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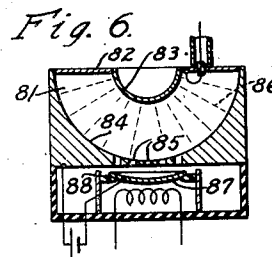
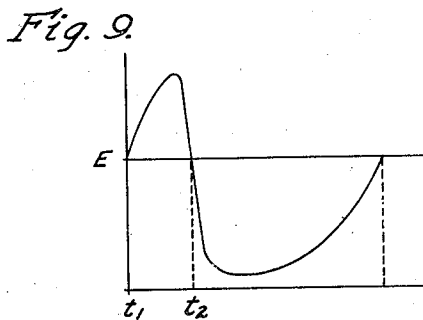
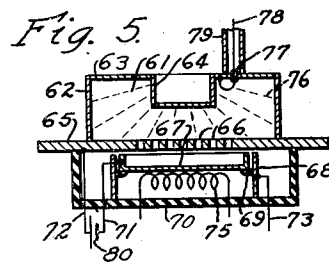
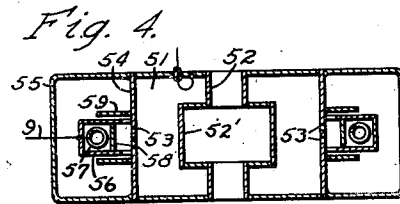
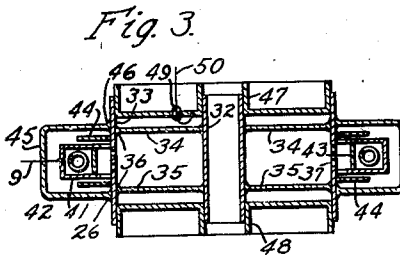
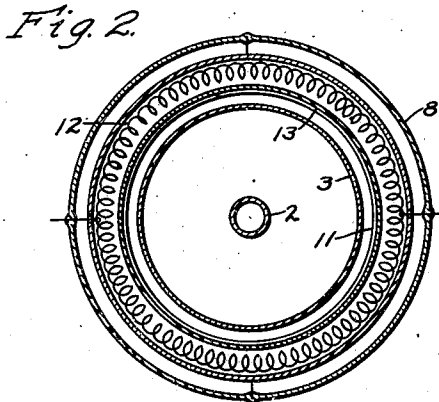
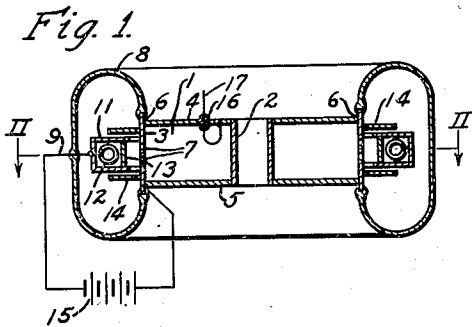
D. ALPERT

2,482,452

CONCENTRIC LINE CAVITY RESONATOR DEVICE

Filed Aug. 19, 1943

2 Sheets-Sheet 1



WITNESSES:

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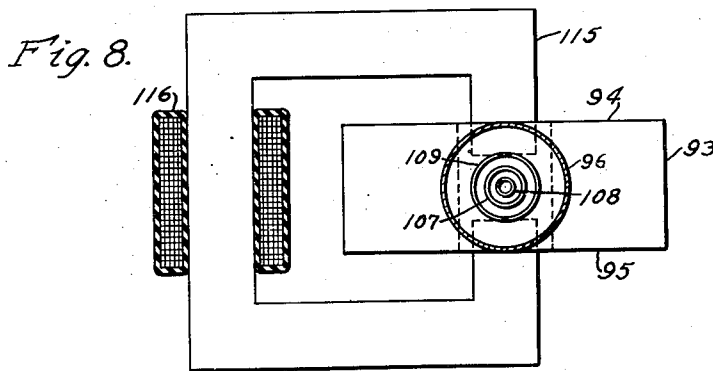
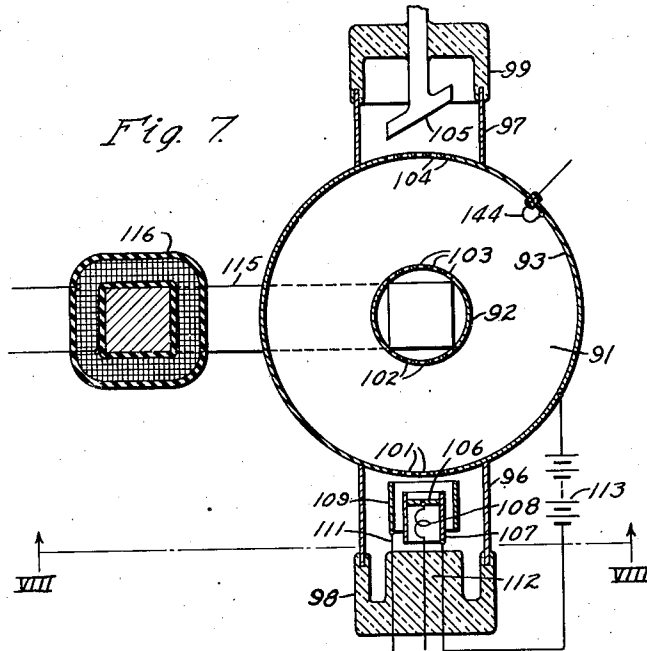
D. ALPERT

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CONCENTRIC LINE CAVITY RESONATOR DEVICE

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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,482,452

CONCENTRIC LINE CAVITY RESONATOR DEVICE

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inghouse Electric Corporation, East Pittsburgh,
Pa., a corporation of Pennsylvania

Application August 19, 1943, Serial No. 499,202

8 Claims. (Cl. 315—5)

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My invention relates to electrical discharge devices in which electrons are projected into electrically-resonant chambers or enclosures, and, in particular instances, relates to devices in which the enclosures are in the form of what may be called segments of a concentric transmission line; that is to say, the resonant chambers comprise a substantially concentric inner and outer conducting cylinder, the annular spacing between the two being closed by conducting end walls. The projection of electrons into such resonant chambers may, by suitably disposing and proportioning the circuit elements, be caused to generate high frequency electrical oscillations or alternatively to abstract power from a supply source to accelerate the electrons to extremely high velocities. Such arrangements may be referred to as devices of the monotron type.

One object of my invention is, accordingly, to devise an effective arrangement for projecting electrons into a resonant chamber of the concentric line type, and to cause electrons traversing paths within this chamber to maintain powerful electrical standing waves therein.

Another object of my invention is to provide an arrangement by which electrons projected into a resonating chamber of the concentric line type may be made to supply electrical oscillations of extremely high frequency to an external circuit.

Still another object of my invention is to provide an electrical oscillation generator for extremely short electric waves which shall be adapted to provide a relatively large electron current, flowing from an electron-emissive source of a comparatively large area into a resonating chamber.

A still further object of my invention is to provide an electrical oscillation generator in which electrons from a source are projected into a resonant chamber which shall be capable of a high conversion efficiency of power from a direct current source to the alternating current power.

A still further object of my invention is to provide a structure for oscillation generators which make use of electrons projected into a resonating chamber in which the chamber itself shall be divided into two portions with the electron flow confined to one portion maintained at a high vacuum, while other portions of the resonating chamber are at atmospheric pressure and may contain induction loops and other circuit and power transmission elements.

Still another object of my invention is to pro-

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vide a high frequency electrical generator in which electrons are projected into a resonating chamber which has the form of a cylinder with a reentrant central portion at one end, whereby an electric field into which electrons are projected increases in intensity as the electron proceeds.

Still another object of my invention is to provide an electrical discharge device in which electrons are projected into the interior of a resonating chamber which has substantially the shape of the cavity between segments of two concentric spherical surfaces.

A further object of my invention is to provide an electrical discharge device in which electrons or other electrified particles may be accelerated to extremely high velocity by passing through the resonating chamber wherein they abstract energy from an alternating electric field maintained in existence in the chamber.

Other objects of my invention will become apparent upon reading the following description taken in connection with the drawings, in which:

Figure 1 is a vertical section;

Fig. 2 is a section along the line II—II in Fig. 1 of one type of electric oscillation generator employing a resonating chamber of the concentric-line type;

Fig. 3 is a section on a diametral plane of a structurally modified form of an oscillation generator of the general type disclosed in Figs. 1 and 2;

Fig. 4 is a section on a diametral plane of an oscillation generator of a type somewhat similar to that of Figs. 1 and 2; but in which the concentric-line resonating chamber is provided with a reentrant portion;

Fig. 5 is a section on a diametral plane through still another type of oscillation generator in which the resonating chamber has the form of a cylindrical cavity having a centrally disposed reentrant portion;

Fig. 6 is a vertical section through an oscillation generator in which the resonating chamber has the form of the space intervening between segments of two concentric spherical surfaces;

Fig. 7 is a horizontal section through an electrical discharge device in which electrons are projected through a resonating chamber of the concentric-line type to impinge upon an X-ray target or other collecting electrode with extremely high velocities;

Fig. 8 is a vertical section along the lines VIII—VIII of Fig. 7; and

Fig. 9 is a graph used in explaining the operation of the arrangement in Fig. 5.

It can be shown that a chamber having the form of a pair of concentric cylindrical conducting surfaces, with the annular space between them closed at each end by conducting plates normal to the axis of the cylinders, can be made to resonate or vibrate electrically with an alternating field of which the electrical component is radial, and the magnetic component comprises circles concentric with the cylindrical axis. The frequency of this mode of vibration is primarily determined by the length L along the axis, this length L being one-half the wave length in the case of the fundamental mode of vibration.

In accordance with the form of my invention shown in Figs. 1 through 4, electrons generated external to the outer cylindrical surface and giving a substantially radially-inward velocity are projected through suitable grids or openings in the outer cylindrical wall. It is found that electrical vibrations will set up in the mode described above in the interior of the annular chamber and that, in consequence of such vibrations, some of the electrons will be accelerated by this electric field, for example, during a one-half cycle thereof, while those electrons following during the succeeding one-half cycle will be retarded. As a result, the first-mentioned set of electrons maintain an average velocity higher than the second set, as a consequence of which the electrons tend to become bunched together, and the stream within the chamber to comprise a flow of alternately high and low electron concentration. It is possible to show that if the transit time of the bunched electrons between the outer and inner cylinders is of the values $1\frac{1}{4}$, $2\frac{1}{4}$, or generally $n + \frac{1}{4}$ (where n is any integer) cycles of the above-mentioned fundamental mode of vibration of the chamber, these electrons will reach the inner cylinder with a velocity substantially less than that with which they entered it. In consequence of this, the electrons give up part of the energy they had on entering the chamber to the alternating electric field within the resonating chamber and thus maintain energetic oscillations therein.

Since the electric field varies inversely in proportion to the radial distance from the central axis of the cylinders, this field increases in intensity as the electrons proceed toward the inner cylinder. As a result of this increasing concentration of the electric field as the electrons proceed, it is possible to insure an almost complete halting of the radial motion of the electrons, thereby attaining a high efficiency of conversion of electrical energy from the direct current source which sets up the electric field which originally accelerated the electrons outside the chamber to the electrical energy of the electrical vibrations within the cylinder.

With the foregoing principles in mind, it may be stated that Figs. 1 and 2 show a chamber 1 having walls comprising an inner cylinder 2, and a concentrically disposed outer cylinder 3 having the annular spaces between them closed by two annular end walls 4 and 5. All of the above-mentioned chamber walls are of conducting material; for example, they may be of copper. The outer cylindrical wall 3 has projecting edges 6 comprising a metal which successfully seals with some suitable insulating material, such as glass. For example, the projecting edges may be formed

by rings of an alloy comprising substantially 18% cobalt, 28% nickel and the remainder iron. In the middle portion of the outer cylinder 3 are provided perforations 7 forming what might be termed a grid through which electrons may be projected into the chamber 1 in a radial direction. Attached by vacuum-tight seals to the projecting edges 6 is an annular structure 8 of glass such as Corning Glass Co.'s G705AJ or other suitable vacuum-tight insulating material. The chamber 1 and the annular enclosure 8 thus form a vacuum-tight enclosure which may be maintained at a high degree of vacuum.

Supported on leads 9 sealed into the glass wall 8 is an annular cathode 11 in the form of an annular metal member having a U-shaped cross-section open on its radially-inward side. Within the member 11 is positioned an electrical heater 12 which may, for example, be in the form of a helix, fed from a local source with electric current through one pair of in-leading wires 9. The radially-inward face of the member 11 is closed by an annular metal member 13 which has its radially-inward face coated with a mixture of barium and strontium or other suitable thermionically-emissive material. The two limbs of the U-shaped member 11 project slightly inward beyond the electron emissive face of the member 13 to form when heated an electron-emissive source which tends to focus electrons and project them through the perforations 7 in the cylindrical face 3. This focusing action may, if desired, be supplemented by auxiliary projecting members 14 which may be electrically connected to the U-shaped member 11 or, if preferred, may be insulated therefrom and provided with means for maintaining them at a desired electrical potential relative to the member 11. The helical heater 12 may be insulated from the surrounding U-shaped member 11 by quartz blocks spaced at suitable intervals around the circumference of the annular member 11. If desired, these quartz blocks may be provided with a trough-like depression in which the heater element 12 securely rests. The precise form of the thermionically-emissive structure 11, 12, 13, 14, is a more or less optional feature of my invention, and any other suitable arrangement known to men skilled in the art may be substituted therefor. The electron-emissive surface 13 is maintained at a sufficient negative potential relative to the cylindrical wall 3 by a suitable external voltage source 15, so that the electrons emitted from the surface 13, when the element 12 is electrically heated, are projected at substantial velocity through the perforations 7 into the chamber 1. In one wall, for example, of the chamber 1 is provided an insulating bushing 16 through which a lead wire 17 adapted to be connected to an external circuit passes into the chamber 1, wherein it is bent up to form a loop with its end electrically connected to the chamber 1.

The velocity with which electrons enter chamber 1 through perforations 7 which is preferable for insuring the maintenance of electrical vibrations within the chamber may be calculated, in accordance with the relationship pointed out above, as follows. The periodic time of the electric vibrations corresponding to a wave-length equal to $2L$, where L is the distance from plate 4 to plate 5, is

$$\frac{2L}{C}$$

where C is the velocity of light. The velocity of an electron having a transit time over the dis-

tance a from cylinder 3 to cylinder 2 which equals $(n + \frac{1}{4})$ cycles of this periodic time is

$$\frac{a}{(n + \frac{1}{4}) \frac{2L}{C}}$$

The structure just described is evacuated by methods too well known in the electron tube art to require description here, and thereafter maintained at a suitable high vacuum. When electrons accelerated by the potential difference between the chamber 1 and the emitting surface 13 are projected through the perforations 7 into the chamber 1, they fall under the influence of any electrical field therein, such, for instance, as exists when this chamber is electrically vibrating, for example, in its fundamental mode having the electric field projecting radially from cylinder 2 to the cylinder 3. If necessary to initiate such vibrations, electric currents of the necessary frequency may be impressed on the in-leading wire 17 to start the generation of high frequency oscillations in the chamber 1; however, such initial stimulation will usually not be found necessary to start oscillation of the chamber 1. The method and reason for generation of oscillations within the chamber 1 and upon the out-leading conductor 17 having been explained before, it is not believed necessary to expatiate upon the method of operation of the device shown in Figs. 1 and 2.

The method of my invention shown in Fig. 3 is more suitable than that shown in Figs. 1 and 2 for certain purposes. It comprises an inner conductive cylinder 32 and an outer conductive cylinder 33, which are interconnected with each other by walls 34, 35, of glass or other suitable vacuum-tight insulating material. The walls 34 and 35 may be sealed to the cylinders 32 and 33 by welding to the latter suitable rings 36 of the alloy mentioned in connection with Figs. 1 and 2. The wall 33 is provided with perforations 37 similar to those in wall 3 described in Fig. 1, and there is likewise provided a thermionically emissive cathode 41, 42, 43, 44, substantially identical with that described in Fig. 1. The cathode structure 41, 42, 43, 44, is enclosed within an annular glass member 45 which may be sealed to suitable rings 46 of the alloy already mentioned which are welded to the cylinder 3.

Respectively above and below the glass walls 34 and 35 are provided a pair of annular conducting trough-like members 47, 48 which fit with reasonable closeness into the annular space between the cylinders 32 and 33. Through an insulating bushing 49 a lead wire 50 may be brought into the space between the member 48 and the glass wall 35, where it is bent over into the form of a loop adapted to transmit vibrations to a load circuit as in the manner of the lead wire 17 in Fig. 1. The arrangement in Fig. 3, comprising the members 47 and 48 which are detached from and move relative to the glass walls 34 and 35, has the advantage of permitting a variation at will of the distance L between them which, as previously stated fixes the resonant frequency of the oscillations generated within the chamber bounded by walls 32, 33, 47, 48.

Fig. 4 shows a structure for oscillation generators which is similar to that described in connection with Figs. 1 and 2, except as regards the shape of the conducting walls of the resonating chamber. In Fig. 4 the resonating chamber 51 has as its interior face what may be described as a cylindrical portion 52 which is expanded for

a certain distance midway of the axis, to form a larger cylindrical or reentrant portion 52'. The advantage, for certain purposes, of providing the reentrant portion 52' in the inner cylindrical wall is that it results in a more rapid concentration of the electric field within the chamber, as the electrons move radially inward after they pass through perforations 53 in the external wall 54 of the reentrant chamber. Since the annular glass enclosure 55 for the electron source 56, 57, 58, 59 is substantially the same in nature as the elements 11, 12, 13, 14 in Figs. 1 and 2, it is believed that no further description of Fig. 4 is necessary here.

Fig. 5 shows a modified form of oscillation generator in which the direction of projection of the electrons into the resonating chamber is parallel to the central axis (which is vertical in Fig. 5) instead of radial, as in the modifications so far discussed. The resonant chamber 61 comprises an external conducting cylindrical wall 62 closed at the top by conducting end plate 63 which has a central projecting portion 64, preferably of cylindrical shape. The base of the resonant chamber 61 comprises a conducting plate 65 having a central area somewhat larger in diameter than the cylindrical projection 64 above mentioned, which is filled with perforations 66 through which electrons may be projected into chamber 61. Below the perforations 66 is positioned a cathode 67 comprising a circular plate coated with thermionically emissive materials, and preferably provided with an upturned edge portion which extends toward but does not quite contact the plate 65. Surrounding and projecting slightly beyond the edges of this edge portion is a conducting ring 68, at which the plate 65 may, if desired, be attached by supporting insulators 69. The conducting ring 68 and the base plate 65 are supported from an insulating foundation 70. Inleading wires 71, 72 are projected by which the plate 65 may be maintained at a sufficient positive potential relative to the cathode 67, to accelerate and project electrons emanating therefrom through the perforations 66. The conducting ring 68 may, if desired, be connected directly to the cathode 67, but for some purposes it will be found desirable to provide it with an inleading wire 73, by which it may be maintained at a particularly potential adapted to more effectively focus electrons emanating from the cathode 67 upon the perforations 66. An electric heater 75 is provided by which the cathode 67 may be maintained in a thermionically-emissive condition.

When the resonant chamber 61 is set in vibration, the electrical field will have substantially the configuration indicated by the broken lines 76. In some portion of the walls of the resonant chamber 61, for example, in the wall 63 not far from the central cylindrical projection 64 is positioned an insulating bushing 77 through which an inleading wire 78, forming a loop within the chamber, may conduct electric energy to external circuits through a concentric line 79.

As in the case of the former resonator shown in Figs. 1 to 4, the potential impressed on the plate 65 relative to the cathode 67 is such as to cause the electrons passing through the perforations 66 to enter the chamber 61 with such a velocity, that the time they require to reach the projection 64 is $n + \frac{1}{4}$ cycles of the fundamental mode of vibration of the chamber 61, which has the electric field distribution represented by the broken lines 76. When this adjustment is made,

the electrons entering the chamber 61 through the perforations 66 will transform the energy imparted to them from the direct current source 80 into power at the frequency of vibration of the electrical field within chamber 61, and will thus maintain energetic oscillations therein. The energy of these oscillations may be transmitted to external circuit through the inleading wire 78, as in the case of the corresponding operation of the Figs. 1 to 4 modifications of the invention. In some cases it may be desirable to stimulate the resonance of the chamber 61 by initially impressing oscillations of this same frequency on the inleading wire 78.

The advantage for certain purposes of the Fig. 5 modification of my invention is that the reentrant chamber has a high shunt impedance, and that the electric field within the chamber becomes rapidly more concentrated as the electron moves along its path from the perforations 66 to the projection 64. As a result of the above-mentioned high shunt impedance, the losses principally through Joulean heating of the chamber walls are reduced by the presence of the projection 64. This shunt impedance may be defined as that resistance which, when shunted across the alternating voltage traversed by the electron path, will dissipate power at the same rate as the actual power dissipation in the resonating chamber. The increasing concentration of the electric field, as the electron moves forward within the chamber 61, increases the percent of the direct current energy from the source 80 which is converted into alternating energy resident in the electric vibrations within the chamber 61.

Decreasing the diameter of the projection 64 which, at least through a certain range of values, tends to increase the above-mentioned "shunt impedance," likewise tends to increase the rate of concentration of the electric field as the electron moves towards the projection 64 from the perforations 66.

A modified form of resonator of the general type shown in Fig. 5 is illustrated in Fig. 6. The resonating chamber 81 comprises a conducting end plate 82 having a hemispherical central protuberance 83 thereon. The other wall of the chamber may comprise what may be considered to be an approximately hemispherical conducting surface 84 having in its central portion a series of perforations 85 which are thus positioned nearly vertically below the hemispherical projection 83. It will be noted that the chamber 81 may be caused to be derived from the chamber 64 in Fig. 5 by rounding the corners of the projection 64, and by similarly rounding the corner where the outer cylinder 62 in Fig. 5 joins the base plate 65. The result of this change of configuration of the chamber is to give an electric field somewhat similar to that illustrated by the broken lines 86, which is nearly radial of the space between the two hemispherical surfaces 83 and 84. For certain purposes, this field distribution is more advantageous than that in Fig. 5 in producing high "shunt impedance" and high conversion efficiency from direct current to alternating current.

It may be desirable for many purposes to make the cathode 87 in the form of a spherical surface substantially concentric with the surface 84. The spherical surface 87 may be provided with upturned edges and may be surrounded by a conducting ring 88 which may either be directly connected to the surface 87 or may be maintained at regulatable potential relative thereto for focusing

purposes, as described in the analogous cathode of Figs. 1 to 5. The remaining portions of the structure of Fig. 6 being substantially similar to corresponding elements in Fig. 5, no further description of them is considered to be necessary.

Turning now to Fig. 8, there is shown a device in which the properties of resonating chambers are made use of to accelerate electrons to extremely high velocities, with the result that they may be used for generation of extremely hard X-rays or for other purposes where extremely high velocity electrons are desirable. Thus the concentric chamber 91 in Figs. 7 and 8 has a cylindrical internal wall 92 and a concentric outer wall 93 which are closed by circular end plates 94 and 95. All of these parts may be of conducting material, for example, copper. Projecting radially from the outer cylindrical wall 93 are two cylindrical conducting portions 96, 97 which are preferably terminated by metallic rings comprising the alloy mentioned in connection with Fig. 1, as adapted to provide desirable seals to glass. The projecting cylinders 96 and 97 are capped to their outer ends by enclosures 98 and 99 of glass, the whole structure thus far described constituting a vacuum-type enclosure.

The central portion of the wall 93 enclosed within the projecting cylinder 96 is provided with perforations 101, and similar perforations 102, 103 and 104 are provided in the walls of the cylinders 92 and 93. The purpose of these perforations 101, 102, 103 and 104 is to permit electrons, projected through the perforations 101 from a source about to be described in the cylinder 96, to pass through the walls 92 and 93 into the interior of the cylindrical projection 97. Sealed into glass cap 99 is positioned an anode or target 105, of any suitable type well known to the electrical discharge tube art, for the purpose desired to be achieved by the impact of high velocity electrons. For example, the member 105 may be the target from which X-rays are to be emitted when it is struck by high speed electrons passing through the perforations 101, 102, 103, 104.

Within the enclosure formed by the cylinder 98 and its glass cap 98 is provided a suitable cathode 106 of a type well known in the electron-gun art, which may comprise a metal cylinder 107 enclosing a helical electric heater 108. The end of the cylinder 107 is coated with a mixture of barium and strontium oxides or any other thermionically-emissive material, and is provided with upturned edges to help in focusing the electrons emitted from the cathode 106 in a direction circular to the axis of the cylinder 107. The cylinder 107 is surrounded by an auxiliary focusing cylinder 109 which may be connected to the cylinder 107, or alternatively may be provided with an inleading wire 111 by which its potential may be fixed at any suitable value relative to the cylinder 107 for aid in focusing the electrons emitted from the cathode surface 106. The cathode cylinder 107 and the detached end of the heater 108 are provided with inleading wires passing through the press 112 and supported therefrom in ways now well known in the electronics art.

By means of a suitable source of voltage 113, the cylindrical surface 93 may be maintained at any desired voltage relative to the cathode 106, in consequence of which arrangement electrons emitted by the surface 106 may be projected through the perforations 101, 102, 103 and 104 into the cylindrical projection 97. The anode 105 may be provided with means for maintaining it at a desired voltage relative to the cylinder 93.

The chamber 91 has a mode of electrical vibration in which the lines of electric force are substantially radial, and when electrons enter the chamber 91 through the perforations 101 they will be acted upon by this electric field, and their velocity at the time they reach the perforations 102 can be shown to depend upon the values of this electric field, and the length of time which the electrons spent in traversing the path between perforations 101 and perforations 102. Some of the electrons passing through the perforations 101 will be accelerated by the electric field so that the time that they spend in traversing the path between 101 and 102 will be less than that corresponding to the velocity with which they entered the perforations 101, while others of these electrons will be retarded and traverse the path between the perforations 101 and 102 with a lower velocity. As a result, the faster electrons will tend to overtake the slower electrons, and there will be a bunching effect in the electron stream emanating from the perforations 102. If the exit energy of the electrons emanating from the perforations 102 is plotted against the time each electron entered perforations 101, it can be shown that a curve similar to Fig. 9 will result where ordinates represent energy of the electrons emanating from perforations 102, and abscissae represent the time of entry of the electron through the perforations 101. It will be seen from Fig. 9 that the electrons, whose energies are plotted within the range t_1 , t_2 have their energies increased above the value E , which latter represents the energy with which they pass through the perforations. These same electrons will continue with energy unabated in traversing the space between the perforations 102 and 103, since it does not form a portion of the electrically vibrating chamber 91, and it can be shown that the energies and hence the translation velocities of certain of these electrons will be further increased as they traverse the space between the perforations 103 and 104, where they are again acted upon by the oscillating electric field within the resonant space 91. Certain of the original electrons will accordingly enter the cylinder 97 with a higher velocity than that to which they had attained when they left the cylinder 96. They have in fact abstracted energy from the current source which maintained the resonant oscillations within the chamber 91, since those electrons which reach grid 102 with energy less than E cause such resonant oscillations of chamber 91 to be maintained. To take a specific instance, it can be shown that the energy of the electrons emanating from the perforations 104 may be increased to 500 or 600 kilovolts, whereas their energy on entering the perforations 101 was only 100 kilovolts.

It is, of course, desirable that of the electrons emanating from the perforations 102, only the high velocity ones should pass through the perforations 103 and continue onward ultimately to impinge upon the anode 85. This selection of high velocity electrons may be effected by providing a magnetic field in the interior of the cylinder 92 having a direction parallel to the axis thereof. A magnet core 115 excited with direct current winding 116 may be provided for this purpose. It can be shown by calculations well known to those versed in the electronic art that the electrons passing through such a field will follow curved paths, the radius of curvature in any particular path depending upon the velocity of the electrons traversing it. Thus, by locating the per-

forations 103 in the wall of cylinder 92 in a position corresponding to the paths of high velocity electrons through cylinder 92, and leaving the wall of cylinder 92 solid at the terminus of the paths of lower velocity electrons, it can be insured that only the high velocity electrons emanating from the perforations 102 will pass through the perforations 103 to enter the chamber 91 for the second time. The magnetic deflecting field above-mentioned should be substantially limited to the interior of the cylinder 92; if this is done the electrons emanating from the perforations 103 into the chamber 91 will thereafter traverse straight line paths across the latter. The position of the cylinder 97 and the perforations 104 should, of course, correspond to the terminus on the wall of cylinder 93 of the paths just mentioned.

Another possible method of insuring that only the fastest electrons emanating from perforations 102 shall reach the perforations 103 would be to insert a grid with a high negative potential relative to the walls of the cylinder 92 midway in the path of the electrons between perforations 102 and 103. In such case the perforations 102, 103, 104 and anode 105 should line up with the rectilinear path of electrons projected by cathode 106 through perforations 101. Such a grid would turn back the slower electrons emanating from the perforations 102, and cause them ultimately to impinge on the cylinder 92, but would permit electrons with a velocity high enough to pass through the openings in the grid to reacquire velocity and leave the perforations 103 with the same velocity that they left the perforations 102.

In the foregoing I have described particular embodiments of the principles of my invention, but these principles are capable of application in many alternative forms which will be evident to those skilled in the art. For example, I have described electrons as the electrified particles projected into the resonating chambers, but it will be evident to those skilled in the art that substantially any electrified body may replace them, the relation between their entrance velocity and the dimensions of the resonating chamber being substantially the same as described for electrons. Also other forms of resonating chamber and other modes of vibration (i. e., other directions for the alternating electric field) may be employed provided the electrified particles are projected with a velocity component along this field.

I claim as my invention:

1. An electrical discharge device comprising a chamber having conducting walls in the form of an outer cylinder having perforations in its wall and an unperforated inner cylinder interconnected at each end by electrically conducting material, an electron emissive source positioned adjacent to said perforations and insulated from said walls, and means included by said device for impressing an electric field in the region adjacent said source for projecting electrons from said source through said perforations into said chamber.

2. An electrical discharge device comprising a chamber having conducting walls in the form of an outer cylinder having an annular band of perforations in its wall and an inner cylinder interconnected at each end by electrically conducting material, an electron emissive source positioned adjacent to said perforations and insulated from said walls, means included by said device for impressing an electric field in the region adjacent said source for projecting electrons from

said source through said perforations into said chamber, and coupling means having a portion projecting within said chamber for transmitting energy resident in an electric field inside said chamber to a work circuit.

3. An electrical discharge device comprising a chamber having conducting walls in the form of an outer cylinder having an annular band of perforations in its wall and an inner cylinder interconnected at each end by electrically conducting material, an electron emissive source, positioned adjacent to said perforations and insulated from said chamber, a vacuum-tight enclosure maintained at a high vacuum enclosing said source and said perforations, and means included by said device for impressing an electric field in the region adjacent said source for projecting electrons from said source through said perforations into said chamber.

4. An electrical discharge device comprising a chamber having conducting walls in the form of an outer cylinder having perforations in its wall and an unperforated inner cylinder interconnected at each end by electrically conducting material, an electron emissive source, positioned adjacent to said perforations and insulated from said chamber, a vacuum-tight enclosure maintained at a high vacuum enclosing said cathode and said perforations, means included by said device for impressing an electric field in the region adjacent said source for projecting electrons from said source through said perforations into said chamber, and coupling means having a portion projecting within said chamber for transmitting energy resident in an electric field inside said chamber to a work circuit.

5. An electrical discharge device comprising a chamber having conducting walls in the form of an outer cylinder having a perforated area in its wall and an inner cylinder interconnected at each end by electrically conducting material, said area subtending a major portion of the circumference of said outer cylinder, a linearly extending electron emitter subtending said perforated area, means included by said device for impressing an electric field in the region adjacent said source for causing electrons from said source to be projected through said perforations into said chamber, and means having a portion projecting within said chamber for utilizing the energy of electrical oscillations produced within said chamber.

6. An electrical discharge device comprising a chamber having conductive walls in the form of an outer cylinder having perforations in its walls and an inner cylinder interconnected at each end by electrically conducting material, an electron emissive source positioned adjacent to said perforations and insulated from said chamber, means included by said device for impressing an electric field in the region adjacent said source for projecting electrons from said source through said perforations into said chamber, the radial distance between said inner and said outer cylinders being such that said electrons traverse it in a

time equal to $n + \frac{1}{4}$ cycles of the fundamental mode of electrical vibration of said chamber where n is any integer.

7. An electrical discharge device comprising a chamber having conducting walls in the form of an outer cylinder having perforations in its walls and an inner cylinder interconnected at each end by plates of electrically conducting material, an electron emissive source positioned adjacent to said perforations and insulated from said chamber, means included by said device for impressing an electric field in the region adjacent said source for projecting electrons from said source through said perforations into said chamber, said electrons passing through said perforations with a velocity which is substantially

$$\frac{a}{\left(n + \frac{1}{4}\right) \frac{2L}{c}}$$

where a is the radial distance from the inner of said cylinders to the outer of said cylinders, L is the distance between said plates, c is the velocity of light, and n is any integer.

8. An electrical discharge device comprising a chamber having conducting walls in the form of an outer cylinder having a perforated area in its wall and an inner cylinder interconnected at each end by plates of electrically conducting material, said area subtending a major portion of the circumference of said outer cylinder, a linearly extending electron emitter subtending said perforated area, means included by said device for impressing an electric field in the region adjacent said source for causing electrons from said source to be projected through said perforations into said chamber, and means coupled to a member projecting into said chamber for utilizing the energy of electrical oscillations produced within said chamber, said electrons passing through said perforations with a velocity which is equal to

$$\frac{a}{\left(n + \frac{1}{4}\right) \frac{2L}{c}}$$

where a is the radial distance from the inner of said cylinders to the outer of said cylinders, L is the distance between said plates, c is the velocity of light, and n is any integer.

DANIEL ALPERT.

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