My invention relates to a device for producing electron rays of great energy.

The object of my invention is to produce by very simple means, above all without the use of high voltages, electron rays of great energy, for instance rays having a velocity corresponding to the application of several million volts.

It has hitherto been proposed to employ for this purpose a magnetic alternating field by which an electric eddy field is produced which imparts to the electron the required speed. In this case the arrangement is carried out in such a manner that the electron path encloses the magnetic field in the same manner as the turns of the secondary winding of a transformer encloses the transformer core as well as the flux traversing this core.

In a known arrangement of this type an annular highly exhausted discharge vessel encloses the core of a three-legged transformer whose central core is provided with an exciting winding connected to an alternating voltage of the usual voltage and frequency. A glowing cathode which emits the electrons necessary for the radiation is arranged in the discharge vessel. Besides the exciting field also an additional magnetic field produced by permanent magnets acts on the electrons, the magnetic field serving to maintain the electrons circulating about the transformer core in a certain plane determined by the discharge vessel, that is, to prevent the electrons from striking the walls of the vessel.

Experiments have been conducted with these known devices have shown that while the principle, on which the device operates, is useful and in some respects far more suitable than other methods for imparting high speed to the rays, the proposals hitherto suggested cannot be utilized for the design of a practical device. Only by the use of the improvements such as form the subject matter of the invention is it possible to obtain really practical results.

The invention relates substantially to the guiding of the electrons within the eddy field in such a manner that they are not ejected prematurely from the eddy field. Further features of the invention relate to the production of the electric eddy field as well as to the introduction of the electrons at the beginning of the acceleration into the eddy field and to the release from the field at the end of the acceleration.

Of particular importance are the provisions made for stabilizing the electron path within the eddy field. In order that the electron may take up energy within the electric eddy field it must wander within the field by following the forces of the field. If in this case the particular advantage of the eddy field that the same charge may repeatedly follow one and the same line of force is to be utilized the charges must, therefore, revolve in succession about the central magnetic flux many times. In order that the electron may remain during its numerous revolutions on a circular path a force directed towards the center of the circular path must annul the centrifugal force of the electron mass. Since the speed of the electron (and in the neighborhood of the velocity of light the electron mass) increases the longer the electron has been accelerated by the eddy field, the centrifugal force increases with time; consequently, also the centripetal force must be increased in proportion to time. The object of the invention is, therefore, to determine an electric or magnetic field which by the forces of the field exerted on the electron charge stabilizes the electron on a given circular path. A stabilizing or a guiding field must be provided such as is also the case with the above-mentioned known device, in which said field has been produced by permanent magnets of a given arrangement. In this case, this stabilization must also be still effective even if the rotating electron experiences "interferences" of whatever kind whether it begins its flight in the eddy field under false initial conditions (for instance with an initial velocity deviating from the desired direction) or whether the electron experiences during its numerous revolutions a "collision" with one of the residual gas molecules even present at the highest vacuum, which causes a sudden (small) change of the direction of flight and of the flying speed. These unavoidable interferences must be permissible within a certain definite magnitude without deviating the electron considerably from the ideal "desired path" along which a completely undisturbed electron would revolve within the eddy field. Furthermore, a stabilizing field must, also compensate for its own faults. It would not help any to create a stabilizing field which would compensate for the above-mentioned interferences of the electrons only in the case of an entirely ideal field, but the stabilizing field must be of such nature as to bring about the compensation even in the case of slight deviations from the ideal field (for instance slight deviations from the rotation symmetry) which deviations cannot be avoided in the case of the actual realization of the field.

The main object of the guiding field consists in maintaining the radius of the path at a constant level. This may be done by utilizing the centrifugal force of the electron mass.

The following arrangement is best for this purpose: the electron path is traversed by an electric field directed towards the center of the circular path. By the force of this electric field the electron charge is subjected to a centripetal acceleration. The magnitude of this acceleration must be increased in such a way that the product of the speed and the radius of the path is constant during the revolution of the electron. Therefore, the electric field must have a constant magnitude and the electron path must be directed towards the center of the circular path. The field may be continuously supplied at the center of the circular path, or by the introduction of a suitable arrangement in the electron path the field may be formed by a suitable arrangement in the electron path.
constant value. Consequently, the field must be such that a circular path is described by an electron, the radius thereof remaining constant within a given time interval, although the centrifugal force increases with time. The centrifugal force of the revolving electron may be annulled by an electric field having field lines running radially outwardly, the lines of force of the magnetic field being perpendicular to the plane of the path. In order to guide an 11 million volt electron along a circle of 5 cm. radius a radial electric field of about 2.106 volts/cm. would be necessary. The distance between the electrodes for this electric field should be of a sufficient magnitude to permit also "disturbed" electrons deviating somewhat from the desired path to freely fly. The distance should be of the order of 1 cm. Consequently, a voltage of some millions of volts between these electrodes would be necessary only to guide the electron along a circular path which voltage, therefore, would be of the same order of magnitude as the speed of the electrons themselves. Consequently, the entire method would not afford any advantages at all. To guide an 11 million volt electron along a circle of 5 cm. radius, however, only a magnetic field of about 7000 gauss is necessary which may be easily created. The "guiding field" which guides the electron along a circular path about the central magnetic flux must, consequently, be a magnetic field.

The arrangement in principle is as follows: A central iron core carries the magnetic flux \( \phi \) varying at spaced intervals and produces about it the electric field. The guiding field \( H_r \) is produced by two cylindrical pole pieces which enclose the central iron core and, therefore, the central magnetic flux and which guide the electrons on circles about the magnetic flux. The guiding field should not, as already proposed, be produced by a permanent magnet, for if the revolving electrons are accelerated with time to a greater extent the radius of path would become greater and greater in the case of a constant intensity of the guiding field. In order that the radius of the path may remain constant the intensity of the guiding field \( H_r \) must, consequently, increase with time. Since the speed of the electrons depends only upon the central magnetic flux, and since the relation between the speed of the electrons and the guiding field is also unequivocal in the case of the radius \( R \) of the path being maintained constant, the necessary intensity of the guiding field \( H_r \) must be only dependent upon the magnitude of the central flux. In order that the radius \( R \) of the path may remain constant the following condition must be fulfilled:

\[
\phi = 2\pi R H_r = 2\pi B_i \text{ in vacuum (1)}
\]

The flux \( \phi \) must, therefore, be twice as strong as it would be if the guiding field \( H_r \) were homogeneously filled up the interior of the circular path in order that the radius \( R \) of the paths of electrons may remain unchanged ("1:2 condition"). This condition holds good even within the range of relativistic speeds. It also holds good as to the sign, i.e., the central flux and the guiding field must increase in the same direction at the ratio 1:2. Assuming that the direction of the central flux \( \phi \) is positive an increase in flux produces an eddy field revolving in one direction. The guiding field must be then so directed that the electrons therein revolve in such a direction as to be accelerated by the eddy field.

A guiding field directed in opposite direction would cause the electrons to revolve against the eddy field so that the motion of the electrons would be checked.

Owing to the fact that the central flux \( \phi \) and the guiding field \( H_r \) must have the same direction and be proportional to each other both are excluded by the same winding. The guiding field \( H_r \) with its air gap which substantially determines the magnetic resistance is proportional to the instantaneous value of the exciting current. In order that the flux \( \phi \) be proportional to the guiding field the flux \( \phi \) must, therefore, also be proportional to the exciting current. This, however, not the case with closed iron cores owing to the non-linearity of the magnetic iron characteristic \( B \propto (H) \), even within the unsaturated range. In order to bring about the proportionality, an air gap—whose magnetic resistance is great as compared to that of the remaining iron path and, therefore, ensures the proportionality between flux and guiding field—is also provided in the iron leg.

In the accompanying drawings I have shown different forms of an arrangement by which the desired result may be accomplished. In these drawings—

Fig. 1 is a diagrammatic illustration, in sectional elevation, of a magnetic body designed to illustrate the general principle on which the invention is based.

Fig. 2 shows diagrammatically the pole elements for producing the guide field.

Fig. 3 shows an advantageous form of such pole elements.

Figs. 4 through 9 show each in transverse section different constructions of acceleration pole elements which are composed in several different ways of laminations and wires.

Fig. 10 shows in sectional elevation a practical construction according to the present invention, it being assumed that the pole element there shown constitute portions of a magnetic body which in general principles is constructed as shown in Fig. 1, and

Fig. 10 shows in plan view the form of the electron vessel P in Fig. 10.

Referring to Fig. 1, in this arrangement the same amperere turns W produce the flux \( \phi \) in the central leg and the guiding field \( H_r \) between the pole shoes P. Since the flux \( \phi \) enclosed by the electron circular path \( R \) should correspond to a field having an average magnitude twice as great as the guiding field \( H_r \), the air gap in the central leg must be made correspondingly smaller than that between the poles P of the guiding field.

The arrangement shown in Fig. 1, even though the 1:2 condition be properly fulfilled, would only be suitable if the electrons were and would remain "undisturbed". "Undisturbed" are such electrons, for which the condition is fulfilled that they were produced with the speed zero on the circle \( R \) at the moment at which the guiding field passes through zero.

That the arrangement shown in Fig. 1 is not yet suitable to stabilize also disturbed electrons on the desired circle \( R \) may be deduced when assuming that an electron revolving on the circle \( R \) has a small speed component in the upward direction which it either already had from the moment it entered the eddy field or has acquired during the flight owing to a collision with a residual gas molecule. This speed component is
not influenced in the above-mentioned homogeneous magnetic field \( H_0 \), since it runs parallel to the lines of the magnetic field. Even if this speed component amounts to \( 10^3 \) cm/sec. (this corresponds to an energy of only about 3.10^{-15} \text{ volts}) it causes the electrons within the 5.10^{-3} sec., during which time they must remain in the magnetic field at an energization at 50 cycles, to be ejected 5 cm. from the plane of the desired circle and, therefore, strike the wall of the discharge vessel. It is also possible that the speed components of the electrons in this direction resulting from the thermic disorder of their motion are still of a greater order of magnitude so that the electrons remain a sufficiently long time in the eddy field. Care should, therefore, be taken by means of repulsive forces to prevent such a faulty speed from ejecting an electron at any distance from the plane of the desired circle in the upward or downward direction and to cause the faulty speed to bring about at most a hunting—if possible attenuated—about the desired plane with smallest possible amplitudes.

25. This may be attained according to the invention by rendering the guiding field somewhat non-homogeneous so that it decreases with increasing distance from the axis. The lines of force are then bent outwardly (Fig. 2) so that also radial components \( H_r \) of the magnetic field are produced. In the case of symmetrical electrodes these radial components of the magnetic field disappear in the central plane \( M \) between the electrodes. In this case the radial field components above the central plane are directed from the inside to the outside, whereas those below the central plane are directed from the outside to the inside.

So long as the electron flies on a circle in the central plane \( M \) it is not subjected to any changes, since the radial components of the magnetic field are not present in the central plane \( M \). If now the electron possesses a speed component in the upward direction—small as compared to the total speed—and if the circular path of the electron displaces itself gradually in the upward direction, electrodynamic forces between the flying electron and the radial field components are now added to the forces hitherto considered alone between the flying electron and the axial field component. The force of the component exerted on the electron is perpendicular to the (tangential) direction of flight of the electron and perpendicular to the radial field component: A force \( k \) in axial direction is, therefore, obtained (Fig. 2) which acts in a downward direction in the case of the electron circular path being displaced in the upward direction, as this is proved by the right-hand rule. The electron is, therefore, driven back into the central plane. Since within the zone below the central plane the direction of the radial field component is reversed as in the space above the central plane, the action of the radial component consists in this case in a deviation of the electron in an upward direction that is to say the electron is again driven back toward the central plane. Such a non-homogeneous field decreasing outwardly stabilizes, therefore, the electron circular path in the central plane.

70. Conversely a magnetic field increasing outwardly and having radial components in opposition would cause an increase in the deviation of the electron in the upward directed forces which would drive the electron still further in the upward direction and vice versa. Such a magnetic field attracts, consequently, the electron circular path to the pole pieces or to the wall of the discharge vessel and is, therefore, unsuitable for stabilizing purposes.

Since the magnitude of the radial field component—as proved by the computation of such a potential field—is proportional to \( E \) for small deviations \( z \) from the central plane (see Fig. 2) a field decreasing outwardly results in a repulsive force which is proportional to the deviation \( z \): the electron performs, therefore, harmonic oscillations about the central plane.

Besides the faulty speed in the axial direction the guiding field must also compensate for faulty speeds in the radial direction. Such a faulty speed, for instance, occurs if an electron revolving properly in the central plane experiences a deviation by colliding with a residual gas molecule, which deviation causes a sudden change in direction of the electron which may, however, remain in the central plane. Also by these faulty speeds oscillations of the electron are produced, but they have in this case a radial direction.

To prevent these disturbances the guiding field is rated according to the invention in such a manner that the condition of stabilization

\[
-1 \frac{R}{H} \frac{dH}{dR} < 0
\]

is fulfilled with an optimum as to the exclusion of deviations of the electron from the desired path in the case of

\[
\frac{R}{H} \frac{dH}{dR} = -\frac{1}{2}
\]

The guiding field should, therefore, decrease always to a lesser extent, preferably half as much, than indirectly proportional to this radius.

This condition is to be considered in connection with the above-mentioned 1:2 condition according to the Equation (1), i.e., that radius which encloses a field, whose mean value refers to the area of the circle is just twice as great as the field prevailing at the periphery should fall within a non-homogeneous field zone which fulfills the condition of the Equation (2) and preferably of the condition of Equation (3).

An essential feature of the invention is the design of the pole pieces, which must be such that the field produced therebetween has the above-mentioned properties of stabilization. In Fig. 3 is shown a form of the invention based on the following considerations: If the two hyperbola branches 1 and 2 are caused to rotate about the axis a two hyperboloids are produced. The field created between the two hyperboloids decreases steadily outwardly. In the neighborhood of the axis the field is practically homogeneous, at a considerable distance \( R \) from the axis where the hyperboloid contacts approximately with the asymptotes the field decreases practically with \( 1/R \). The expression \( E/RH \cdot dH/dR \) characteristic for the non-homogeneity of the field varies in this case from 0 on the axis to \(-1 \) at infinity; excepting the case in which \( E = 0 \), the hyperbola field, therefore, fulfills in all cases the condition of Equation (2). But it does not at first fulfill the 1:2 condition of Equation (1) in any case whatever. That is to say, in the pure hyperbola field there does not exist a circle, whose area in average covers just twice as strong a field as that prevailing at the periphery; the inner field is always too weak. Consequently, in order to utilize the hyperboloid as stabilizing pole piece form, the inner field must be strengthened; for instance, by rendering the distance between the pole pieces 75
in the neighborhood of the axis smaller than is the case with hyperboloids. This may be accomplished by arranging inner pole pieces A and B, as shown in Fig. 3. In this case there is always a radius which is smaller, the stronger the central flux is made. The strengthening of the central flux is preferably effected in such a manner that the radius of the circle becomes equal to half the focal distance, for in this case the hyperbola field fulfills the optimum condition

$$ R/DH/dR = 1/2 $$

However, the inner pole pieces A and B owing to the stray field thereof disturb the hyperbola field proper in an undesired manner (see Fig. 3) and the circular electron path must be, therefore, placed so far outwardly or the auxiliary pole pieces must be carried out with such a small radius that the electrons are not any longer substantially influenced by this stray field. However, this means a limitation of the greatest possible inner flux \( \phi \) which should on the other hand be rendered very strong in order to attain electrons of great energy. It is, therefore, necessary to prevent the stray flux from extending too far in the lateral direction. This may be accomplished if the central flux is not caused to pass through one air gap but if this air gap is subdivided into a large number of small air gaps which, of course, may be filled up with any non-magnetic material. Since, however, the stray flux spreads only over zones of the magnitude of the width of the air gap, only a much smaller distance of the revolving electron from the central pole pieces is necessary. The stray flux may be even practically eliminated if a space as formed by the lines of force of the undisturbed hyperbolic field is filled up with pulverized iron which is embedded in the form of a compressed pulverized iron core into an insulating material. In this case it is possible by the proper choice of the iron filling factor to obtain such an average permeability that the central magnetic flux produced thereby satisfies the 1:2 condition. Consequently, the desired circle \( R \) of the electron may then be placed very close around the central flux and a very high electron end speed is obtained with the small flux. The pole pieces must be extended so far outwardly as to be able to rely extensively upon the pure hyperbolic field in the vicinity of the desired circle.

Strictly speaking with laterally limited pole pieces the field lines are, of course, displaced further outwardly over the entire space than would be the case with the pure hyperbolic field. This may, however, be compensated for in the surrounding of the desired circle \( R \) if the pole pieces are caused to move away from one another to a somewhat lesser extent for a short distance outwardly as is the case with hyperboloids. In this circle which is bounded with a relatively stronger field, whose cross pressure of the field lines can again force back the field into the vicinity of the desired circle approximately into the zone of a pure hyperbola field. A small total diameter of the pole pieces not only reduces the dimensions of the apparatus but also the power required for setting up the field.

Besides the above-described features for the design of the pole pieces adjacent to the field space it is essential to the stabilization of the electrons during their flight in the eddy field that the total arrangement be rotation symmetrical as far as possible with respect to the axis of the circular electron path. Only in the case of a rotation symmetry, the field lines of the electrons are concentric circles. For this purpose the central iron leg, which is made of laminations on account of the eddy currents, must be given a rotation symmetrical design. If the laminations were stacked as shown in Fig. 4, that is to say, not according to a rotation symmetrical design, then it would not be possible to avoid an unsymmetry of the field. According to the invention the laminations for the central leg are, therefore, so arranged as to form an involute yoke as shown in Fig. 5.

The iron core may also be made of a bundle of wires as disclosed in Fig. 6 such as is the case with induction coils; in this case, however, a body is attained which has a poor iron filling factor. A body consisting of a continuously wound lamination as shown in Fig. 7 creates an approximately rotation symmetrical field. The latter, however, acts in the outer layer as a secondary winding having a relatively high turn voltage so that a very reliable insulation is necessary between the individual layers which again impairs the iron filling factor. Since the turn voltage is smaller and in the interior a very reliable insulation may be dispensed with a lamination reel (Fig. 7) may, nevertheless, be employed preferably for filling up the central hole (Fig. 8) which is necessary in an involute yoke (Fig. 5) for which purpose also a bundle of wires may be employed (Fig. 9). Of the high-grade types of iron permalloy is above all suitable, since it combines sufficient saturation with very high permeabilities in the unsaturated state.

To provide a rotation symmetrical eddy field it does not suffice to design the central iron leg rotation symmetrically. The magnetic flux must, moreover, be such as to form also exteriorly as far as possible a rotation symmetricaly closed circuit. This may be accomplished if the magnetic circuit of a straight cylindrical iron core—as is the case with induction coils—is closed on all sides by air. However, in this case the expanded stray field and the power which has to be supplied for setting up the stray flux would give rise to trouble. Furthermore, such a stray field may easily be brought out of symmetry by outer iron or also by metal masses. If, on the other hand, the magnetic circuit were closed by iron, access to the eddy field in the case of a complete rotation symmetry would be completely prevented, consequently it would be impossible to get also the generated rapid electrons out of the eddy field. In order to attain at all events an approximate rotation symmetry the closing of the magnetic circuit according to the invention is not effected by one end yoke, but at least by two, if possible by more yokes, in which case an adjustable air gap may be provided in each yoke in order to distribute the magnetic flux symmetrically.

Further features of the invention consist in introducing the electrons in a convenient manner into the eddy field and to release the same again from the field.

For introducing the electrons into the eddy field a glowing cathode \( 33 \) (Fig. 10) is employed which is placed in the neighborhood of the desired circle of the circular electron path in a highly exhausted discharge vessel, \( 31 \) disposed in the space between the acceleration poles \( 12, 13 \) and arranged co-
axially therewith. The circular electron path is indicated at 32.

The glancing cathode may in this case have, for instance, the form of a wire ring which is disposed somewhat above or below the desired circle. It would also be possible to close this wire ring and to heat it by induction by the short circuit current created therein. This would be of advantage owing to the maintenance of a complete rotation symmetry and to the elimination of particular heating connections. Nevertheless, this kind of heating is not preferable, since the magnetic field of the heating current disturbs the guiding field. The heating current has the tendency to attract the electrons to the glancing cathode. The effect of the heating current and of the heating voltage drop may, however, be completely suppressed in the case of a separately heated cathode if an alternating current of the same frequency and phase as the exciting current of the magnetic field is employed as heating current, as indicated in Fig. 10. This means that the heating voltage being lower due to the short circuit current of the guiding field and does not interfere in the time-intervals in which the emission of the electrons from the glancing cathode is needed. The short circuit current heating works, however, with a current having the same frequency but not the same phase (owing to the ohmic current component in the heating filament).

Another way of introducing the electrons into the field consists in shooting an electron ray to which an acceleration has been imparted already outside the pole pieces into the eddy field. The shooting in of slow electrons into the eddy field in the immediate neighborhood of the passage of the magnetic field through zero is preferable, since then the peripheral velocity of the eddy field is greatest as compared to the electron energy, that is to say it might exert its stabilizing action already after a relatively small number of revolutions.

As soon as the speed of the electrons has attained approximately its maximum value the electrons pass into the saturation of the guiding field to leave the desired circle and to be ejected from the magnetic field. Such disturbances may be produced in a variety of ways. For instance, an additional interfering field could be set up rapidly, for instance, an electric field between a particular electrode and its surroundings by a properly time-controlled transient wave or by a magnetic interfering field through a properly controlled energization of a particular coil. It is, however, very much simpler to utilize a disturbance caused by saturation of the iron, since the latter occurs each time automatically without specific indication in the case of magnetic fields of high intensity, i.e., just at the moment when the acceleration of the electrons has come to an end.

If by the saturation of the iron the guiding field \( H \) in the arrangement shown in Fig. 4 is caused to be increased only up to a certain maximum value but the central flux \( \Phi \) is caused to be further increased so that also the electric eddy field is further maintained, the electrons revolving in the guiding field are further accelerated without the guiding field being in any way increased. Consequently, the circular electron path expands. The expansion may be such that the circle expands up to a maximum from which the magnetic field decreases with \( dB/\sqrt{R} / H < -1 \) or to a further extent, and, therefore, the circular electron path explodes.

Such a saturation of the guiding field may be effected with an arrangement of the pole pieces as disclosed in Fig. 10. While in the central portion the flux \( \Phi \) passes through cylindrical pole pieces 12, 13—with the exception of the air gaps and the compressed pulverized iron core \( I \), the cylindrical pole pieces \( P \) which produce the guiding field \( H \) are provided with a restricted passage \( A \). The entire flux for the guiding field (inclusive of the stray field) passes through this restricted passage and by suitably dimensioning the restricted passage \( A \) it is possible to render, by proceeding from any given value of the guiding field, the flux intensity in the restricted passage so high that the iron becomes saturated at that point and, therefore, acts as an additional magnetic resistance for retarding or preventing a further increase of the guiding field. The enlarged portions of the cylindrical pole pieces located beyond the restricted passage are in this case only under the influence of such a low flux intensity that here the high permeability of the iron is maintained. The surfaces of the pole pieces which determine the form of the guiding field remain magnetic equipotential surfaces as in the case of lower guiding field intensities and cause the guiding field to drive back on the circular path even the electrons which have strayed away after the saturation of the iron has occurred. Only the circular path itself expands with the above-mentioned results.

The guiding field windings \( P \) and the acceleration field windings \( W' \) are preferably connected to a source of sinusoidal voltage and are, not fed with sinusoidal current, which may be easier effected from an electrotechnical point of view after the saturation of the guiding field the flux of the guiding field does not increase any longer, but the total flux must continue to increase in a sinusoidal manner owing to the sinusoidal voltage applied, the central flux now increases much more than before the saturation of the guiding field. However, this means that the increase of the guiding field expands the circular electron path in a twofold manner: Not only the increased check of the guiding field but also the electrical intensity of the eddy field increased by the increased central flux contributes to expand the circular path. This double utilization of the saturation of the iron permits to bring about even in the case of not so high-grade iron a rather sudden beginning of the expansion of the circular electron path, which is desirable, since the final energy thereby attained is the higher, the longer the electrons fly along the small radius. In the space between the central pole pieces 12, 13 and the restricted passage \( A \) in the cylindrical pole piece a particular field winding may be still accommodated which may be employed for correction in the case of small dimension faults of the stabilization conditions, since the ampere turns of the field winding enclose only the central flux.

It may be further pointed out that the pole pieces of the central magnetic field and the cylindrical pole pieces for the guiding field may be brought separately into operation with the yoke or main body of the magnetic arrangement.

The system operates in the following manner. Let us assume that at a given instant the two magnetic fields pass through zero value and the cathode \( C \) is glowing. From this instant the intensities of the two fields increase. The ac-
acceleration field generated in the pole pieces 12, 13 acts upon the electrons emanating from the glowing cathode and moves them in the circular path 32. A deviation of the electrons from this path is prevented by the effect of the guide field which increases in intensity simultaneously with the acceleration. While the field intensity of both fields increase, the electrons travel at higher and higher speeds on their circular path.

If now the excitation of all pole pieces exceeds a given value, the guide field prevailing between the pole pieces 14, 15 attains its saturation value, while the acceleration field which prevails between pole pieces 12, 13 still increases in intensity. This disturbance of the previously existing ratio between the intensities of the two fields has the effect that the electrons fly out of their circular path at a tangent. They impinge at their final speed upon the wall of vessel 31. The speed attained by them may be of such magnitude that it may readily correspond with electric potential differences of the order of 10 to 20 million volts.

As will be noted from Fig. 105, which shows a plan view of discharge vessel 31, an outlet nozzle 35 is provided in a manner known in the type of vessel. The axis of this nozzle is tangentially located with respect to the outer circle of vessel 31, so that the electrons, radially deflected in the manner aforesaid, are discharged therefrom in the form of an electron beam 5. This beam may be used for instance for therapeutic irradiation by directing the beam against the portions of the human body under treatment.

Irradiation by such a high speed electron stream has the advantage over X-ray irradiation, that by high speed electrons biological effects can be obtained which occur only at a penetration to a certain depth of the treated object.

The entire occurrence just described takes place within a time t of less than 1/4 period. When that time has elapsed, the arrangement becomes ineffective, until the magnetic fields again pass through their zero value, when the play begins anew. In this second half period, however, the electrons are accelerated on a circular path in the reverse direction.

The magnetic field necessary for the production of 10 to 20 million volt electrons accumulates, when completely developed, an energy of about 1 kilowatt second. If it were excited at 50 cycles per second a resistance of 50 to 100 kva. (with a cos φ = 0.1) is necessary, whereas when excited at 500 cycles per second about 500 to 1000 kva. are required. At least in the second case the inductive wattless power will be compensated for by a condenser lying in parallel relation to the magnetic winding in order to dispense with a large-sized generator. An oscillating circuit tuned to the operating frequency must, consequently, be provided.

Although the invention may be used for various purposes, for which electrons of high speed are necessary it is very essential to therapeutics.

I claim as my invention:
1. A device for generating electron rays of great energy by means of an electric eddy field produced by a magnet field varying with time, comprising a source of electrons, an evacuated vessel containing said source and constructed to provide a circular path for said electrons, means for producing a magnetic field varying with time for accelerating the electrons in a circular path and whose field axis coincides with the rotation axis of the electron stream, means for producing a guide field for the electron stream which varies similarly with time and which coaxially surrounds said acceleration field, said guide field-producing means being arranged so that the field intensity decreases outwardly with increasing radius of the electron path but at a rate not more than inversely proportional to the path radius increase, the means for producing said two fields being normally proportioned relatively to one another so that the guide field has always one-half the intensity of the accelerating field, and means for disturbing the relative intensities of said two fields when the electrons have attained the desired speed.

2. A device for generating electron rays of great energy by means of an electric eddy field produced by a magnet field varying with time, comprising a source of electrons, an evacuated vessel containing said source and constructed to provide a circular path for said electrons, means for producing a magnetic field varying with time for accelerating the electrons in a circular path and whose field axis coincides with the rotation axis of the electron stream, means for producing a guide field for the electron stream which varies similarly with time and which coaxially surrounds said acceleration field, said guide field-producing means being arranged so that the field intensity decreases outwardly with increasing radius of the electron path approximately at an inverse ratio of 5:1, the means for producing said two fields being normally proportioned relatively to one another so that the guide field has always one-half the intensity of the accelerating field, and means for disturbing the relative intensities of said two fields when the electrons have attained the desired speed.

3. A device for generating electron rays of great energy by means of an electric eddy field produced by a magnet field varying with time, comprising a source of electrons, an evacuated vessel containing said source and constructed to provide a closed circular path for said electrons, a magnetic body having two opposing pole elements disposed coaxially with said electron path and being spaced apart and carrying energizing windings adapted to produce a magnetic acceleration field varying with time, two further opposing pole elements on said magnetic body carrying energizing windings for producing a guide field for the circular electron stream simultaneously varying with time, said guide pole elements surrounding said acceleration pole elements rotation-symmetrically and being shaped so that the intensity of the guide field produced by them is always equal to half the intensity of the acceleration field, said guide pole elements being also constructed so that the intensity of their generated field decreases with increasing distance from the pole axis but not more than inversely proportionally to the electron path radius increase, and means for disturbing the relative intensities of said two fields when the electrons have attained the desired speed.

4. A device for generating electron rays of great energy by means of an electric eddy field produced by a magnet field varying with time, comprising a source of electrons, an evacuated vessel containing said source and constructed to provide a closed circular path for said electrons, a magnetic body having two opposing pole elements disposed coaxially with said electron path and being spaced apart and carrying energizing windings adapted to produce a magnetic acceleration field varying with time, two further oppos-
posing pole elements on said magnetic body carrying energizing windings for producing a guide field for the circular electron stream and similarly varying with time, said guide pole elements surrounding said acceleration pole elements rotation-symmetrically and being shaped so that the intensity of the guide field produced by them is always equal to half the intensity of the acceleration field, said guide pole elements being also constructed so that the intensity of their generated field decreases with increasing distance from the pole axis but not more than inversely proportional to the electron path radius increase, and means for disturbing the relative intensities of said two fields when the electrons have attained the desired speed, the opposing faces of said guide poles being shaped as hyperboloids within the range of the field produced by them.

5. A device for generating electron rays of great energy by means of an electric eddy field produced by a magnet field varying with time, comprising a source of electrons, an evacuated vessel containing said source and constructed to provide a closed circular path for said electrons, a magnetic body having two opposing pole elements disposed coaxially with said electron path and being spaced apart and carrying energizing windings adapted to produce a magnetic acceleration field varying with time, two further opposing pole elements on said magnetic body carrying energizing windings for producing a guide field for the circular electron stream and similarly varying with time, said guide pole elements surrounding said acceleration pole elements rotation-symmetrically and being shaped so that the intensity of the guide field produced by them is always equal to half the intensity of the acceleration field, said guide pole elements being also constructed so that the intensity of their generated field decreases with increasing distance from the pole axis but not more than inversely proportional to the electron path radius increase, and means for disturbing the relative intensities of said two fields when the electrons have attained the desired speed, the space between said acceleration field pole elements being bridged by a mass consisting of iron powder and an insulating binder.

7. A device for generating electron rays of great energy by means of an electric eddy field produced by a magnet field varying with time, comprising a source of electrons, an evacuated vessel containing said source and constructed to provide a closed circular path for said electrons, a magnetic body having two opposing pole elements disposed coaxially with said electron path and being spaced apart and carrying energizing windings adapted to produce a magnetic acceleration field varying with time, two further opposing pole elements on said magnetic body carrying energizing windings for producing a guide field for the circular electron stream and similarly varying with time, said guide pole elements surrounding said acceleration pole elements rotation-symmetrically and being shaped so that the intensity of their generated field decreases with increasing distance from the pole axis but not more than inversely proportional to the electron path radius increase, the magnetic body portion carrying the guide field poles being suitably shaped to produce in said portion by the field, generated in said guide poles, magnetic saturation when a desired flux density is attained, the value of which is below that at which the acceleration pole elements become saturated.

8. A device for generating electron rays of great energy by means of an electric eddy field produced by a magnet field varying with time, comprising a source of electrons, an evacuated vessel containing said source and constructed to provide a closed circular path for said electrons, a magnetic body having two opposing pole elements disposed coaxially with said electron path and being spaced apart and carrying energizing windings adapted to produce a magnetic acceleration field varying with time, two further opposing pole elements on said magnetic body carrying energizing windings for producing a guide field for the circular electron stream and similarly varying with time, said guide pole elements surrounding said acceleration pole elements rotation-symmetrically and being shaped so that the intensity of the guide field produced by them is always equal to half the intensity of the acceleration field, said guide pole elements being also constructed so that the intensity of their generated field decreases with increasing distance from the pole axis but not more than inversely proportional to the electron path radius increase, the pole elements for the acceleration field having uniform cross-section throughout their entire lengths, and the pole elements for the guide field having a sufficiently reduced cross-section at suitable points of their lengths, so that saturation of said pole elements when the flux density therein exceeds a given value at which the acceleration pole elements remain still unsaturated.

9. A device for generating electron rays of great energy by means of an electric eddy field produced by a magnet field varying with time, comprising a source of electrons, an evacuated vessel containing said source and constructed to provide a closed circular path for said electrons, a magnetic body having two opposing pole elements disposed coaxially with said electron
path and being spaced apart and carrying energizing windings adapted to produce a magnetic acceleration field varying with time, two further opposing pole elements on said magnetic body carrying energizing windings for producing a guide field for the circular electron stream and similarly varying with time, said guide pole elements surrounding said acceleration pole elements rotation-symmetrically and being shaped so that the intensity of the guide field produced by them is always equal to half the intensity of the acceleration field, said guide pole elements being also constructed so that the intensity of their generated field decreases with increasing distance from the pole axis but not more than inversely proportional to the electron path radius increase, and means for disturbing the relative intensities of said two fields when the electrons have attained the desired speed, the magnetic body outside of said two kinds of pole elements forming a return circuit for the opposing pole elements being in a plane located substantially in the rotation axis of the electron stream.

10. A device for generating electron rays of great energy by means of an electric eddy field produced by a magnet field varying with time, comprising a glow cathode serving as a source of electrons, an evacuated vessel containing said source and constructed to provide a closed circular path for said electrons, a magnetic body having two opposing pole elements disposed coaxially with said electron path and being spaced apart to accommodate said vessel between them and carrying energizing windings adapted to produce a magnetic acceleration field varying with time, two further opposing pole elements on said magnetic body carrying energizing windings adapted to produce a guide field for the circular electron stream and similarly varying with time, said guide pole elements surrounding said acceleration pole elements rotation-symmetrically and being shaped so that the intensity of the guide field produced by them is always equal to half the intensity of the acceleration field, said guide pole elements being also constructed so that the intensity of their generated field decreases with increasing distance from the pole axis but not more than at an inverse ratio to said distance, means for disturbing the relative intensities of said two fields, a common alternating voltage source for the energizing windings of said acceleration and guiding pole elements so as to produce equal variations as to time in the fields produced by said elements, said glow cathode being connected to the same voltage source so that the cathode voltage and the magnetic fields attain their zero values at the same time.

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