention applicable to radio communication.

Referring to Fig. 1 in more detail, there is shown a cross section of a magnetron construction including a hollow cylindrical cathode, surrounded by a metallic cavity resonator. The cathode lies in the axis of the tube and extends from both ends of the cavity resonator. This cavity resonator is a metallic cylinder closed at the ends (not shown) to provide an electrically closed chamber in which there is arranged to appear a periodically reversing electromagnetic field. The cathode is insulated from the cylinder by means of suitable insulating seals, such as glass. For cooling the cathode water is preferably supplied through the insulating seals so as to flow through the interior of the cathode in order that the cathode be the coolest surface exposed to the vacuum. Such a water cooling arrangement is shown in Fig. 1a and also in my copending application Serial No. 534,066, filed May 4, 1944, now U.S. Patent 2,420,744 granted May 20, 1947. The space between the cathode and the inner walls of the cavity resonator is evacuated in the manner of any well known vacuum tube device. Surrounding the cavity resonator there is provided a coil energized from a unidirectional source so as to provide a magnetic field in the direction parallel to the cathode. If desired, coil 3 can be replaced by a permanent magnetic field poles placed at the ends of the cavity resonator adjacent the seals, so as to produce a magnetic field in a direction parallel to the cathode. The cavity resonator, by virtue of its
metallic surface, serves as the anode of the tube structure.

A source of controllable direct or low frequency potential and power 5 has its negative terminal connected through a parallel tuned circuit 6 to the cathode while the positive terminal of the source is connected to the cavity resonator, as shown. A bypass condenser 7 is connected across the positive and negative terminals of source 5. A source 8 of very high frequency power is coupled through a suitable glass seal 9 to the interior of the cavity resonator by means of a coupling loop 10. Source 8 may, for example, be of the order of 1000 megacycles and serves to excite the generator. Tuned circuit 5 may be tuned to a low radio frequency of the order of one megacycle, by way of example, or even to a high audio frequency. The cavity resonator 2 is arranged to be resonant to a frequency of 1000 megacycles, which is the frequency of source 8. The magnetron may, as a preferred example, be so dimensioned that it is resonant for a mode of cavity resonance in which a circumferential electric field may be set up at the frequency of source 8 which is much higher than the frequency of the main oscillations in tuned circuit 6. Preferably this is done by making the cavity resonator 2 the frequency controlling element in the oscillator. Output energy of relatively low radio frequency, for example, one megacycle, is derived from the tuned circuit 6 by means of coil 11, which is coupled to the inductance of tuned circuit 6. By way of illustration only, the output of coil 11 is shown connected to a typical induction furnace arrangement 20 comprising a crucible within a heat insulation chamber.

The high frequency electric field is made to be adjustable in order to obtain best operation, but need not be very great. A total peak electric field potential around the whole circumference at the line of maximum field, of a few thousand volts should suffice to cause a large portion of any circulating electrons present between cathode and anode to gain enough energy from the electric field to strike the cathode with sufficient velocity to produce substantial secondary emission from the cathode 4. The magnetic field is preferably adjusted to give resonance of electron motion at the frequency of the source 8. In this way there is some co-relation between the magnetic field and the frequency of the power source 8 for easiest and most efficient operation. This co-relation, however, is not essential, provided the strength of the driving electric field supplied by source 8 is sufficiently great to give the required energy to the electrons to bombard the cathode.

To understand the operation of the invention, it should be noted that so long as the anode-to-cathode potential provided by source 5 is above the cut-off potential corresponding to the particular strength of magnetic field used, and the magnetron dimensions, so that all electrons emitted from the cathode are directly drawn to the anode on their first trip from the cathode, then any electron released from the cathode or released at any point between the cathode and the anode will be pulled immediately to the anode and thereby removed from the free vacuum. The possible path of such an electron is illustrated by the dash line 12, which shows what happens when the anode-to-cathode potential is so high (above cut-off) that all electrons are directly drawn to the anode on their first trip. When this occurs, the anode-to-cathode potential is considered to be above the cut-off potential. Because the cathode is unheated, and therefore has extremely low electron emission, and the vacuum between the cathode and anode is supposed to be good, it will be evident that only negligible currents can flow between the anode and the cathode when the anode-to-cathode potential is much above the cut-off potential. However, when the anode-to-cathode potential is low, below the cut-off potential, then electrons leaving the cathode will in whole or in part be returned to the cathode by the magnetic field and will follow some such paths as indicated by the curved dash lines 13. When the electrons leave the cathode and move out toward the anode and back again, some electrons will be accelerated by the very high frequency field produced by source 8 in such manner that they arrive back at the cathode with excess velocity and potential and cause secondary emission from the cathode. The curved dash lines 14 indicate the paths of a plurality of secondary electrons which are released from the cathode in response to bombardment from an electron in one of the paths 13 reaching the cathode. The secondary electrons in turn may traverse the evacuated space and some of them will arrive back at the cathode at a lower potential. Thus an extremely small electron emission may be multiplied rapidly until it becomes a large space charge limited emission. During this process, those electrons which lose energy due to the very high frequency field (mainly out-of-phase electrons) and which do not return all the way to the anode, will strike the anode instead and may constitute a very large anode current. This anode current is augmented by electrons forced out to the end plates of the closed cylindrical anode, by space charge repulsion causing motions more or less parallel to the magnetic field. In this way there is produced a condition of anode input current flow only when the anode-to-cathode potential is low.

If now, the anode-to-cathode direct current input potential supplied by source 5 is adjusted so as to start with an optimum low potential from the anode power source, and this potential then raised, it will be evident from the foregoing that operation will start with a low anode current. As this direct current input potential rises to the critical or cut-off value, emission from the cathode will suddenly stop (because now all electrons are drawn directly to the anode 2) and the anode-to-cathode direct current will be interrupted, starting an oscillation in the output tuned circuit 6. The oscillation in tuned circuit 6 causes a variation in potential which is then augmented by the interruption of circulating electron current when the overall anode potential is relatively high; that is, the superposition of the alternating potential of tuned circuit 6 on that of source 5 will momentarily raise the total anode potential above cut-off. The oscillation also causes a variation in potential which produces a flow of circulating electron current when the overall anode potential is relatively low, caused by the reversal in polarity of the potential across tuned circuit 6 which pushes the total effective anode potential below the cut-off value during a portion of each cycle of oscillation of circuit 5. This oscillation strength will then increase to a limiting value. This relationship is more clearly understood from an inspection of Figs. 3 and 3a which shows one particular condition of operation of the tube of Fig. 1.
In Fig. 3, the three horizontal lines are respectively labeled "Zero voltage," "Cut-off potential for the magnetron," and "Normal operating direct current potential of source 5." It will be seen that the direct current potential of source 5 is considerably above the cut-off potential for the magnetron, and hence at this value of potential all electrons emitted from the cathode in the circuit of Fig. 1 will be drawn directly to the anode. The alternating potential of tuned circuit 6 is shown in the form of a sine wave. It is only when the alternating potential of the tuned circuit 6 is in the negative direction that it will oppose the direct current potential of source 5 and set up an effective or total anode potential which falls below the cut-off potential for the magnetron.

These points at which the total anode potential is below cut-off occur in the time interval 1 during which a circulating space charge is permitted to build up in the magnetron and to produce pulses of anode-to-cathode current. Fig. 3c graphically illustrates the pulses of output current available in output coil 11.

After radio frequency oscillations have been started by the potential of source 5 less than the cut-off potential, then the anode potential from source 5 may be increased to its operating value which would normally be much above what would be the cut-off value in the absence of oscillations in tuned circuit 6. Subsequent strength of oscillation will increase and high power input and output can be obtained so long as the secondary emission ratio from the cathode remains high enough for electron emission to reach a saturation value when the overall anode potential is a minimum.

In practice I have found that apparently there is always some residual though extremely small electron emission in magnetrons which is enough to provide starting and growth of emission. This may be due to photo emission caused by light rays penetrating the glass parts of the tube, or due to the action of cosmic rays and also due perhaps to a continuous redistribution of volatile materials from condensation and re-evaporation from the cathode surface accompanied by the release of high and low frequency vibrations. Experiments on the effect of temperature distribution have shown that even those vacuum tubes with the best commercially obtainable vacuum contain traces of volatile materials which are continually evaporated and condensed on the surfaces. By changes in temperature distribution affecting the distribution and density of these materials on the surfaces, it has been possible to produce profound effects upon the operation, reliability, and break-down potentials of vacuum tubes. For this reason it is preferred that the cathode surface be so cooled as to become the coolest surface exposed to the vacuum, thus causing high secondary emission to be maintained.

There is also evidence that cathode surfaces are made to show a large secondary emission ratio as a result of the unnatural molecular arrangements formed by ion bombardment. A hot cathode loses this activation almost as fast as it occurs but a cold cathode can hold it for a relatively long period. Cooled in order to hold its operating surface at a lower temperature than any of the other surfaces exposed to the vacuum and to aid in holding a large secondary emission ratio. Cooling the cold cathode to such a low temperature tends to cause the volatile materials in the vacuum tube to accumulate continually on the cathode.

up high frequency electric fields which, in conjunction with the anode direct current potential and the magnetic field, will make it possible for secondary emission to grow may be used. By way of example, the very high frequency input may be applied as a potential between the anode and cathode in the manner illustrated in Fig. 2. The parts of Fig. 2 which are the same as those in Fig. 1 have been given the same reference numerals. It should be noted in Fig. 2 that the excitation source of very high frequency power 8 is applied between the anode and cathode by virtue of a very high frequency circuit 14, the primary winding of which is coupled to the source 8 and the secondary winding of which is coupled between the cathode 2 and the negative terminal of the source 8. The parallel tuned input circuit 9 comprises an inductance coil and a variable condenser, but this variable condenser is connected in series with the by-pass condenser 7, both condensers being in parallel to the inductance coil. Except for this difference, the tuned circuit 6 is similar to the tuned circuit 6 of Fig. 1, and is tuned to the cut-off frequency. It is preferred that the excitation frequency from source 8 be coordinated with the magnetic field produced by coil 3, in order to make the electron transit time match the excitation frequency, which is the condition requiring least excitation potential; or, if desired, electron transit time frequency may be made much greater than the excitation frequency, in which case growth of secondary emission may take place due to the falling electric field phenomenon in magnetrons which I have previously described in my co-pending application Serial No. 477,062 filed February 25, 1943, now U.S. Patent 2,427,781, granted September 23, 1947. The use of the falling electric field phenomenon requires higher excitation potentials to be used but has the advantage of avoiding critical adjustments.

In the practice of the present invention, it should be noted that the cathode emission is produced only when it is needed to supply anode current. This is an advantage because it permits the attainment of relatively high emission, thus producing efficient and low cathode power dissipation. By way of comparison only, it should be noted that in conventional tubes the cathode emits continuously and requires relatively high heating energy which is avoided to a large degree in the practice of the present invention.

A further advantage of the present invention lies in the fact that the construction of the oscillator is simple, inasmuch as there is no necessity for the use of control electrodes. Since the oscillator of the invention is not dependent on thermionic emission from the cathode, it is not necessary to employ a high emission density to obtain good emission efficiency. For this reason it is possible to use in the present invention cathodes so large that to heat them for producing thermionic emission according to conventional practice would be entirely impractical.

This feature of the invention allows the use of relatively small space charge densities and the attainment of high efficiencies. As mentioned above, it is preferred that the cathode be cooler than the filament of the cold cathode to such a low temperature that to cause the volatile materials in the vacuum tube to accumulate continually on the cathode.
ode surface and thus help to maintain a high secondary emission ratio. For example, if caesium, rubidium, potassium, sodium, lithium, strontium, barium or thorium are present in the vacuum tube, these materials will accumulate on the cathode, and can, under suitable conditions, cause very large increases in secondary emission. At the present time these materials are not used in high voltage high power tubes of conventional design because it has not been possible to keep a layer of them on a hot cathode under the required conditions. In accordance with the present invention, however, by using a cold cathode whose operating surface is maintained at a lower temperature than any of the other surfaces exposed to the vacuum in the tube, these materials can be kept mostly on the cathode. By maintaining the cathode colder than any other surface of the tube exposed to the vacuum, it is believed possible to use even highly volatile caesium to activate the cathode, and as the caesium is evacuated from the cathode surface partly by bombardment, this material may be continually replaced by condensation on the cold surface. In this way, I am able to provide greatly improved secondary emission cathodes due to the control of the temperature distribution. A further advantage of caesium is that it tends to evaporate in the form of ions which will bombard the cathode surface to some extent, thereby helping to maintain a surface full of electrical stresses of the kind needed to produce a large secondary emission ratio.

If desired, a small priming current for the cold cathode can be supplied from a hot cathode and the amount of this priming current controlled by suitable auxiliary electrodes. In this way I can obtain space charge limited and controlled priming current rather than emission limited priming current.

A still further advantage of the present invention lies in the fact that it provides a highly efficient means for converting low frequency or direct energy into audio or radio frequency energy.

In constructing the oscillator of the invention, the following condition should preferably be fulfilled. In addition to having a cold cathode with the highest possible ratio of secondary emission, there should be a sufficiently high ratio between the frequency of the cathode exciting current and the oscillating frequency. This is because it takes a little time for the growth of secondary emission and this time should be a small fraction of the time of one cycle of output oscillations, as a result of which the time it takes for secondary emission to build up to an operating value should be small compared to the time period of a cycle of tuned circuit 6 or 6', and preferably shorter compared with the time periods in successive cycles during which it is desired that anode-to-cathode current flow.

In order to better understand the invention, the following theoretical reasoning will be given. It is to be understood, however, that this theoretical reasoning is merely given for the purpose of exposition and that in order the invention may be better appreciated. While this theoretical exposition is believed to be correct, it is not of necessity complete, nor does the operation of the invention depend upon its accuracy or otherwise.

Let us assume that the emission from the cold cathode may be made to double for each cycle of the very high frequency excitation potential. If we consider a cycle after the growth of emission begins, the emission current will then have increased by a ratio of about 2. If a current of 100 amperes or 100 coulombs per second is required, and this required amount is produced by a minimum initial current corresponding to a single electron in one cycle of excitation current, or

\[ F = 6.28 \times 10^{10} \]

amperes, where \( F \) is the excitation frequency and \( 6.28 \times 10^{10} \) is the number of electrons required to make a coulomb, then:

\[ \frac{F}{2 \times 2} = 6.28 \times 10^{10} = 100 \text{ amperes} \]

\[ \log \frac{6.28 \times 10^{10}}{F} = \log 2 \]

For various values of excitation frequency \( F \), the number of cycles required to reach a current of 100 amperes and the corresponding time in microseconds, assuming a single electron starts the growth on the first effective cycle, will be as given in the following table for the above assumption:

<table>
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<th>Excitation frequency in megacycles</th>
<th>Number of cycles to reach 100 amperes</th>
<th>Microseconds to reach 100 amperes</th>
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<tr>
<td>1</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>10</td>
<td>45.7</td>
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<tr>
<td>100</td>
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<tr>
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</tr>
<tr>
<td>10,000</td>
<td>0.0035</td>
<td>0.0035</td>
</tr>
</tbody>
</table>

As a refinement in the construction of the embodiment of Figs. 1 and 2, it may be found helpful to so arrange and adjust the lengths of the connections from the very high frequency source 8 and the couplings that the source 8 delivers a maximum of excitation power after secondary emission current is built up and some lesser value when emission is not active. This will hold down potentials when emission is not required but hold them up when emission is required, and take a minimum of average power from the source 8. As an alternative to supplying excitation from a separate source such as \( \), or in addition to it, it may be possible to produce magnetron oscillations in the tube as an aid to producing secondary emission.

The invention, although described above particularly with reference to a power converter is not limited to such use, since it can be used for communication purposes on relatively low frequencies. If used for communication, modulation may be accomplished by keying the potential of source \( \$ \) for telegraphy, or varying the resonant frequency of tuned circuit \( \$ \) for producing frequency modulation. If desired, the potential of source \( \$ \) can be modulated to produce amplitude modulation of the output power. I may also produce amplitude modulation by variably absorbing the output power and by varying the coupling to the load, preferably with a saturable iron core modulator.

The term "cold cathode" used in this specification and the claims is used to define a cathode which is not heated directly from an external source, as distinguished from the conventional thermionic cathode which is heated by electrical power from an external source.

Fig. 4 shows one embodiment of the invention.
which can be used for radio communication employing amplitude modulation. The potential of source 3 is modulated by source 21 through an audio transformer 22. Output from tuned circuit 6 is fed to an antenna 23. The parts of Fig. 4 which correspond with similar parts in Fig. 1 have been given the same reference numerals. The operation of the system of Fig. 4 will be obvious from what has been stated above.

What is claimed is:

1. The method of operating a magnetron oscillator having a secondary emissive cold cathode and a surrounding anode structure, which comprises exciting said oscillator with very high frequency power of a frequency higher than the desired output frequency, and supplying said anode with an oscillating potential which oscillates between a value which is positive relative to said cathode and much higher than what would be the normal cut-off potential in the magnetron in the absence of output oscillations output thereby inhibiting the growth of secondary electrons from said cathode, and a value below the normal cut-off potential but which is still positive relative to said cathode at which last value there is a growth of secondary electrons.

2. An electron discharge device and circuit therefor comprising a secondary emissive cold cathode extending along the longitudinal axis of said device, said cathode emitting electrons at a ratio greater than unity when impacted by primary electrons, an anode surrounding said cathode, there being an evacuated space between said cathode and anode, means providing a magnetic field whose flux lines are substantially parallel to said cathode, and means supplying said anode with a polarizing potential which is positive relative to said cathode and which periodically varies from a value above cut-off, at which secondary emission from the cathode is inhibited to a value below cut-off at which there is a growth of secondary emission, the time interval during which the potential on said anode is above the cut-off value being longer than the time interval during which it is below the cut-off value.

3. An electron discharge device oscillator comprising a cold cathode capable of emitting secondary electrons when bombarded by other electrons, said cathode extending along an appreciable portion of the length of said device, a resonant anode structure surrounding said cathode, means providing a magnetic field whose flux lines are substantially parallel to said cathode, a source of anode potential coupled to said anode through a tuned output circuit, means for supplying a relatively high frequency electric field to said oscillator at a frequency greater than the resonant frequency of said tuned output circuit, means for supplying to said anode a potential which is positive relative to said cathode and which is higher than what would be the cut-off value in the absence of output oscillations, said tuned output circuit superimposing alternating potential on the potential of said source to thereby cause the total effective anode potential to periodically fall below the cut-off value and enable the growth of total electron emission accompanied by pulses of electron current through the device.

4. An electron discharge device oscillator comprising a cold cathode capable of emitting secondary electrons upon bombardment by other electrons, said cathode extending along an appreciable portion of the length of said device, a resonant anode structure surrounding said cathode, a source of controllable direct current potential, and connections from said source to said anode and cathode for supplying said anode with a positive potential relative to said cathode, a tuned output circuit connected between said anode and said source, means for supplying a magnetic field whose flux lines extend substantially parallel to said cathode, a source of relatively high frequency power of a frequency greater than the frequency of said tuned output circuit coupled to one of said connections from said source of controllable direct current potential for setting up a relatively high frequency electric field in said oscillator, said source of direct current potential being adjusted to supply to said anode a positive potential which is higher in value than what would be the value of the cut-off potential in the absence of oscillations, said output tuned circuit superimposing an alternating potential on said direct current source which causes the total effective anode potential to oscillate at the frequency of said tuned circuit from a value above cut-off to a value below cut-off but still positive relative to said cathode.

5. The method of operating an electron discharge device having a cold secondary emissive cathode, a surrounding resonant anode structure and a magnetic field whose flux lines extend substantially parallel to said cathode, which comprises exciting said oscillator with relatively high frequency power of a frequency higher than the desired output frequency, supplying said anode with a low value of polarizing potential which is positive relative to said cathode to thereby produce a large anode current, raising said value of polarizing potential to the cut-off value for said device at which the electrons strike the anode on their first outward trip, and then causing said anode potential to oscillate at the output frequency between values above and below said cut-off value.

6. An electron discharge device oscillator comprising a cold cathode capable of emitting secondary electrons upon bombardment by other electrons, said cathode extending along an appreciable portion of the length of said device, a resonant anode structure surrounding said cathode, a source of controllable direct current potential, and connections from said source to said anode and cathode for supplying said anode with a positive potential relative to said cathode, a tuned output circuit connected between said anode and said source, means for supplying a magnetic field whose flux lines extend substantially parallel to said cathode, a source of relatively high frequency power of a frequency greater than the frequency of said tuned output circuit coupled to one of said connections from said source of controllable direct current potential for setting up a relatively high frequency electric field in said oscillator, said source of direct current potential being adjusted to supply to said anode a positive potential which is higher in value than what would be the value of the cut-off potential in the absence of oscillations, said output tuned circuit superimposing an alternating potential on said direct current source which causes the total effective anode potential to oscillate at the frequency of said tuned circuit from a value above cut-off to a value below cut-off.

7. A vacuum tube oscillator comprising a tubular cathode capable of emitting secondary electrons when bombarded by other electrons, a metallic cavity resonator surrounding said cathode
and constituting an anode, said cathode passing through opposite walls of said resonator and being insulated therefrom, means providing a magnetic field with flux lines parallel to said cathode, a cooling system for passing cooling fluid through said tubular cathode, a source of anode polarizing potential coupled to said anode through a tuned output circuit, means for supplying a relatively high frequency electric field to said oscillator at a frequency greater than the resonant frequency of said tuned output circuit, said source supplying to said anode a positive potential which is higher than what would be the cut-off value in the absence of output oscillations, said tuned output circuit superimposing alternating potential on the potential of said source to thereby cause the total effective anode potential to periodically fall below the cut-off value and enable the growth of total electron emission.

8. The method of operating a magnetron oscillator having a secondary emissive cold cathode and a surrounding anode structure, which comprises exciting said oscillator with very high frequency power of a frequency higher than the desired output frequency, supplying said anode with an oscillating potential which oscillates between a value which is much higher than what would be the normal cut-off potential in the magnetron in the absence of output oscillations to thereby inhibit the growth of secondary electrons from said cathode, and a value below the normal cut-off potential relative to said cathode at which last value there is a growth of secondary electrons, and supplying said anode a maximum value of electron current during those intervals when said oscillating potential is below the cut-off potential and a lesser value of electron current during those intervals when said oscillating potential is above the cut-off potential.

9. The method of operating a magnetron oscillator having a secondary emissive cold cathode and a surrounding anode structure, which comprises exciting said oscillator with very high frequency power of a frequency higher than the desired output frequency to provide a high ratio of exciting frequency to output frequency, and supplying said anode with an oscillating potential which oscillates between a value which is positive relative to said cathode and much higher than what would be the normal cut-off potential in the magnetron in the absence of output oscillations to thereby inhibit the growth of secondary electrons from said cathode, and a value below the normal cut-off potential but which is still positive relative to said cathode at which last value there is a growth of secondary electrons, whereby the time for the growth of secondary electrons to an operating value is small compared to the time period of a cycle of said output frequency.

10. The method of operating an electron discharge device oscillator having a secondary emissive cathode, a surrounding resonant anode structure, and a substantially constant magnetic field parallel to said cathode, which includes applying a relatively high frequency potential between anode and cathode as well as a very low frequency including zero frequency potential in excess of what would be the cut-off value in the absence of oscillations, and superimposing on said potential an alternating potential whenever the momentarily raises the total effective anode potential considerably above the cut-off value and then reduces the total effective anode potential below the cut-off value for a time interval which is small compared to the time period of a cycle of said alternating potential.

11. A transmitter for communication purposes comprising an electron discharge device oscillator having a cold cathode emitting secondary electrons when bombarded by other electrons, said cathode extending along an appreciable portion of the length of said device, a resonant anode structure surrounding said cathode, means providing a magnetic field whose flux lines are substantially parallel to said cathode, a source of anode polarizing potential coupled to said anode through a tuned output circuit, means for supplying a relatively high frequency electric field to said oscillator at a frequency greater than the resonant frequency of said tuned output circuit, said source supplying to said anode a positive potential which is higher than what would be the cut-off value in the absence of output oscillations, said tuned output circuit superimposing alternating potential on the potential of said source to thereby cause the total effective anode potential to periodically fall below the cut-off value and enable the growth of electron emission, and means for modulating the energy produced in said tuned output circuit in accordance with the intelligence to be transmitted.

12. A transmitter in accordance with claim 11, characterized in this that said modulating means includes a circuit for modulating the direct current power input to the oscillator to thereby control the time of growth of total electron emission to an operating value.

13. A converter of low frequency or direct current power to higher frequency energy suitable for use for induction heating purposes, comprising an evacuated electron discharge device having a cold cathode capable of emitting secondary electrons when bombarded by other electrons, said cathode extending along an appreciable portion of the length of said device, a resonant anode structure surrounding said cathode, means providing a magnetic field whose flux lines are substantially parallel to said cathode, a source of said power to be connected between said anode and said cathode for supplying said anode with a polarizing potential, a magnetic field source connected between said anode and one terminal of said source, means for supplying a relatively high frequency electric field to said oscillator at a frequency greater than the resonant frequency of said tuned output circuit, said source supplying to said anode a positive potential which is higher than what would be the cut-off value in the absence of output oscillations, said tuned output circuit superimposing alternating potential on the potential of said source to thereby cause the total effective anode potential to periodically fall below the cut-off value and enable the growth of total electron emission.

14. An electron discharge device and circuit therefore comprising a secondary emissive cold cathode extending along the longitudinal axis of said device, said cathode emitting electrons at a ratio greater than unity when impinged by primary electrons, an anode surrounding said cathode, there being an evacuated space between said cathode and anode, means providing a magnetic field whose flux lines are substantially parallel to said cathode, and means supplying said anode with a polarizing potential which is positive relative to said cathode and which periodically varies from a value above cut-off, at which
secondary emission from the cathode is inhibited to a value below cut-off at which there is a growth of secondary emission.

CLARENCE W. HANSELL

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