Oct. 12, 1943. G. C. BALDWIN 2,331,788

MAGNETIC INDUCTION ACCELERATOR

Filed Jan. 20, 1942 2 Sheets-Sheet 1

Fig. 1.

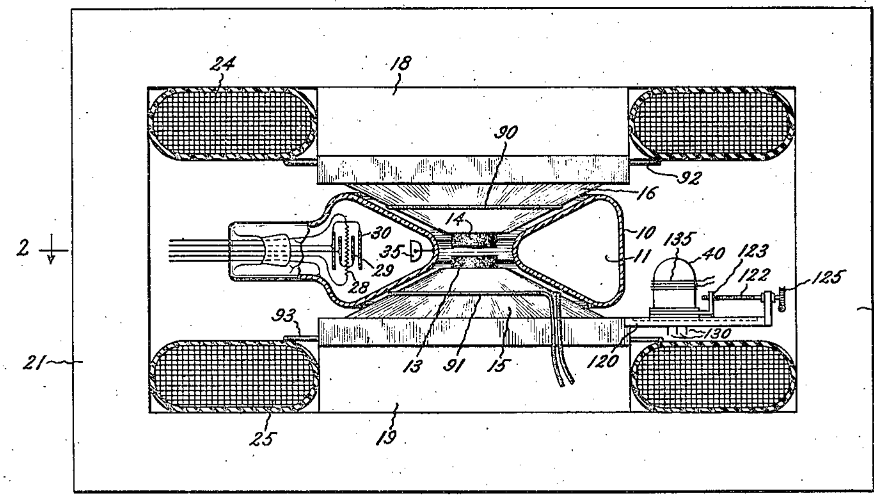

Fig. 2.

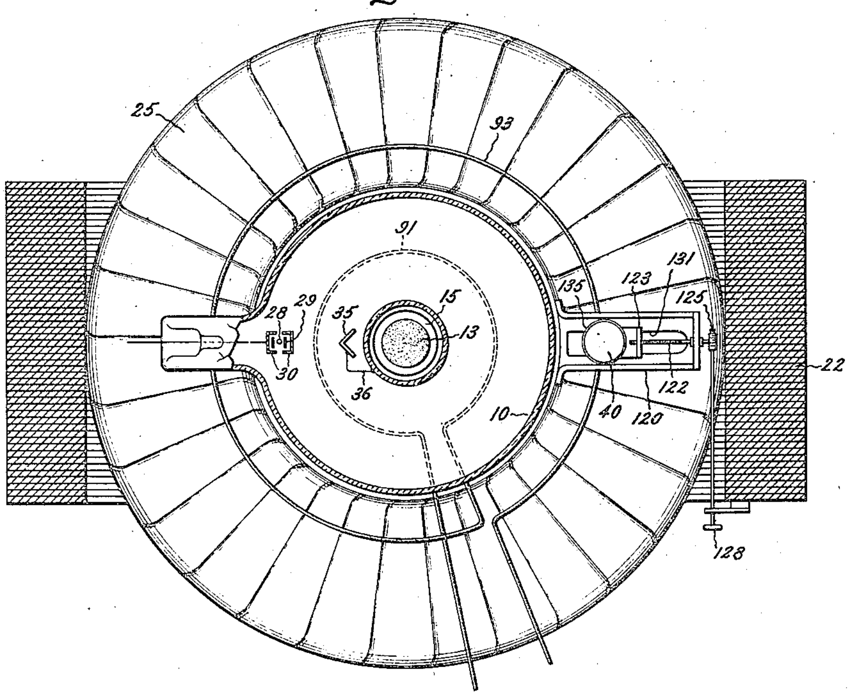

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Fig. 3.

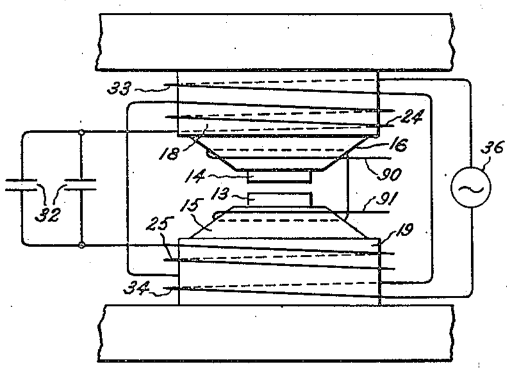


Fig. 4.

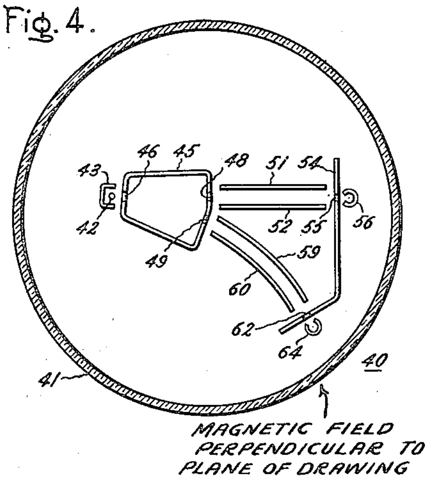


Fig. 6.

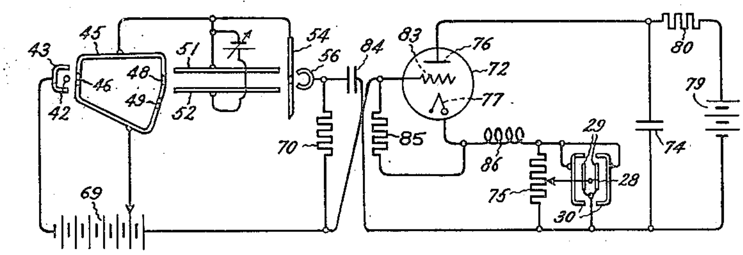


Fig. 7.

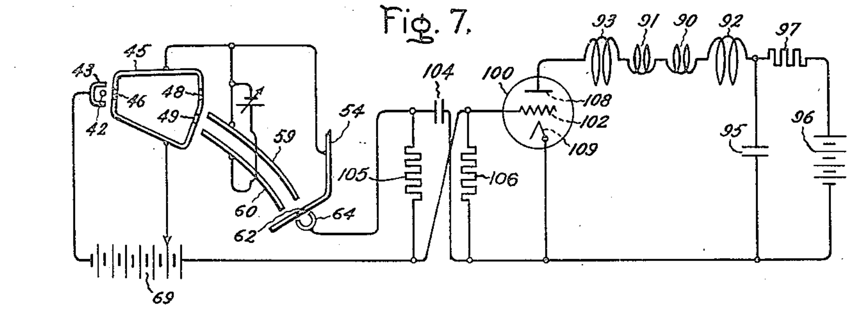


Fig. 5.

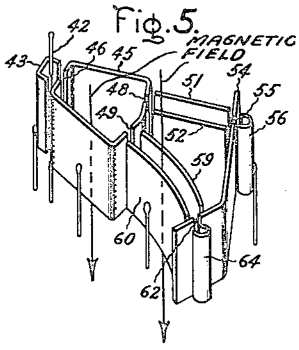
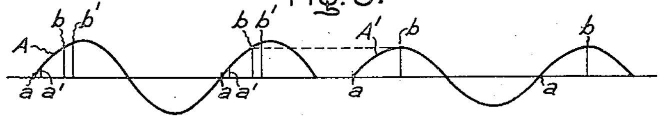


Fig. 8.



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Patented Oct. 12, 1943 2,331,788

UNITED STATES PATENT OFFICE

2,331,788

MAGNETIC INDUCTION ACCELERATOR

George C. Baldwin, Urbana, Ill., assignor to General Electric Company, a corporation of New York

Application January 20, 1942, Serial No. 427,474

13 Claims. (Cl. 250—27)

The present invention relates to apparatus for accelerating charged particles, such as electrons, by means of magnetic induction effects, and is especially applicable in connection with apparatus of the general character described in application Serial No. 365,520, filed November 13, 1940 in the name of Donald W. Kerst, said application being assigned to the General Electric Company, a corporation of New York.

Apparatus of the character referred to typically includes a closed vessel and a magnetic system for producing a time-varying magnetic field of such space distribution as to confine charged particles projected within the vessel to a circular orbit along which the particles are continuously accelerated by the field as it increases in magnitude. When the particles have been accelerated to a desired velocity, they are diverted from the accelerating orbit and used for the production of useful biological or other effects.

In the operation of magnetic induction apparatus of the type specified, a major problem consists in the provision of suitable means for introducing charged particles into the orbital path in which acceleration is to occur, while another problem involves the provision of means for effectively diverting or releasing the particles after their acceleration has proceeded to the desired degree. In connection with both the functions referred to in the foregoing, (i. e. injection and release of charged particles), a primary difficulty is that of correlating the action of the injecting and releasing means with the variations of the accelerating field. The latter field is conveniently produced by the operation of a cyclically variable current supply source, such as a source of alternating current, so that the acceleration of the particles is an intermittent procedure. Injection of particles is found to be most effective if electrons are introduced into the accelerating orbit at a time when the accelerating magnetic field strength is near its zero value, whereas it is desirable to release the particles from the accelerating field at a time when the field is approaching a maximum value. In order to permit some degree of flexibility in output, it is further desirable to be able to control the particle-releasing agency so as to cause particles to be released at various points in the cycle of variation of the accelerating field.

The present invention has as an object the provision of means by which the foregoing desiderata may be accomplished in a simple and reliable fashion. In this connection, an important feature of the invention consists in the provision of a device actuated directly by the variations of the accelerating field to control either the injection or the release of charged particles, and in the preferred arrangement, to control both of these functions in correlated fashion. In one embodiment, the means employed for this purpose comprises a magnetically controlled electronic switch which is positioned within the region of influence of the magnetic field by which acceleration is accomplished and which is operative to control the energization of a particle-injection means at one instant and to control the energization of a particle-releasing means at another instant.

The features which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the drawings in which Fig. 1 is a partially sectionalized elevation of an accelerating apparatus suitably embodying the invention; Fig. 2 is a cross section taken on line 2—2 of Fig. 1; Fig. 3 represents schematically a fragmentary portion of the apparatus of Fig. 1 and illustrates the mode of energization of the magnetic structure of the apparatus; Fig. 4 is a sectional view showing the internal construction of a magnetically controlled electronic switch forming one of the elements of Fig. 1; Fig. 5 is a perspective view supplementary to Fig. 4; Fig. 6 is a circuit diagram showing means for controlling the injection of electrons in the apparatus of Fig. 1; Fig. 7 is another circuit diagram showing means for energizing the electron-releasing system of the apparatus; and Fig. 8 is a graphical representation useful in explaining the invention.

Referring particularly to Fig. 1 there is shown in section a closed glass vessel 10 which defines within its interior an annular chamber 11. As will be explained in greater detail at a later point the vessel 10 encloses a circular orbit in which electrons may be accelerated to a high voltage, say on the order of several million volts. The vessel is preferably highly evacuated, although the presence of a small amount of gas is permissible under some circumstances. A high resistance coating, such as an extremely thin layer of silver (not shown), may be advantageously applied to the interior surface of the vessel to prevent wall-charging and the like.

The accelerating mechanism comprises a magnetic structure having generally circular pole pieces which are coaxial with the annular vessel

10. These pole pieces include a pair of juxtaposed circular parts 13 and 14 which consist, for example, of laminated iron and which are respectively supported on conically tapered parts 15 and 16. The tapered parts in turn are based upon large cylinders 18 and 19 which connect with closed magnetic cores 21 and 22 so as to provide a complete path for magnetic flux. The elements of the magnetic structure are constituted of ferromagnetic material and should be of laminated or otherwise subdivided construction, so as to minimize eddy currents.

The magnetic structure is excited by means of a pair of series connected coils 24, 25, which are mounted on the cylinders 18 and 19 and which are energized in such manner as to produce a time-varying flux in the magnetic circuit. The energizing means may appropriately be of the character shown in Fig. 3 which illustrates diagrammatically a portion of the structure of Fig. 1. The coils 24 and 25 are shown connected in series with one another and with a bank of condensers 32 which are of such capacity as to resonate with the inductance of the coils at a frequency corresponding to the desired frequency of operation of the apparatus. (This may be, for example, on the order of 600 cycles per second, although frequencies differing widely from this value are also usable.) To supply the losses of the resonant circuit thus formed, the coils 24 and 25 may be coupled to primary coils 33 and 34 which are directly energized from an A. C. power source 36. A relatively small amount of power supplied by the source 36 will serve to maintain the resonant system in excited condition.

Within the closed vessel 10 (Fig. 1) and also within the region of influence of the magnetic field produced by the pole pieces 15 and 16 there is provided a thermionic cathode 28 which, in conjunction with the other electrode structure shown, serves to generate an intermittent stream of electrons. These electrons are affected by the magnetic field in two ways. In the first place, since the field is in a direction transverse to the plane of the electron motion, it tends to force the electrons to follow a generally circular orbit. Secondly, the time-varying flux enclosed by the orbit of any particular electron necessarily produces an accelerating action on the electron. In this latter respect, the apparatus as a whole consists essentially of a transformer with a secondary comprising a circular path along which the various electrons are accelerated. Although, in general, the voltage per turn in such a transformer is low, the electrons can achieve very high velocities (e. g. several million volts) because of the tremendous number of turns which they may execute during a single cycle of the field variation.

It has been shown that by a proper design of the magnetic structure the field existing at the electron orbit may be caused to produce a centripetal force in balance with the centrifugal tendencies of the accelerated electrons. In general, this result requires that the following relationship be satisfied: $\phi=2\pi r^2 H_r$, where ϕ is the flux included within the electron orbit, r is the radius of the electron orbit, and H_r is the field strength at the orbit. This equation obviously means that the flux ϕ must be twice as strong as that which would be produced by a homogeneous field equal to the field H_r extending over the entire area enclosed by the orbital electron path.

The condition just specified may be realized by making the reluctance of the magnetic path greater by an appropriate amount at the electron orbit than its average reluctance within the orbit. In order to maintain fixed proportionality between the enclosed flux and the guide field (i. e. the field H_r) at all times during the accelerating period, one may include in the magnetic path an air gap or its equivalent. It is readily practicable to control the dimensions of such a gap from point to point over the pole area in such a fashion as to effect the balanced relationship of guide field and enclosed flux which is desired for the purpose specified above.

A principal problem in the operation of apparatus of the type under consideration consists in introducing electrons into the accelerator. In general, however, it is found that the difficulties of electron injection may be to a large extent overcome by providing an electron source which is actually within the region of influence of the magnetic field and which is of such character as to provide electrons having a definite initial direction and velocity. The arrangement shown in Figs. 1 and 2 is of this character and comprises a coiled filamentary cathode 28 having substantial extension in a direction parallel to the axis of symmetry of the vessel 10. This cathode is enclosed laterally by a pair of metal electrode elements 29 which are arranged in juxtaposed relation so as to provide at their edges a pair of slots which permit the escape of electrons emitted by the cathode in a direction generally tangential to the outer wall of the vessel 10. The members 29 are in turn enclosed by a somewhat similar pair of conductive elements 30 positioned to provide slots in alignment with the slots provided between the members 29. During periods of operation of the electron injector, the electrode elements 29 are normally maintained at a potential which is negative with respect to the cathode 28, and the elements 30 are maintained at a relatively positive potential. With this arrangement the resultant electrostatic fields tend to produce a thin ribbon of electrons proceeding in both directions through the slots provided between the various electrode elements. With a given direction of the magnetic field, only the electrons projected from one side of the electrode system are utilized, the remainder (that is, those projected in the other direction) being deflected away from the accelerating orbit against the outer wall of the enclosing vessel. Best results are obtained by injecting the electrons with an energy of at least several hundred electron volts, this being obtained by application of appropriate potentials to the electrodes 29 and 30.

For satisfactory operation it is found desirable in most cases to limit the introduction of electrons to the period when the magnetic field strength is small since this condition apparently results in maximum acceptance of electrons. The fulfillment of this requirement presupposes some means for accurately correlating the electron-injecting means with the variations of the magnetic field, and the present invention has for one of its objects the provision of such means.

In this connection there is provided in the construction of Fig. 1 a magnetically controlled switch in the form of an electronic discharge tube 40 which is mounted in proximity to the poles of the magnetic structure so as to be within the region of influence of at least the fringing portion of the time-varying magnetic field produced between these poles. This tube is suitably of the character illustrated in Fig. 4 and includes within a sealed envelope 41 an assembly of electrodes adapted to produce a concentrated stream or ray of electrons. The means employed in this connection includes a heatable cathode 42 having associated with it a channel-shaped electrode 43 which may be connected to the cathode and which serves to concentrate into a directed stream the electrons released by it.

For the purpose of giving these electrons velocity and direction there is further provided in proximity to the cathode 42 an accelerator 45 which consists of a cage-like structure having a collimating aperture 46 in alignment with the cathode. The structure 45 is provided in the wall more remote from the cathode 42 with a pair of additional openings 48 and 49 through either of which the electron stream may leave the structure provided it is properly directed.

The location of the opening 48 is such as to permit passage of the electron stream through it when the stream is in an undeflected condition, that is, when it is projected in a straight line from the cathode 42 as is true in the absence of a magnetic or electrostatic deflecting field. Upon egress from the opening 48, the beam passes between two parallel conducting plates 51, 52 and through a further collimating element 54 having a small opening 55. Passage of the beam through this latter opening causes it to impinge upon a collecting electrode 56, the function of which will be described more fully at a later point.

In the event that the electron stream proceeding from the cathode 42 is deflected laterally, as by the action of a magnetic field, it may, when the deflecting field is of the proper strength, leave the structure 45 through the opening 49. In this case it passes between a second pair of plates 59 and 60 and after passing through a second collimating opening 62 provided in the electrode 54, is collected by an alternative collecting element 64.

In the use of the device 40 in the application now under consideration, the arrangement is such that the electron stream proceeding from the cathode 42 is enabled to reach the collector 56 only when the magnetic field between the accelerator poles 15 and 16 is of zero value or very close to this value. Under these circumstances there will be no deflection of the beam by the field, so that straight line projection of it may be assumed. However, as soon as the field rises to an appreciable value, deflection of the electron stream will occur in accordance with well-known principles of electromagnetic action and current flow to the current collector 56 will be interrupted. For present purposes the orientation of the tube 40 with respect to the accelerating magnets is preferably made such as to assure deflection of the electron stream of the tube in a plane which cuts across the collimating apertures 48, 49, 55 and 62, a condition which prevails when the axis of the tube is parallel to the common axis of the pole pieces 18 and 19.

The arrangement described in the foregoing may be made use of to obtain exact correlation of the variations of the accelerating magnetic field with the functioning of the electron injecting system of the annular accelerating device 10. This is accomplished in one embodiment of the invention by the circuit illustrated in Fig. 6 in which figure the elements 28, 29 and 30 will be recognized as corresponding to the similarly numbered parts of Figs. 1 and 2. Parts 42 to 54 inclusive are elements which have been described in connection with Fig. 4. 69 is a battery for supplying potential to the various electrodes of the switching tube.

Let it be assumed that the induction accelerator is in operation and that at a chosen instant of time the accelerating magnetic field has such a value that the electron stream projected from the cathode of the tube 10 is not permitted to reach the collector 56.

At an instant later, when the magnetic field has passed its maximum value and has returned to zero, the electron stream will be restored to its undeflected condition and will then impinge abruptly upon the collector so that a pulse of current will be initiated in the collector circuit. In the arrangement illustrated this circuit includes a resistor 70 across which a voltage appears as the result of the aforementioned current pulse. In order to cause the voltage pulse thus produced to initiate the injection of electrons into the accelerating orbit of the device 10 there is provided in circuit between the electrode 56 and the injecting electrode structure a controlled discharge tube 72 which may be a gas-filled thyratron and which has the function of abruptly energizing the injecting electrodes of the device 10. The power supply circuit which is employed in this connection includes a condenser 74 which is adapted to be connected across a potentiometer 75 when the tube 72 is fired. A direct current supply source 79 is connected to the condenser through a current limiting resistor 80 and acts to charge the condenser when the tube 72 is in a non-conductive condition. Firing of the tube 72 is accomplished by the use of a control grid 83 which is connected to a terminal of the resistance 70 through a blocking condenser 84. (If desired, an amplifier may be included in this circuit.) A grid-leak resistor 85 is connected between the grid 83 and the cathode 77 to permit the grid to be normally maintained at a somewhat negative bias.

With this circuit, as soon as current flows through the resistor 70 (i. e. upon receipt of a current pulse by the collector 56), voltage is impressed on the grid 83 and the tube 72 is rendered conductive. The consequent current flow through the resistor 75 results in making the electrodes 30 positive with reference to the cathode 28 while making the electrodes 29 relatively negative. Accordingly, electrons are projected into the accelerating chamber in accordance with the previously explained mode of functioning of the electrodes 28, 29 and 30. Inductance 86 connected in series with the tube 72 assures that after the condenser 74 is discharged, an instantaneous reversal of potential across the tube 72 occurs so that the tube is again rendered non-conductive and the injection of electrons abruptly terminated. No further injection can occur until the magnetic field again approaches zero value, at which time the electron stream proceeding from the cathode 42 is again permitted to strike the collector 56.

It is in most instances desirable to inject electrons only on alternate half cycles (i. e. when the magnetic field passes through zero in a particular direction), and for this reason it will ordinarily be expedient to provide some means for preventing the triggering of the injecting circuit when the field is passing through zero in the unwanted direction. This may be done in one way by energizing the accelerating electrode 45 (Fig. 4) from the alternating current source by which the magnet coils 33 and 34 are supplied

(i. e. rather from the battery 69 as in the circuit of Fig. 6). With this arrangement the circuit connections should, of course, be such as to assure a positive potential on the electrode 45 as the magnetic field passes through zero in the wanted direction and to apply negative potential to the electrode when the field is varying in the opposite sense. When these conditions are fulfilled, the electron beam of the switching tube is cut off on alternate half cycles so that it becomes inoperative during such half cycles to trigger the injecting circuit regardless of the magnitude of the magnetic field acting on it.

In addition to the problem of injecting electrons at a proper time, there further exists the problem of releasing the electrons from the accelerating orbit after they have attained the desired high velocity. The accomplishment of this end requires a disturbance of balance between the accelerating field and the guide field maintained by the operation of the magnetic structure so that the accelerated electrons may escape from the circular orbit to which they are otherwise confined. One means for producing this unbalance comprises auxiliary field-producing coils mounted in proximity to the accelerating chamber and excited in such fashion as to modify the distribution of the accelerating field. For this use it has been found advantageous to provide in connection with the pole pieces 15 and 16 (Fig. 1) coils 90 and 91 which are disposed on the pole faces and which, in a preferred method of use, are connected in series in such a sense that current flow is in the same direction through both coils. With this arrangement, when the auxiliary coils 90 and 91 are energized, the radial gradient of the magnetic field (i. e. the change of field with radial position) is altered, the flux within the electron orbit being increased and the field gradient at the orbit being made more rapid, or vice-versa, depending upon the direction of the current in the auxiliary coils. This occurrence serves to make the electron orbit unstable radially so that electrons are permitted to escape from it, either in an inward or an outward direction according to the sense in which the field of the auxiliary coil disturbs the balanced condition of the magnetic system.

In a construction such as that shown in Fig. 1, in which the target 35 is near the inner periphery of the accelerating chamber, the direction of excitation of the coils 90 and 91 should be such as to favor the escape of electrons from the normal orbit in the inward direction so that the escaping electrons may be intercepted by the target. This is a condition which will obtain if the energization of the coils is such as to decrease the magnetic flux within the electron orbit and to increase the radial gradient of the field at the orbit.

Since the coils 90 and 91 link the major portion of the flux passing between the pole pieces 15 and 16, there is a considerable voltage developed in these coils as a result of the time-varying character of this flux. Because this voltage produces undesirable disturbances in the circuit used to energize the coils, it is desirable to suppress it, and for this purpose it has been found helpful to include compensating coils 92 and 93 in series with the coils 90 and 91. The coils 92 and 93 are suitably attached to the surfaces of the coils 24 and 25 and are reversely connected with respect to the coils 90 and 91, so that the voltage induced in them by the variations of the magnetic flux passing through the poles 15 and 16 tends to oppose the voltage generated by this flux in the coils 90 and 91. The number of turns in the respective coils can be made such that these voltages are approximately equal, with the result that little or no net voltage will appear in the external circuit.

The use of the compensating coils 92 and 93 has the further advantage of reducing the self-inductance of the circuit in which they are connected and hence of minimizing the voltage required to excite the orbit-shifting coils 90 and 91. This result is attributable to the fact that the mutually bucking effect of the two sets of coils reduces the net flux produced by the coils in the main magnetic circuit to a very low value, thus making the self-inductance of each coil correspondingly low.

The use of coils such as 90 and 91, and the further use of such coils in combination with the compensating coils 92 and 93 are features invented by Donald W. Kerst and are described and claimed by him in application Serial No. 445,465 filed June 2, 1942 and assigned to the same assignee as the present application. These features are not intended to be claimed herein.

As has been stated, it is imperative for satisfactory results that the energization of the orbit-disturbing coils 90 and 91 be correlated with the variations of the accelerating field so as to release the electrons only when they have reached the desired velocity. This end can be readily accomplished by a further application of the electronic switch 40; the mode of its use in this connection being indicated in Fig. 7.

In the last named figure it will be observed that there are shown electrodes 42 to 64 corresponding to similarly numbered electrodes of Fig. 4 and also that there are shown diagrammatically the auxiliary field-producing coils 90 and 91 and the compensating coils 92 and 93, these being connected in series. Energization of the coils 90 and 91 is controlled by an intermittently conducting discharge device 100 operable to place the coils in circuit with a condenser 95 which is charged from a unidirectional voltage source 96 through a current limiting resistor 97.

Like the device 72 of Fig. 6, the device 100 may be a gaseous thyratron capable of being rendered conductive only upon the application of a pulse of positive voltage to the grid 102 of the device. In the present instance such pulses are applied by connecting the grid through a blocking condenser 104 to a resistor 105 which is in circuit with the collecting electrode 64. (Negative bias is normally maintained on the grid by the combined action of the condenser 104 and an associated resistor 106.) With this arrangement voltage appears across the resistor 105 whenever current is received by the electrode 64, this being an event which occurs only when the field between the pole pieces of the indication accelerator is of sufficient magnitude to cause the electrons from the cathode 42 (Fig. 7) to be deflected through the openings 49 and 62 in the electrodes 45 and 54. Assuming that this event occurs when the accelerating field is approaching its maximum value, it is apparent that triggering of the tube 100 will occur at a time when the electrons within the annular vessel 10 are fully accelerated. At this time, current will be permitted to flow between the anode 108 and the cathode 109 of the tube 100 and the coils 90 and 91 will be abruptly energized by a discharge from the condenser 95. The effect will be, therefore, to permit an abrupt contraction of the electron orbit within the vessel 10 so that the accelerated electrons may be intercepted by the target with the consequent production of useful radiations (e. g. X-rays). After the condenser 95 is fully discharged, the tube 100 will again be rendered non-conductive and the electron-releasing system conditioned for a further operation at the end of the next accelerating cycle.

It is in many cases desirable to make the time of disturbance of the electron orbit controllable so that some choice in the matter of the velocity of the released electrons is possible. This flexibility may be realized in the construction of Fig. 1 by providing for adjustment of the position of the electronic switch 40. This may be accomplished, for example, by mounting the switch on a bracket 120 in such fashion that the switch may be moved toward and away from the poles 15 and 16 of the magnetic structure. To permit such movement the base of the tube 40 is set in a slot or keyway in the bracket 120 and is moved back and forth in this slot by the action of a threaded drive shaft 122 coacting with a correspondingly threaded member 123 secured to the tube base. The rotation of the shaft 122 may be controlled in a convenient manner by a worm 125 which is driven from a threaded shaft 126, the latter terminating in a readily accessible knob 128. In order to permit the desired motion of the tube 40 to take place without destroying the electrical connections to the tube, the tube may be provided with flexible leads 130 which are brought out through a slotted opening 131 in the bottom of the bracket 120.

By the arrangement described the energization of the orbit-disturbing coils 90 and 91 may be delayed by pulling the tube 40 away from the poles of the magnetic structure so that the tube lies in a relatively weaker field. Under these circumstances the electron beam from the cathode 42 will not be sufficiently deflected to strike the electrode 64 until the accelerating field reaches a higher value than would be required with the tube 40 in a closer position. Consequently, energization of the coils 90 and 91 and the ensuing disturbance of the electron orbit will be correspondingly retarded. It is worthy of note that motion of the device 40 to and from the pole structure does not greatly disturb the time of energization of the injecting system (Fig. 5) since this always occurs (in the mode of operation postulated above) when the field strength is near zero, a condition which is obviously attained concurrently at all points within the region of influence of the magnetic structure.

In order to permit a still further degree of adjustability in the operation of the electronic switch 40 there may be provided in connection with it an adjusting coil 135 (Fig. 1) wound, for example, upon the outer surface of the tube envelope. By passing current through this coil in the appropriate sense the beam may be initially biased in either direction desired. Such biasing may be used, for example, to secure alignment of the path of the undeflected beam with the collimating openings 48 and 55 or, alternatively, to retard or advance the instant of impingement of the beam (as deflected by the accelerating field) upon either of the collecting electrodes 56, 64.

The operation of the apparatus as a whole with reference to the correlation of the electron injecting and releasing means to the variations of the accelerating field is illustrated by the graphical representation of Fig. 8. In this figure the curve A represents the variations in magnitude of the accelerating magnetic field as it is excited from the alternating current supply source 36 (Fig. 3). When the field is near zero value, as at the points *a*, the electron stream of the electronic switch 40 will be undeflected so that current flow may occur to the collecting electrode 56 with resultant excitation of the injecting electrodes of the device 10 (i. e. in accordance with the operation of the circuit of Fig. 6). At a later time, when the magnetic field has attained a value *b* sufficient to produce deflection of the electron stream of the tube 40 into a position in which it impinges upon the collecting electrode 64, the auxiliary coils 90 and 91 will be abruptly energized and the accelerated electrons will be deflected from the accelerating orbit so as to enable them to strike the target 35.

If it is desired to change the time of electron release by means of the magnetic biasing coil 135 (Fig. 1) this may be done in one way by passing current through the coil in such a direction that the field of the coil tends to oppose the deflecting action of the field produced by the accelerating magnet. Under these circumstances the injection of electrons will be delayed, say to the time *a'*, and the release of electrons will be correspondingly retarded to a time *b'*, the amount of such retardation being in each case determined by the amount of biasing field employed.

Alternatively, the time of electron release may be changed without concurrently changing the time of electron injection supply by moving the electronic switch 40 away from the aceclerating pole structure by appropriate rotation of the adjusting knob 128 (Fig. 2). In this case the effect as far as the tube 40 is concerned is equivalent to that which would be obtained by reducing the maximum value of the accelerating magnetic field, say to the extent indicated by the curve A' of Fig. 8. Under these circumstances, the field intensity *b* required to trigger the electron releasing circuit is attained only at a relatively later point in the magnetic cycle. However, the time of electron injection *a* is not appreciably affected.

While the invention has been described by reference to a particular embodiment thereof, it will be understood that numerous changes may be made by those skilled in the art without actually departing from the invention. I therefore aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

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

1. A magnetic induction accelerator including means defining a chamber within which charged particles may follow an orbital path, means effective when energized to inject charged particles within said chamber, means adjacent to said chamber for producing a time-varying magnetic field of such space distribution as normally to confine charged particles within the chamber to a desired orbit while continuously accelerating them along said orbit, auxiliary field-producing means adapted when energized to modify the distribution of said time-varying field in such fashion as to cause the accelerated particles to deviate from said orbit, and means located within a region of influence of said time-varying field and being actuable thereby for successively energizing said injecting means and said auxiliary field-producing means at intervals

determined by the attainment of selected magnitudes of said field.

2. A magnetic induction accelerator including a chamber within which charged particles may follow an orbital path, means effective when energized to inject charged particles within said chamber, means adjacent to said chamber for producing a time-varying magnetic field of such space distribution as normally to confine particles within the chamber to a desired orbit while continuously accelerating them along said orbit, means adapted when energized to modify the distribution of said time-varying field in such fashion as to cause the accelerated particles to deviate from said orbit, and means including a magnetically controlled electronic switch positioned within the region of influence of said time-varying field for successively energizing said injecting means and said field-modifying means at intervals determined by the attainment of selected magnitudes of said time-varying field.

3. A magnetic induction accelerator including a chamber within which charged particles may follow an orbital path, means effective when energized to inject charged particles within said chamber, means adjacent to said chamber for producing a time-varying magnetic field of such space distribution as normally to confine charged particles within the chamber to a desired orbit while continuously accelerating them along said orbit, auxiliary field-producing means adapted when energized to modify the distribution of said time-varying field in such fashion as to cause the accelerated particles to deviate from said orbit, an electronic switch including means for producing a deflectable ray of electrons, said switch being in proximity to said first-named field-producing means whereby deflection of said ray is controlled by the variations of said time-varying magnetic field, a pair of displaced collecting electrodes within said switch for respectively collecting said electron ray in two different conditions of deflection thereof, means responsive to collection of said ray by one of said electrodes for energizing said injecting means, and means responsive to collection of said ray by the other of said electrodes for energizing said auxiliary field-producing means, whereby the energization of said injecting and auxiliary field-producing means is correlated to the variations of said accelerating field.

4. A magnetic induction accelerator including a chamber within which charged particles may follow an orbital path, means effective when energized to inject charged particles within said chamber, means adjacent to said chamber for producing a time-varying magnetic field of such space distribution as normally to confine particles within the chamber to a desired orbit while continuously accelerating them along said orbit, auxiliary field-producing means adapted when energized to modify the distribution of said time-varying field in such fashion as to cause the accelerated particles to deviate from said orbit, an electronic switch including means for producing a deflectable ray of electrons, said switch being in proximity to said first-named field-producing means whereby deflection of said ray is controlled by the variations of said time-varying field, a first collecting electrode within said switch for collecting said ray when the ray is in an undeflected condition, means connected with said collecting electrode for energizing said injecting means upon collection of the electron ray by the electrode, a second electrode for collecting said electron ray when the ray is deflected by said time-varying field, means in circuit with said second electrode for energizing said auxiliary field-producing means upon collection of the ray by said electrode, and means for adjusting the position of said switch with respect to said time-varying field, whereby the time of energization of said auxiliary field-producing means may be modified without concurrently modifying the time of energization of said injecting means.

5. In a magnetic induction accelerator, a source of charged particles, means defining a chamber within which particles from said source may follow an orbital path, means adjacent to said chamber for producing a time-varying magnetic field of such space distribution as normally to confine the particles to a desired orbit while continuously accelerating them along said orbit, auxiliary field-producing means adapted when energized to modify the distribution of said time-varying field in such fashion as to cause the accelerated particles to deviate from said orbit, and means actuable by said time-varying field when it has attained a given magnitude to produce abrupt energization of said auxiliary field-producing means.

6. In a magnetic induction accelerator, a source of charged particles, means defining a chamber within which particles from said source may follow an orbital path, means adjacent said path for producing a time-varying magnetic field of such space distribution as normally to confine the charged particles to a desired orbit while continuously accelerating them along said orbit, auxiliary field-producing means disposed in proximity to the path of said charged particles and effective when energized to modify the distribution of said time-varying field in such fashion as to permit the accelerated electrons to leave said orbit, a current-supply source adapted to be connected to said auxiliary means to energize the same, and means positioned within the influence of said time-varying field and actuable by said field to connect said supply source to said auxiliary means when the field has attained a given magnitude.

7. A magnetic induction accelerator including a source of charged particles, means defining a chamber within which particles from said source may follow an orbital path, means adjacent to said chamber to produce a time-varying magnetic field of such space distribution as normally to confine the particles to a circular orbit while continuously accelerating them along said orbit, means adapted when energized to modify the distribution of said time-varying field in such fashion as to cause the accelerated particles to deviate from said circular orbit, and a magnetically controlled electronic switch positioned within the region of influence of said time-varying field and actuable when the field has attained a given magnitude to produce abrupt energization of said modifying means.

8. A magnetic induction accelerator including a source of charged particles, means defining a chamber within which particles from said source may follow an orbital path, means adjacent to said chamber for producing a time-varying magnetic field of such space distribution as normally to confine particles within said chamber to a circular orbit while continuously accelerating them along said orbit, auxiliary means adapted when energized to modify the distribution of said time-

varying field in such fashion as to cause the accelerated particles to deviate from said circular orbit, a magnetically controlled electronic switch positioned within the region of influence of said time-varying magnetic field and effective to control the energization of said auxiliary means in dependence upon the variations of said field, and means for adjusting the location of said switch with reference to said field-producing means so as to vary the time of energization of said auxiliary means.

9. A magnetic induction accelerator including means defining a chamber within which charged particles may follow an orbital path, means adjacent to said chamber for producing a time-varying magnetic field of such space distribution as normally to confine particles within the chamber to a desired orbit while continuously accelerating them along said orbit, means effective when energized to inject charged particles within said chamber, and means actuable by said time-varying field when it has attained a given magnitude to produce abrupt energization of said injecting means.

10. A magnetic induction accelerator including a chamber within which charged particles may follow an orbital path, means adjacent to said chamber for producing a cyclically varying magnetic field of such space distribution as normally to confine particles within the chamber to a desired orbit while continuously accelerating them along said orbit, means effective when energized to inject charged particles within said chamber, a potential source adapted to be connected to said injecting means to energize the same, and means positioned within the region of influence of said cyclically varying field and actuable by said field to connect the said potential source to the injecting means at times when the said field has a selected magnitude thereby to produce intermittent, abrupt energization of said injecting means.

11. A magnetic induction accelerator including means defining a chamber within which charged particles may follow an orbital path, means adjacent to said chamber for producing a cyclically varying magnetic field of such space distribution as normally to confine particles within the chamber to a fixed orbit while continuously accelerating them along said orbit, means effective when energized to inject charged particles within the said chamber, a magnetically controlled electronic switch positioned within the region of influence of said cyclically varying field and actuable when the field attains zero magnitude to produce abrupt energization of said injecting means and thereafter abruptly to terminate the energization of such means.

12. A magnetic induction accelerator including a chamber within which electrons may follow an orbital path, means adjacent said chamber for producing a time-varying magnetic field of such space distribution as normally to confine an electron discharge to a desired orbit within said chamber, means effective when energized to inject electrons into said field, means for releasing electrons from said orbit, a control device in proximity to said time-varying field and including means for producing a beam of electrons which is deflectable in response to the variations of said field, an accelerator having a plurality of apertures, collimating means cooperating with said apertures, electrodes located respectively opposite said apertures for collecting electrons traversing said apertures, means connected with one of said electrodes for energizing said injecting means, and means connected with another electrode for energizing said releasing means.

13. A magnetic induction accelerator including means defining a chamber within which electrons may follow an orbital path, means adjacent to said chamber for producing a time-varying magnetic field of such space distribution as normally to confine electrons within the chamber to a desired orbit while continuously accelerating them along said orbit, means located within the region of influence of said time-varying field which is effective when energized to inject electrons within said chamber, an electric discharge means actuable by said time-varying field when it has attained a given magnitude and connections to produce thereby abrupt energization of said injecting means.

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