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I. LANGMUIR

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HIGH FREQUENCY OSCILLATOR

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Fig. 2.

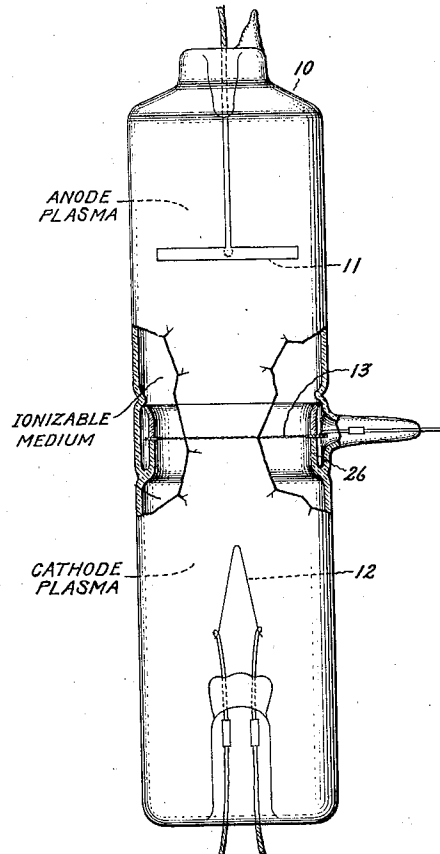
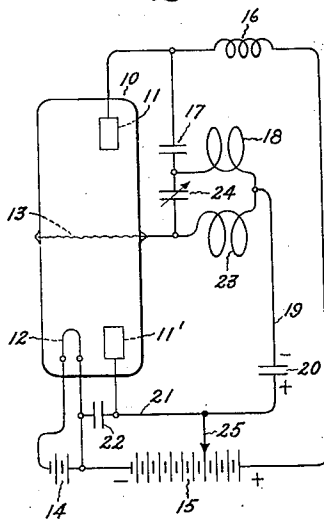


Fig. 1.



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UNITED STATES PATENT OFFICE

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HIGH FREQUENCY OSCILLATOR

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Application March 28, 1934, Serial No. 717,747

10 Claims. (Cl. 250—36)

My invention relates to high and ultra-high frequency oscillators and more particularly to such oscillators utilizing electric discharge devices containing an ionizable medium.

Heretofore, there have been devised numerous circuit arrangements utilizing electric discharge devices for generating electrical oscillations of a frequency suitable for communication, particularly radio. Perhaps one of the best known and most widely used type of oscillators is that comprising a high vacuum, pure electron discharge device. In this type of oscillator the instantaneous increase of the discharge device varies directly with the instantaneous value of the grid potential, so that, by proper interaction between the grid circuit and the output circuit, oscillations are generated of a frequency dependent upon the tuning of one of said circuits, as is well understood by those skilled in the art. This type of oscillator is very stable in operation, but is subject to the disadvantage of a relatively low efficiency due to the large resistance losses in the discharge device. Therefore, it has been difficult to build oscillators of this type which would produce efficiently a relatively high power output.

Other types of oscillators are known to the art, such as those utilizing a cold cathode vapor electric discharge device, and the type known as an inverter. The former has the disadvantage that it is difficult to control accurately the frequency of the generated oscillations and the latter in its present commercial form is limited in its utility by the fact that the deionization time of the discharge device is of such magnitude that high frequency oscillations suitable for communication purposes, are not now obtainable.

I have discovered the following phenomenon to be present in an electrical discharge device comprising an envelope containing an ionizable medium at a pressure which is sufficient to permit ionization of such degree as to form a plasma, but yet not great enough to impede seriously the free motion of electrons. A plasma is generally defined in the art as being an electrically neutral body composed of an ionized medium. These ionizable media may comprise mercury vapor at a relatively low pressure, in which case the pressure would preferably lie within the range of 0.1 to 2 microns, or one of the rarer gases such as argon, helium, or neon. For comparable operation the helium and neon gases are at a pressure of about a millimeter of mercury. If we have an electric discharge device comprising an envelope containing at one extremity an anode and a

and a cathode, and a single grid structure located intermediate the groups of anodes and cathodes, and introduce an ionizable medium into the envelope of the proper pressure, it will be possible to set up within this tube a plurality of plasmas. If we now assume that plasmas have been formed about each group of anodes and cathodes and furthermore that the grid element is sufficiently large to separate the envelope into compartments, a negative charge placed upon the grid will cause the grid to be surrounded by a positive ion sheath which will completely isolate the plasmas from each other. The thickness of the positive ion sheath is dependent upon the cathode temperature, the anode voltage and the charge upon the grid. If the charge or voltage on the grid is varied rapidly, the thickness of the positive ion sheath follows these variations practically instantaneously. If the voltage on the grid is varied sufficiently, the thickness of the positive ion sheath may be reduced to such magnitude that there may be an interchange or flow of electrons between the two plasmas.

In accordance with my invention, I utilize the above phenomenon in the construction and operation of an oscillator having a double plasma electric discharge device. In the preferred embodiment, this double plasma discharge device comprises an envelope containing an anode, a cathode, a grid element and an ionizable medium, such as one of the rarer gases, or mercury vapor at a relatively low pressure. The grid element, which is located between the anode and the cathode, is of sufficient magnitude or is of such configuration that the grid element will completely separate the anode plasma from the cathode plasma. This may be accomplished in a number of different ways, one of which may be to construct the grid of uniform mesh which extends to the sides of the envelopes, thus separating the envelope into two compartments. If now positive potentials are applied to the grid and to the anode and the cathode is energized, ionization will occur. If now a momentary negative charge is placed upon the grid, the ionized medium will be divided into anode and cathode plasmas by the positive ion sheath which forms about the grid. Thus, one compartment contains the anode plasma and the other compartment contains the cathode plasma. This positive ion sheath is substantially continuous and it is capable of preventing or interrupting an electron flow between the two plasmas without the necessity of deionization of the ionizable medium. If this momentary negative charge upon the grid is

succeeded by a periodic variation which tends to cause the grid to become more positive or to cause a variation in the potential difference between the plasmas, the positive ion sheath edges move back and forth during each variation of the grid potential so that during a portion of each cycle the edge of one side of the sheath moves up to the immediate proximity of the grid. At this time, the electrons from one plasma will pass through the grid to the other plasma. The control effect of the grid element does not change the electron flow directly with the instantaneous value of the grid potential, as in the high vacuum type electron discharge device, but it is rather an on and off effect so that the full electron flow is either present or not present, depending upon whether the grid voltage is above or below a certain value. This critical value of the grid voltage depends upon the nature of the ionizable medium within the envelope. Thus, in some instances the charge upon the grid is negative with respect to the cathode and in other instances is negative with respect to the anode potential. This double plasma discharge device has the advantage that there are no large resistance losses, as in the high vacuum type device, as this device operates during the peak of alternating potentials on the grid element with an electron flow which is limited principally only by the cathode emission.

In the electric discharge devices containing an ionizable medium commonly in use today, such as devices known in the art under the trade-mark "Thyratrons", the flow of current through the device is determined by the variation of the ionization of the ionizable medium. In such devices the degree of ionization varies from the time of the initiation of the discharge until the discharge is completed and during the time of nonconductivity the discharge device is in a deionized state. In the double plasma discharge device the ionization or the concentration of ions remains substantially constant and the changes in the anode current during each cycle resulting from the variations in the thickness of the positive ion sheath about the grid are due to a displacement of the electrons but not to a flow of ions or change of ionization intensity.

For this reason the double plasma tube can operate to repeat at the high frequencies at which pure electron (or gas free) discharge devices can operate and it is not restricted to the lower frequencies usually characteristic of devices operating with an ionized medium.

It is an object of my invention, therefore, to utilize such a double plasma electric discharge device in high and ultra-high frequency apparatus.

It is another object of my invention to provide an improved oscillator which will overcome some of the disadvantages of the arrangements of the prior art, and which will be simple, reliable, and powerful in operation.

It is a further object of my invention to provide an improved oscillator utilizing an electric discharge device containing an ionizable medium which will generate powerful oscillations of high and ultra-high frequency.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood by reference to the following description taken in connection with the accompanying draw-

ing in which Fig. 1 discloses an apparatus utilizing one of the tubes described in my invention, and Fig. 2 discloses the preferred form of the double plasma electric discharge device suitable for operation as an oscillator.

Referring to Fig. 1 of the drawing, I have illustrated therein an oscillation generator utilizing an electric discharge device comprising an envelope 10 which is filled with an ionizable medium at a pressure just sufficient to permit an ionization necessary to allow plasma formation yet not of sufficient pressure so as to impede materially or seriously the free motion of electrons. This ionizable medium may comprise mercury vapor at a relatively low pressure or one of the rarer gases such as argon, helium, or neon. The envelope contains the anode 11, the auxiliary anode 11', a cathode 12 and a grid element 13. The grid element, which should be of such configuration or magnitude as to separate adequately the anode plasma from the cathode plasma, is in this instance disclosed as a uniform mesh member which extends to the walls of the discharge device. The cathode 12 is energized from a suitable source of potential 14 and the anode potential is supplied by a source of potential 15. The anode 11 is connected to the source of potential 15 through a lead which includes a choke coil 16 which serves to prevent the high frequency from passing through the sources of potential 14 and 15. The anode to cathode circuit of the anode 11, comprises the following elements: A capacitor 17, an inductor 18, a lead 19, a capacitor 20, a lead 21 and a capacitor 22. The grid-to-cathode circuit comprises the following elements: The inductor 23 which is coupled to the anode inductor 18, the lead 19, capacitor 20, lead 21 and capacitor 22. A variable capacitor 24 connected across the inductors 18 and 23 serves to operate as a tuning means for determining the resonant frequency of the anode and grid circuits. Inasmuch as the operation of the arrangement is not dependent in any way upon the time of deionization of the discharge device, the oscillation period of these circuits may be of a lower order of magnitude than that of the period of deionization of the discharge device. In order to insure the existence of a cathode plasma the anode 11' is connected through the lead 21 and a tap 25 to the source of potential 15.

Due to the fact that the capacitor 20 is connected through the tap 25 to a source of positive potential, a portion of the battery 15, the lower side of the capacitor 20 is positively charged and consequently the upper side of the capacitor has a negative charge. This negative charge is impressed upon the grid 13 thus producing about the grid a positive ion charge. The positive ion charge surrounds each of the individual wires of the grid mesh and if the potential on the grid and the wires are properly proportioned this positive ion charge or sheath will form a substantially continuous layer which normally is impervious to the flow of electrons from the cathode plasma to the anode plasma. A portion of the energy in the high frequency anode circuit is transferred to the grid circuit due to the coupling between the inductors 18 and 23. This transfer of energy from the anode circuit to the grid circuit causes the negative charge upon the grid 13 to be varied and causes a variation of the potential difference between the plasmas. As the charge on the grid is varied the edges of the positive ion sheath move back and forth during each cycle so that during a small portion of each cycle the edge at

one side of the sheath moves up to the immediate proximity of the grid 13. At this time the electrons from one plasma pass through the grid to the other plasma. Thus, there is a flow of electrons from one plasma to the other during the peak of each cycle of the voltage variation on the grid 13, which flow is limited principally by the cathode emission.

While I do not wish to be limited thereto, I believe that the above explanation presents the true theory of the operation of the double plasma electric discharge device as an electric high frequency oscillator.

Reference may now be had to Fig. 2 wherein I have disclosed the preferred embodiment of the double plasma electric discharge device. This figure also shows in detail the manner of supporting and arranging the grid in the envelope of the discharge device so as to separate the anode plasma from the cathode plasma. The device shown in this figure comprises a cylindrical envelope 10 supporting at one end the anode 11 and at the opposite end the cathode 12. The grid element should be of such configuration that the cathode plasma will be separated from the anode plasma by the positive ion sheath formed about the grid. One form of grid which will suffice may be a cylindrical grid preferably of a lesser diameter than said envelope, closed at one end and located so as to enclose substantially either the cathode or the anode. Another form of the grid may be like that disclosed in the present example where the grid is supported by a secondary glass wall 26 which is arranged so that only the uniform mesh of the grid 13 is exposed to the ionizable medium contained within the envelope 10. An advantage gained by supporting the grid element by the secondary glass wall 26 is that no metallic supporting structure of the grid is subject to the ion bombardment commonly known as "sputtering". By placing the proper potential upon the grid 13 a positive ion sheath of substantially uniform thickness will form and serve to separate the ionizable medium into anode and cathode plasmas. It will be noted that the discharge device disclosed in Fig. 2 does not have the auxiliary anode 11' which is disclosed in Fig. 1, as it has been found that under certain conditions this auxiliary anode may be dispensed with.

It is to be understood that while I have shown a means for supplying a negative charge upon the grid 13 in Fig. 1 as a capacitor, that any other means may be substituted, such as a bias battery. Also any other form of transferring a portion of the energy in the anode circuit of the discharge device to the grid circuit may be utilized, such as capacitive coupling. Furthermore, the circuit arrangement disclosed is merely exemplary of one of a number of circuits which may be utilized with the double plasma electric discharge device for the generation and reproduction of high and ultra-high frequency oscillations.

The oscillation generator disclosed and described herein is capable of generating oscillations of 300,000 kilocycles or more.

Due to the fact that current is passed from one plasma to the other during each positive peak of the cycle of the voltage alternations impressed upon the grid, the apparatus operates at a relatively high efficiency because there are no large resistance losses in the discharge device. This apparatus, therefore, has the advantage that it may be used as a power oscillator at high or ultra-high frequency.

While I have shown and described my invention in connection with certain specific embodiments, it will, of course, be understood that I do not wish to be limited thereto, since it is apparent that the principles herein disclosed are susceptible of numerous other applications, and modifications may be made in the circuit arrangement and in the instrumentalities employed without departing from the spirit and scope of my invention as set forth in the appended claims.

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

1. A high frequency apparatus including a discharge device comprising an envelope containing an ionizable medium at a pressure sufficient to permit ionization without material impediment to free electron movement, an anode, a cathode and a control grid element included within said envelope, said control grid being arranged to separate said envelope into anode and cathode compartments, means connected to said anode and said cathode for producing ionization of said medium, and means including said control grid for controlling the interchange of electrons between said compartments without substantial variation of the degree of ionization of said ionizable medium.

2. A high frequency apparatus including a discharge device comprising an envelope containing an ionizable medium at a pressure sufficient to permit ionization without material impediment to free electron movement, an anode, a cathode and a control grid element included within said envelope, said control grid being arranged to separate said envelope into anode and cathode compartments, means connected between said anode and said cathode for producing ionization of said medium, and means for varying an electrical condition of said grid in a manner to control the interchange of electrons between said compartments without substantial variation of the degree of ionization of said ionizable medium.

3. A high frequency apparatus including a discharge device comprising an envelope containing an ionizable medium at a pressure sufficient to permit ionization without material impediment to free electron movement, an anode, a cathode and a control grid element included within said envelope, said control grid element being arranged to separate said envelope into anode and cathode compartments, means for producing normally about said control grid element a substantially continuous positive ion sheath, and means for varying the condition of said positive ion sheath in a manner to control the flow of electrons between said compartments without substantial variation of the degree of ionization of said ionizable medium.

4. A high frequency apparatus including a discharge device comprising an envelope containing an ionizable medium at a pressure sufficient to permit ionization without material impediment to electron movement, an anode, a cathode and a grid element included within said envelope, said grid being sufficient in magnitude and configuration to separate said envelope into anode and cathode compartments, a source of potential connected between said anode and said cathode, means for impressing a potential upon said grid with respect to other elements of said device to produce normally a substantially continuous positive ion sheath between said compartments, a grid-cathode circuit and an anode-cathode circuit for said discharge device, and means for im-

pressing high frequency energy upon said grid-cathode circuit for reproduction in said anode-cathode circuit.

5. A high frequency oscillator including a discharge device comprising an envelope containing an ionizable medium at a pressure sufficient to permit ionization without material impediment to electron movement, an anode, a cathode and a grid element included within said envelope, said grid being sufficient in configuration to separate said envelope into anode and cathode compartments, a source of potential connected between said anode and said cathode, means including a potential impressed upon said grid with respect to other elements of said device to produce normally a substantially continuous positive ion sheath between said compartments, a grid-cathode circuit and an anode-cathode circuit for said discharge device, and means for transferring a portion of the energy present in said anode-cathode circuit to said grid-cathode circuit.

6. A high frequency oscillator including a discharge device comprising an envelope containing an ionizable medium at a pressure sufficient to permit ionization without material impediment to electron movement, an anode, a cathode and a grid all included within said envelope, said grid being located between said anode and said cathode and of such configuration as to separate said envelope into anode and cathode compartments, a source of potential connected between said anode and said cathode, means for impressing a potential upon said grid with respect to other elements of said device sufficient to produce normally a substantially continuous positive ion sheath about said grid, a grid circuit connected between said grid and said cathode, an output circuit connected between said anode and said cathode, and means for impressing a portion of the energy present in said output circuit upon said grid circuit.

7. A high frequency oscillator including a discharge device comprising an envelope containing an ionizable medium at a pressure sufficient to permit ionization without material impediment to electron movement, an anode, a grid and a cathode included within said envelope, said grid separating said envelope into anode and cathode compartments, a source of potential connected between said anode and said cathode, means for impressing a potential upon said grid with respect to other elements of said device to produce normally a substantially continuous positive ion sheath around said grid, said sheath separating said ionizable medium into anode and cathode plasmas, a circuit connected between said grid and said cathode, a circuit connected between said anode and said cathode, and means for transferring a portion of the anode circuit energy to said grid circuit whereby said positive ion sheath will be sufficiently altered to permit electrons to pass from one plasma to the other thereby producing high frequency oscillations.

8. A high frequency oscillator including a dis-

charge device comprising an ionizable medium at a pressure sufficient to permit ionization without material impediment to electron movement, an anode, a cathode and a grid element included within said envelope, a source of potential connected between said anode and said cathode, said grid element being of sufficient magnitude and configuration to separate said medium into anode and cathode plasmas, means for impressing a potential upon said grid with respect to other elements of said device to produce normally a substantially continuous positive ion sheath about said grid, a grid to cathode plasma circuit and an anode plasma to cathode plasma circuit for said discharge device, means for transferring a portion of said second circuit energy to said first circuit, and means for tuning at least one of said circuits to an oscillation period of a lower order of magnitude than the deionization time of said discharge device.

9. A high frequency oscillator including a discharge device comprising anode, cathode and grid elements enclosed within an envelope containing an ionizable medium at a pressure sufficient to permit ionization without material impediment to electron movement, means including a source of potential connected between said anode and said cathode for producing plasmas, plasmas surrounding each of said anode and cathode elements, means for producing normally a positive ion sheath about said grid to separate said anode and cathode plasmas thereby normally restricting the flow of electrons between said plasmas, grid to cathode plasma and anode plasma to cathode plasma circuits for said discharge device, means for tuning at least one of said circuits, and means for transferring a portion of the anode-cathode circuit energy to said grid circuit whereby said positive ion sheath will be altered periodically to vary the flow of electrons between said plasmas.

10. A high frequency oscillator including a discharge device comprising anode, cathode and grid elements enclosed within an envelope containing an ionizable medium at a pressure sufficient to permit ionization without material impediment to electron movement, means including a source of potential connected between said anode and said cathode for producing plasmas, plasmas surrounding each of said cathode and anode elements, means for producing normally a substantially continuous positive ion sheath about said grid to separate said plasmas and to normally restrict the flow of electrons between said plasmas, an anode-cathode circuit including a source of potential tending to cause a flow of electrons between said plasmas, a grid-cathode circuit for said discharge device, means for tuning at least one of said circuits, and means for transferring a portion of the energy of said anode-cathode circuit to said grid-cathode circuit whereby said positive ion sheath and the potential difference between said plasmas will be altered sufficiently to produce a periodic flow of electrons between said plasmas.

IRVING LANGMUIR.