

July 30, 1935.

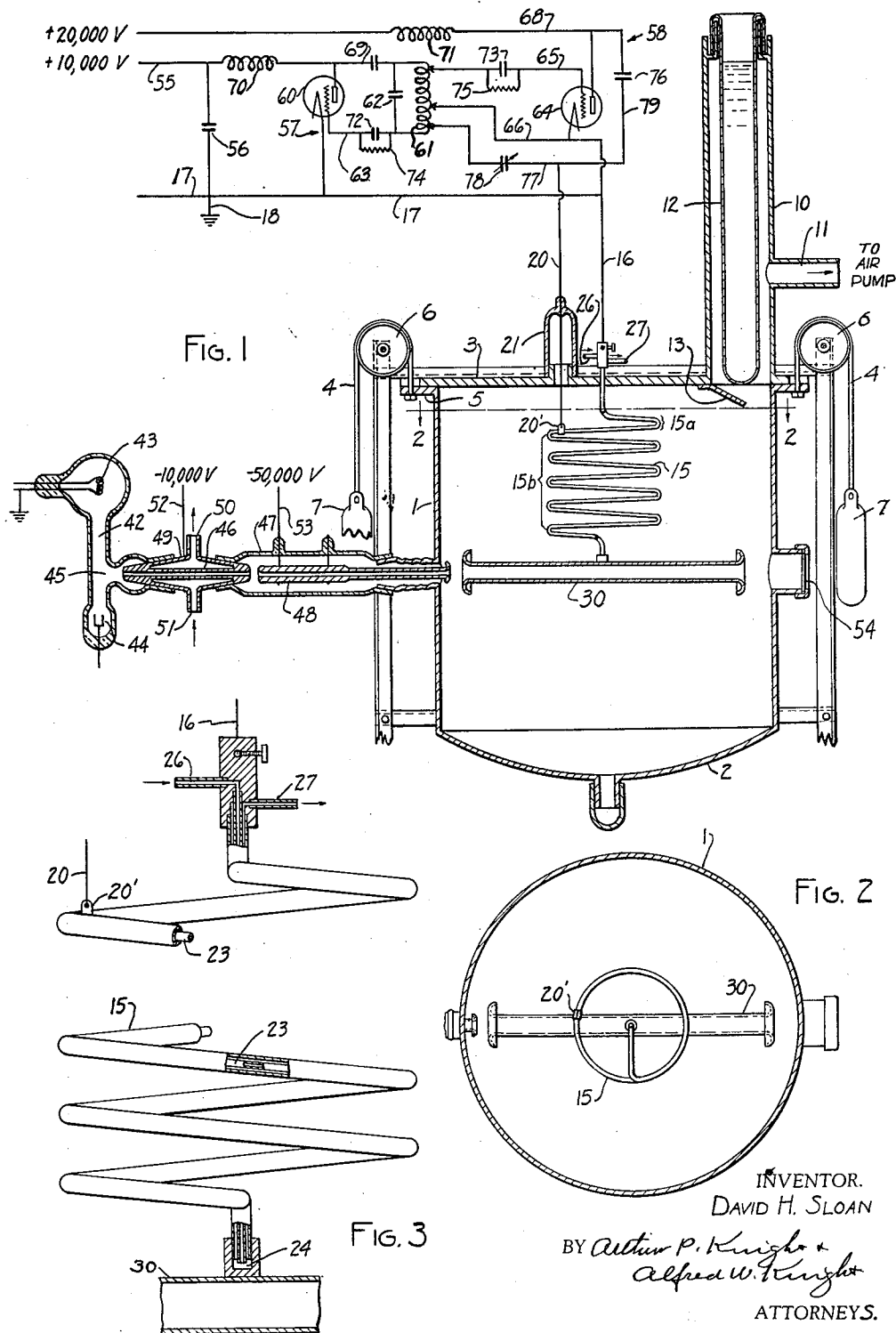
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2,009,457

METHOD AND APPARATUS FOR PRODUCING HIGH VOLTAGE

Filed April 11, 1932

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

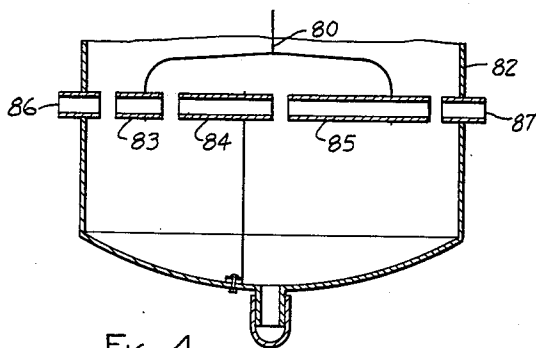


FIG. 4

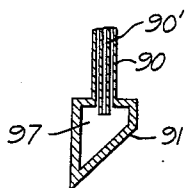


FIG. 5a

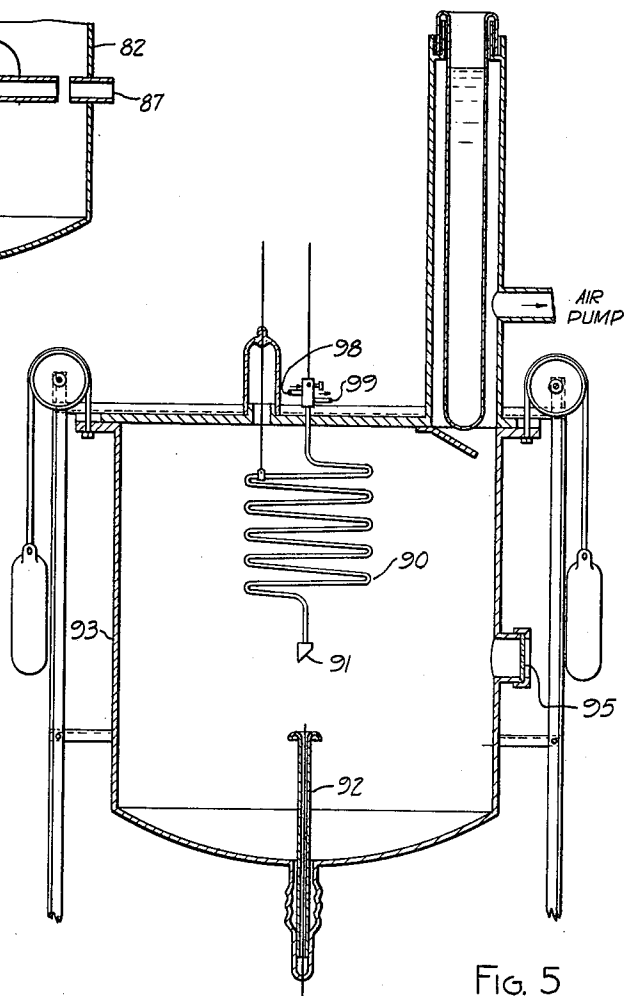


FIG. 5

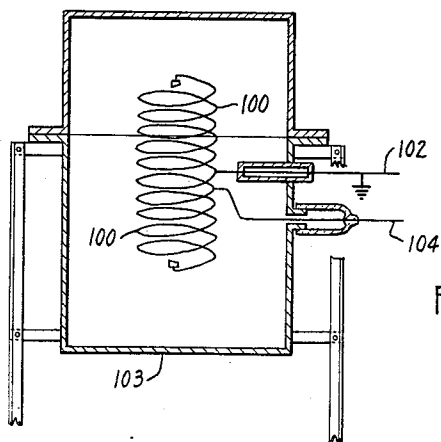


FIG. 6

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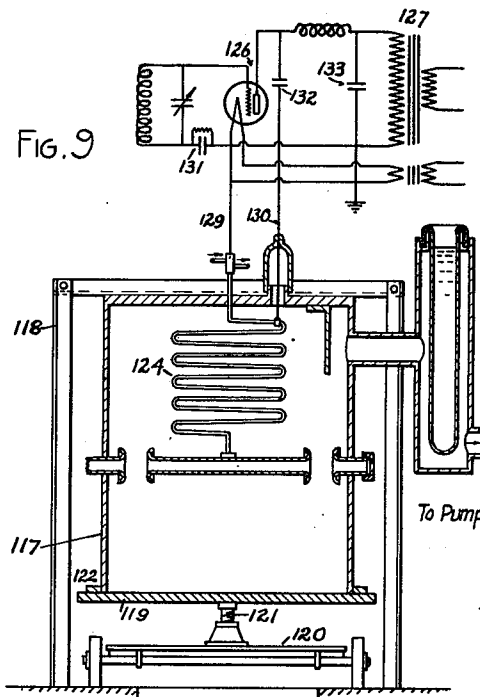
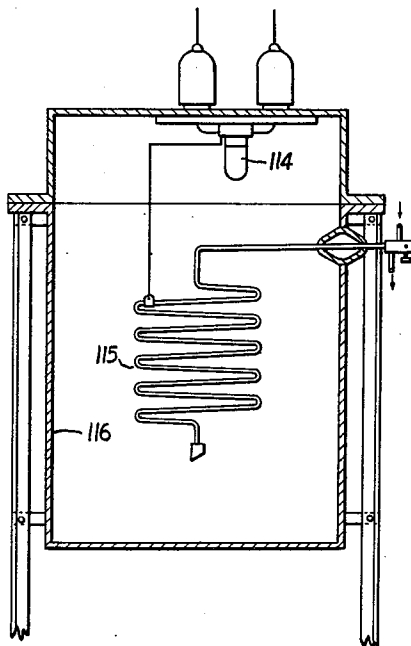
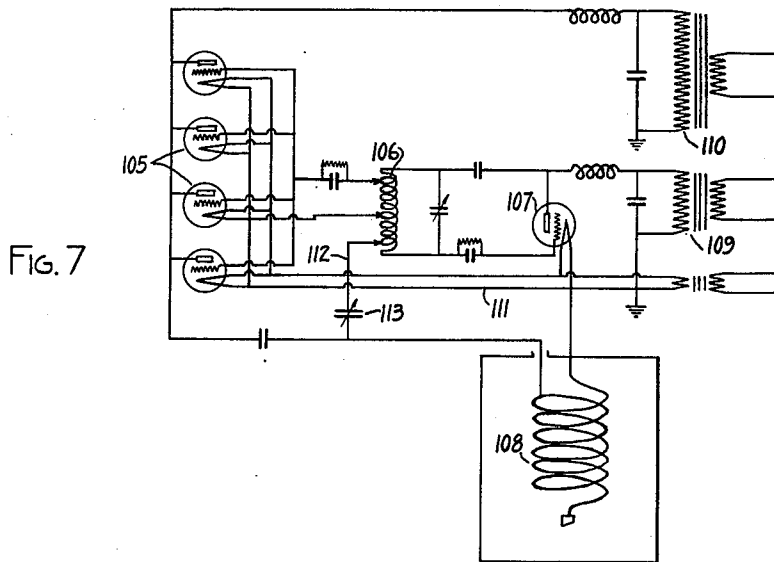
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3 Sheets-Sheet 3



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## UNITED STATES PATENT OFFICE

2,009,457

## METHOD AND APPARATUS FOR PRODUCING HIGH VOLTAGE

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Application April 11, 1932, Serial No. 604,642

4 Claims. (Cl. 250—34)

This invention relates to the production of high frequency alternating high voltage and the main object of the invention is to provide for the production of such high voltage in an efficient and practicable manner.

A particular object of the invention is to provide for generation of high frequency high voltage in such manner that the point or points of maximum voltage in the generating circuit are remote from the points of mechanical support so that the generating parts may be supported by insulators which are connected only to parts of relatively low voltage, thereby minimizing the difficulty of insulation and at the same time provide means for preventing undue heating of the said generating parts.

In the production of high voltages, for example 100,000 to 1,000,000 volts or over, one of the main difficulties is the insulation of the parts and connections at which such high voltages exist as it is a matter of extreme difficulty to provide insulating means which present the necessary mechanical strength for supporting such parts or connections and at the same time are able to withstand the stresses set up by the high voltage electrical field, particularly in case of high frequency voltage. My invention obviates this difficulty by generating the high frequency high voltage in a coil or inductance means which is supported only at portions thereof which are grounded or are at low potential and is also connected to energizing circuit means only at parts which are at relatively low potential, the portions of said coil or inductance at which the high voltage or high potential is generated, being remote from the points of support and of connection to the energizing circuit means and the high voltage generating coil itself being inclosed within a chamber maintained at a high degree of vacuum so that the necessary insulation is provided for withstanding the high voltage generated at the free end of the coil, and the use of solid insulators for support and connection of such high voltage portion of the coil is done away with. My invention provides in connection with a coil supported in this manner, means for circulating cooling medium through the coil so as to prevent undue heating of the coil by reason of the high frequency oscillating current produced therein.

The accompanying drawings illustrate an apparatus suitable for carrying out my invention, and referring thereto:

Fig. 1 is a vertical section of one form of such apparatus, the energizing circuits therefor being

shown diagrammatically, and the apparatus being shown as provided with means for acceleration of ions or electrically charged particles;

Fig. 2 is a section on line 2—2 in Fig. 1;

Fig. 3 is an enlarged vertical section, partly in elevation, of portions of the high voltage generating coil showing the cooling connections therefor;

Fig. 4 is a partial vertical section showing modification of the means for utilizing the high voltage produced for the acceleration of ions;

Fig. 5 is a vertical section of a form of the apparatus which is adapted for the production of X-rays for example;

Fig. 5a is a vertical section of an anti-cathode shown in Fig. 5;

Fig. 6 is a vertical section of a modification of the apparatus in which the high voltage generating coil is made in symmetrically disposed sections corresponding to half wave resonance;

Fig. 7 is a diagram showing circuit connections adapted for energization of the oscillator by a plurality of power amplifier tubes in parallel;

Fig. 8 is a vertical section of a form of the apparatus in which the thermionic tube of the voltage amplifying circuit is inclosed in the same evacuated chamber that contains the resonance coil;

Fig. 9 is a vertical section of a modified form of the apparatus, said figure also showing the application of a self-excited oscillator in connection therewith.

The apparatus shown in Figs. 1 to 3 comprises a casing or chamber 1 of any suitable material, said casing being shown as a vertical cylinder having a closed bottom 2 and mounted in gas tight connection with a top plate 3. As said casing is evacuated in normal operation, it is desirable to construct it of strong material such as iron or steel and of sufficient thickness to withstand a high vacuum. The cylindrical casing 1 is supported in any suitable manner. In Fig. 1, the casing is shown as held against the top plate 3 by means of cables 4 attached to flange 5 on said casing and running over pulleys 6, said cables being provided with counterweights 7 so as to hold the casing up against the top plate, but permitting lowering of the casing for access to the interior thereof when desired, it being understood that in normal operation the casing is held tightly against the top plate 3 by atmospheric pressure. The joint between said plates 3 and flange 5 is sealed in any suitable manner, for example by means of wax. When it is desired to lower the casing as stated, the vacuum therein must first be

eliminated by admission of air or gas thereto. A tube 10 extends upwardly from a top plate 3 and is connected by pipe 11 to suitable evacuating means such as an air pump capable of producing the necessary high vacuum.

A liquid air container 12 is mounted within the tube 10 and serves as a trap for preventing vapors from the air pump from returning to the region of high vacuum within the casing 1, such vapors being condensed on the cold surface of the liquid air container 12 and being removed from time to time by allowing the said trap to warm up and operating the air or gas pump. A screen or shield 13 is shown for preventing injurious radiations from the apparatus within casing 1 from reaching the vapor trap. Any other suitable means may be provided for maintaining the requisite high vacuum within the casing 1.

The high voltage generating means proper consists essentially of a coil or inductance means 15 formed preferably as a helix of relatively few turns and large diameter and considerable spacing between the turns. Said coil is mounted at one end on a suitable support, for example on the top member 3, the other end of said coil being unsupported or free of any mechanical or electrical connection with the casing except through the coil itself, the coil being therefore in the nature of a Tesla coil or resonator supported at one end and having its other end free. The supporting end portion of the coil 15 is at relatively low potential for example, zero potential, being connected through wires 16 and 17 with ground indicated at 18 and casing 1 and top member 3 being also grounded, the supporting portion of the coil 15 may be and preferably is mounted on the top member 3 and in metallic connection therewith. A conductor 20 is connected to the coil 15 at a suitable point thereon, the connection being indicated at 20', so that a relatively small portion 15a of the coil extends between said point of connection and the point of support of the coil and a much longer portion 15b of the coil extends between said point of connection and the free end of the coil, the ratio of length of said two portions of the coil being that which is necessary to secure the requisite voltage multiplication in the coil. The wire 20 extends through a suitable insulator 21 mounted on the head or top member 3 and in sealed connection therewith. Said insulator is the only insulation required for the energizing connections of the coil and inasmuch as the alternating potential existing between the point 20' of the coil and the casing is relatively small compared to the voltage generated by the coil, the installation and maintenance of said insulator involves no difficulties.

On account of the high frequency resonance oscillations in the coil considerable heat is developed therein by the oscillating current and it is desirable therefore to provide cooling means for the coil. For this purpose the coil may be made hollow or tubular as shown in Fig. 3 and it is provided with an inner tube 23 and the passages within the inner tube and between the inner and outer tubes being in communication at the free end of the coil through a chamber 24 and the outer end portions of said passages communicating with inlet and outlet means 26 and 27 for supply of cooling water or other liquid thereto and for circulation of said liquid to the coil. The coil tube 15 and the inner tube 23 form passage means extending from the supported end of the coil to the other end thereof, and thence back to the supported means, said passage means connecting,

adjacent the supported end of the coil, with inlet and outlet connections for circulating cooling medium, for example water, therethrough.

The coil 15 is shown as mounted on top of the casing 1 and extending downwardly from its point of support but it may be mounted in any suitable manner within the casing and may extend upwardly or horizontally or in any desired direction.

The free end of the coil, which in the illustration is the lower end, is provided with any suitable means for utilizing the high voltage developed thereat. For example in Fig. 1 there is shown attached to the lower end of the coil 15 an accelerating tube 30 of suitable conducting material, such as metal, said tube extending transversely within the case 1 and being open at both ends and suitable means being provided for supplying to said tube electrically charged particles, such as ions, in such manner that the ions are accelerated by the action of the electrical field due to the high voltage applied to the tube 30 in the manner hereinafter described.

The ion supply means shown comprises a tube or chamber 42 for containing gas or vapor at low pressure, and a filament 43 mounted within said chamber 42 and provided with means, not shown, for supplying current thereto to maintain the filament at a temperature of incandescence. An anode 44 is provided at the opposite end of said chamber 42 from the filament 43 and said chamber is provided with a passage 45 intermediate its ends communicating with a tube 46 which in turn communicates with a tubular member 47 within which is mounted an insulated tube 48 whose bore is in line with the bore of tubular member 46, member 46 is shown as provided with a jacket 49 having inlet and outlet means 51 and 50 for circulating cooling medium therethrough. Suitable connections, indicated at 52 and 53, are provided for maintaining parts 46 and 48 at high electrical potential as hereinafter set forth.

In the side of the casing 1 opposite the delivery end of the accelerating tube 30 a window 54 may be provided consisting, of mica or other suitable material, through which the accelerated ions may pass to the outside of the casing. Any suitable energizing circuit means may be used for supplying oscillatory current of suitable voltage, amplitude and frequency to the Tesla coil or resonator.

The energizing circuit means shown comprises circuit connections indicated at 55, 17 for supplying current (preferably unidirectional) at suitable voltage, a master oscillator 57 connected to receive such current and to produce electrical oscillations of definite frequency and an amplifier 58 having its input connected to the master oscillator and its output connected to the oscillation coil 15 and adapted to produce the required high voltage in said coil. A capacity 56 is shown as connected across the supply circuit 55, 17.

The master oscillator shown comprises a three-electrode thermionic tube 60, the power supply connections 55, 17 therefor being connected respectively to the plate and filament of said tube and the output connections thereof being connected to inductance 61 and capacity 62 in parallel and being connected to the grid of said tube to enable the tube to act regeneratively and produce oscillations of a definite frequency, it being understood that provision is made, for example by adjustment of either or both condenser 62 and inductance 61 to tune the master oscillator to any desired frequency.

The amplifier comprises a three-electrode

thermionic tube 64 having its input connected by variable connections 65 and 66 to the inductance 61 in the output of the master oscillator, and power supply connections 68 and 17 are provided for the amplifier from a suitable source of high voltage. Choke coils indicated at 70 and 71 are preferably provided in the respective power supply lines 55 and 68 for preventing transmission of high frequency oscillations to the respective high voltage power supply sources. Said power supply sources may be of any suitable type, for example the usual arrangement for producing unidirectional current or voltage from alternating current by means of a step-up transformer and a pair of reversely placed rectifying tubes connected to the secondary thereof so as to deliver to the power supply connections aforesaid rectified impulses corresponding to both half waves of the alternating current and suitable capacity being also generally included in such supply circuit for equalizing the voltage delivered thereby. If desired however, the power supply connection may be made directly to the secondary of a step-up transformer in which case only those half waves will be utilized for which the filaments of the respective thermionic tubes are negative.

The respective connections 63 and 65 to the grids of the tubes 60 and 64 are shown as including capacities 72 and 73 and grid leak resistances 74 and 75, it being understood however that said grid leak resistances may be replaced by batteries or generators of suitable voltage.

The output of the amplifier comprises connection 79 including capacity 76 leading to the line 20 in connection with a portion of the resonance or oscillation coil 15 and the line 66 which is in connection through wire 16 with the grounded end of the coil 15.

In some cases it is advantageous to provide a neutralizing connection indicated at 77 and including a variable capacity 78 between the output connection 20 for the amplifier and the output of the master oscillator, said connection 77 being for example made to a variable point on the inductance 61. By means of this neutralizing connection, it is possible not only to neutralize any regenerative or feed-back action from the output of the amplifier to the input thereof but to effect a super-neutralization so that the master oscillator feeds power directly to the output of the amplifier in addition to the power supplied to such output by the amplifier itself.

The coil 15 constitutes a resonator or standing wave oscillator and in the form of apparatus shown in Fig. 1 the grounded end of said coil is a node of the standing wave, the coil being therefore a quarter wave coil with its node at the grounded end and its anti-node at the free end of the coil, the casing 1, which is in connection with the grounded end of the coil, providing the equivalent of an opposing anti-node for the coil. The connection 20 is made to a portion of the coil 15 which is relatively near a voltage node of the resonant standing wave potential distribution thereon so that the alternating voltage impressed upon such portion of the coil near the node produces a much higher alternating voltage at the free end of the coil.

In place of a quarter wave coil as shown in Fig. 1 a half wave coil as shown in Fig. 6 may be used, the coil in that case comprising two symmetrical portions with the grounded node at mid-length thereof between the said two portions. This form of oscillator or resonator constitutes a doublet, one end being positive when the other is negative,

the center being a voltage node remaining at or near ground potential and having a maximum circulating current. If one-half of this doublet is separated from the other half by an infinite conducting plane normal to the axis of the coil and connected to it at the voltage node, the mode of oscillation will be that of a quarter wave coil of the same wave length and if one of the members of the doublet be omitted, the coil is still corresponding to a quarter wave coil. The conducting surface at the node may be of finite dimensions if properly curved around the quarter wave coil and the function of such a conducting surface is therefore effected, in the case of the form shown in Fig. 1, by the conducting casing 1 which surrounds the coil 15.

In the operation of the apparatus the chamber or casing 1 is evacuated to a high vacuum so that the desired high voltage can be maintained at the free end of the oscillation coil 15 without appreciable or undesirable loss of energy by conduction due to corona discharge through the space between the oscillation coil and the walls of the casing. The energizing circuit is set in operation and the master oscillator is energized thereby and produces oscillations of definite high frequency which are imposed upon the amplifier circuit, said amplifier circuit operating to step up the voltage of the oscillating current and deliver the multiplied voltage to the input connections 20 and 16 of the oscillation coil 15. The portion 15a of the coil which is connected to the output of the amplifier comprises a small fraction, for example one-fifth to one-fiftieth of the total length of the coil 15, and the voltage or potential difference produced at the opposite ends of the coil is multiplied, so that the maximum voltage between the free end of the coil and the grounded casing is many times the voltage delivered to the coil from the amplifier.

The connection of the energizing circuit to the oscillation coil 15 is to a small fraction 15a of said coil having a line resistance  $R''$  just sufficient to match approximately the plate to filament resistance  $R_p$  of the energizing vacuum tube or tubes. If  $R'$  is the line resistance or parallel impedance,  $L$  the total inductance,  $R$  the equivalent series resistance and  $C$  the total capacity, largely distributed, of the oscillatory circuit, then  $R'$  equals  $L/RC$ . Also with approximately unity coupling between the inductance  $L'$  and  $L''$  of the sections 15a and 15b of the coil 15, the ratio of the line resistance  $R''/R'$  approaches the value  $L''/(L'+L'')$ . It will be understood that the total inductance  $L$  is given by the relation  $L=L'+L''+2M$ , where  $M$  is the mutual inductance of the portions 15a and 15b of the coil. The coil section 15a having line resistance  $R''$  has impressed across it a voltage  $V''$  comparable in magnitude to the plate supply voltage of the amplifier and, with resonance, the voltage  $V''$  produces voltage  $V$  across the total inductance  $L$  approximately given by the relation  $V/L$  equals  $V''/L''^{1/2}$ . The inductance means or coil 15 is shaped to give a high value of  $L/RC$  so that a very small portion  $L''$  of the total inductance  $L$  is sufficient to produce a line resistance  $R''$  equivalent to the plate to filaments resistance  $R_p$  of the tube of the amplifier thus producing a very large ratio of  $V/V''$ , which ratio may amount for example to one hundred or more.

At or near resonance frequencies the circuit may oscillate with any number of standing waves or fractions thereof, including harmonics, to which the system will respond. The two most im-

portant modes of oscillation of the system are quarter and half wave-length standing waves, with or without other harmonics superposed. The useful range includes wave-lengths between 10 meters and 200 meters as well as shorter and longer waves than these.

The high frequency high voltage generated in the manner above described may be utilized in various ways, for example as shown in the drawings it may be used for the acceleration of positive ions or protons which are generated by electronic collision in the tube 42 and given preliminary acceleration by the accelerating tubes 46 and 48 which may, for example be maintained at negative voltages of 10,000 and 50,000 respectively.

The accelerating tube 30 connected to the free end of the oscillation coil 15 is given an alternating potential which oscillates for example between one million volts negative and one million volts positive. With voltage amplification factor of one hundred as above referred to this alternating voltage at the free end of the oscillation coil will be produced by power supply at 10,000 volts to the plate circuit of the amplifier.

During the half waves for which the tube 30 is at negative potential, the positive ions passing from the tube 48 are delivered to and longitudinally of tube 30 and are subjected to acceleration due to the extremely high negative voltage of tube 30, say from 100,000 to 1,000,000 volts, and the frequency of the oscillation is so controlled that a reversal of potential takes place as the ion passes through the tube 30, so that a further acceleration of the ion takes place as the ion leaves the tube by reason of the high positive potential of the tube at that time. The high speed ion may then pass through the window 54 to any suitable means for utilization thereof, experimentally or otherwise.

The invention may also be applied in connection with the other modes of acceleration of ions or other electrically charged particles, for example in connection with the method disclosed by R. Wideroe Archives für Elektrot., 21, 387 (1929). Fig. 4 shows a modification of the apparatus suitable for such purpose, the conductor indicated at 80 in said Fig. 4 being in connection with and supported by the lower end of the oscillation coil mounted within the casing 82 and operated in the manner above described to produce high frequency high voltage at the conductor portion 80, a series of tubes 83, 84, 85 are mounted in aligned arrangement within the casing 1 and alternate tubes 83 and 85 are connected to and supported by the conductor member 80, the intervening tube or tubes, for example in the illustration the tube 84, being grounded, or a doublet oscillation coil is used as above referred to, said intervening tube sections may be connected to the opposite antinode of the coil. Suitable means are provided for supplying ions through a tube 86 in line with the tube sections 83 etc. and a tube or window 87 is provided for delivering the accelerated ions to any suitable means for receiving or utilizing the same. The successive sections 83, 84 etc. are made of progressively increasing length, corresponding to the distances travelled by the ions as they are accelerated during successive half waves of the high frequency voltage applied to the tube sections so that in passing through each tube section the ions are subject to an attractive accelerating force on entering the tube and a repulsive accelerating force on leaving the tube, in accordance with the method of Wideroe referred to.

Another application of the invention is for pro-

duction of X-rays, the apparatus shown in Fig. 5 being suitable for that purpose and being similar in all respects to that above described except that the oscillation coil or resonator 90 is provided at its lower end with target 91 which is opposite and spaced from a cathode 92 which is supported on the casing 93 and is grounded by connection with said casing. The casing 93 is evacuated as above described so that extremely high voltages, say from 100,000 to 1,000,000 volts or more may be produced at the target 91 without production of undesirable corona discharge or other discharge through the space between member 91 and the wall of the casing 93.

The oscillation coil 90 is energized by means such as above described so as to maintain high frequency alternating voltage at the member 91 and during the half waves at which said member 91 is positive it acts as an anode and receives impact of electrons from the cathode 92 which although at ground potential is negative with respect to the anode. Such impact of electrons with the target 91 results in the production of X-rays or Roentgen rays which are emitted in the desired direction for example by suitably forming the impact receiving face of target 91, a window 95 of suitable material such as mica being provided if necessary in the wall of casing 1 in the path of such X-rays to permit passage of such X-rays to the outside of such casing for utilization thereof.

In case the voltage is of the order of one million volts or more a special window means is not necessary as the X-rays are sufficiently hard in that case to penetrate the metallic walls of the casing 1. With a casing of about 2 feet in diameter the walls may be sufficiently strong to withstand the necessary vacuum with a wall thickness of about one-fourth inch and X-rays produced with the voltage of one million or more are able to penetrate walls of such thickness without undue loss of energy.

On account of the heat generated by the impact on the anode member 91 it will generally be necessary to cool the same and for that purpose the same liquid that is caused to circulate through the coils 90 by connections 98 and 99 and internal tube 90' may be also caused to circulate through the member 91 which is provided with passage means such as shown at 97 in Fig. 5a for that purpose.

The form of the invention shown in Fig. 6 is similar to that shown in Fig. 5 except that the oscillation coil is formed as a doublet supported and connected at its principal node by conductor 102 to the casing 103. The high tension energizing connection 104 is made to a part of one of the members 100 of the doublet so as to produce standing waves corresponding to half wave operation as above referred to. In other respects the construction and operation may be as above described in connection with Figs. 1 and 5.

For greater amplification than can be obtained by a single power amplifying tube, a plurality of such tubes may be used in parallel as shown at 105 in Fig. 7, the input of all of these tubes being connected to the inductance means 106 which is connected to the output of the master oscillator tube 107 in the same manner as above described. The output of all of the tubes 105 is connected to the oscillation coil 108 which may be similar in construction and operation to the coil 15 shown in Fig. 1. In Fig. 7 the power supply circuits to the master oscillator and power amplifier lead di-

rectly from the secondaries of step-up transformers 109 and 110 without the interposition of rectifying means, this being a permissible arrangement where one-half wave utilization is sufficient.

5 In case utilization of both half waves of the alternating current is required, the usual arrangement for rectifying by means of thermionic tubes or otherwise can be used. In Fig. 7 the energizing circuit means for the filaments of the thermionic tubes is shown at 111. A neutralizing connection 112 including variable capacity 113 is provided between the output of the power amplifier and the input thereof.

10 If desired the energizing thermionic tube for the power amplifier may, as shown in Fig. 8, be located inside the evacuated chamber 116 containing the oscillation coil as shown in Fig. 8 wherein 114 indicates the thermionic tube of the power amplifier whose output is connected to the oscillation coil 115 in the manner above described, the construction being otherwise as above described.

15 Fig. 9 illustrates a form of the apparatus in which the containing casing 117 is suspended from a frame 118 and is closed at the bottom by a closure plate 119, mounted on a truck 120 and elevated by a jack 121 so as to make a tight joint with a flange 122 on the bottom of the casing 117. The apparatus may be otherwise constructed as in the forms above described. This construction has the advantage that it enables removal of the closure plate 119 for inspection, replacement or adjustment of the parts therein contained without disturbing devices attached to the side walls, such as ion sources, etc. I have shown in this figure a self-excited oscillator circuit for energization of the resonance coil 124. Said self-excited oscillation circuit may comprise a three-electrode thermionic tube 126 having its plate circuit connected to the secondary of a step-up transformer 127 and having its grid circuit connected for regeneration and oscillation so as to impress upon the wires 129, 130 leading to a portion of the coil 124 high frequency voltage which is multiplied by the action of the coil as above described to produce the desired high voltage. In this figure, 131 indicates a grid bias condenser in the grid circuit; 132 indicates a high tension blocking condenser in the connection to the coil 124; and 133 indicates a radio frequency by-pass condenser in parallel with the secondary winding of transformer 127.

20 In each of the embodiments of invention shown, the construction is such as to permit of extremely high voltages, together with considerable power output and the oscillating high voltage electrical energy thus produced is utilized in the acceleration of electrically charged particles which may be ions as in the case of the form shown in Fig. 1, or electrons as in the case of the form shown in Fig. 5.

25 A further embodiment of the invention is dis-

closed in my copending application Ser. No. 699,833, filed November 27, 1933; and claims specific to the X-ray apparatus hereindescribed are presented in that application.

I claim:

1. An apparatus for the high-velocity acceleration of particles carrying electrical charges and of the type including an evacuated vessel housing an accelerating electrode and means for emitting electric charge-carrying particles in position for acceleration by said electrode, characterized by the fact that an oscillation coil is mounted within and has one end supported by the evacuated vessel, the other end of said coil being spaced from the wall of said vessel and having the accelerating electrode mounted thereon, said coil being hollow from end to end and having means therein defining a cooling passage extending from the supported end of said coil to the electrode end thereof and back to the supported end.

2. In apparatus for the high-velocity acceleration of a stream of electrically charged particles such as electrons or ions, an evacuated vessel, an oscillation coil within said vessel and having one end supported on a wall thereof, the other end of said coil being spaced from the walls of said vessel, an accelerating electrode mounted on the said spaced end of said coil, means for emitting electrically charged particles to be accelerated by said electrode, means for applying a high-frequency voltage to a portion of said coil adjacent the supported end thereof, and passage means within said coil for circulating a cooling medium from the supported to the electrode end thereof and then back to the supported end.

3. Apparatus as claimed in claim 2, wherein said electrode is of tubular form, and said means for emitting electrically charged particles is positioned substantially on the axis of said electrode.

4. Apparatus for the high-velocity acceleration of electrically charged particles, said apparatus comprising an evacuated vessel, an oscillation coil within said vessel and having one end supported on a wall thereof, the other end of said coil being spaced from the walls of said vessel, an electrode mounted upon and supported by said other end of the coil, said electrode being a tube of conducting material and open at both ends, means external of said electrode for delivering ions to and longitudinally of the said electrode, and means for producing electrical oscillations in said coil to produce an alternating electrical potential at said electrode, thereby to effect periodic accelerations of ions supplied thereby by said ion-delivering means, said vessel being provided with means for passage of such accelerated ions at high velocity through the wall of the vessel.

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