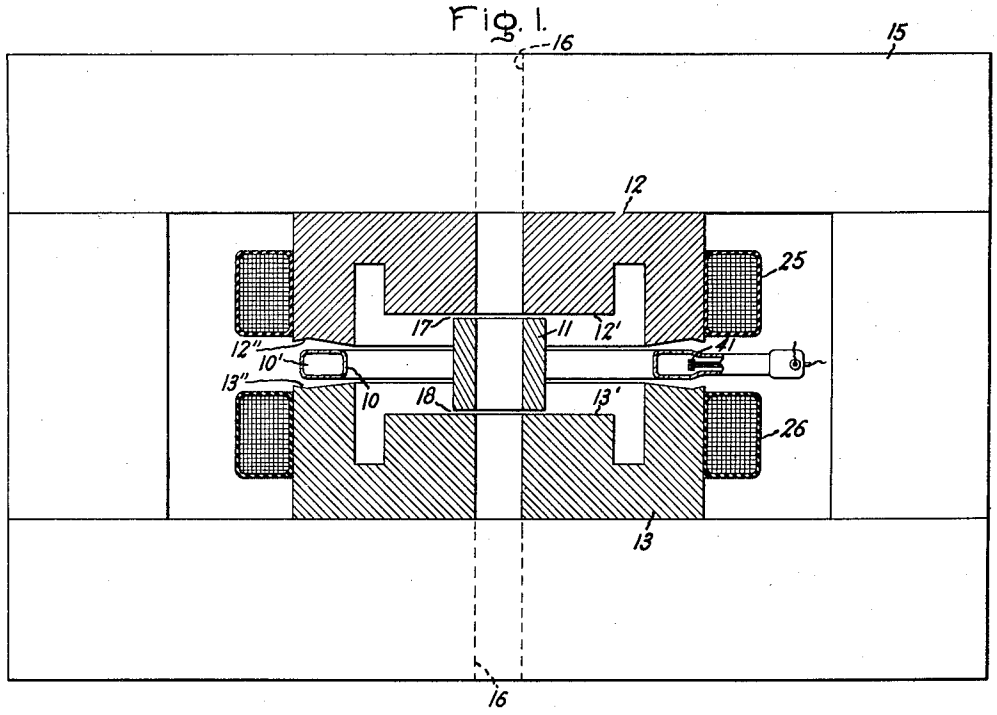
May 15, 1951 A. M. GUREWITSCH 2,553,312

APPARATUS FOR IMPARTING HIGH ENERGY TO CHARGED PARTICLES

Filed Aug. 17, 1946 4 Sheets-Sheet 1

Fig. 1.



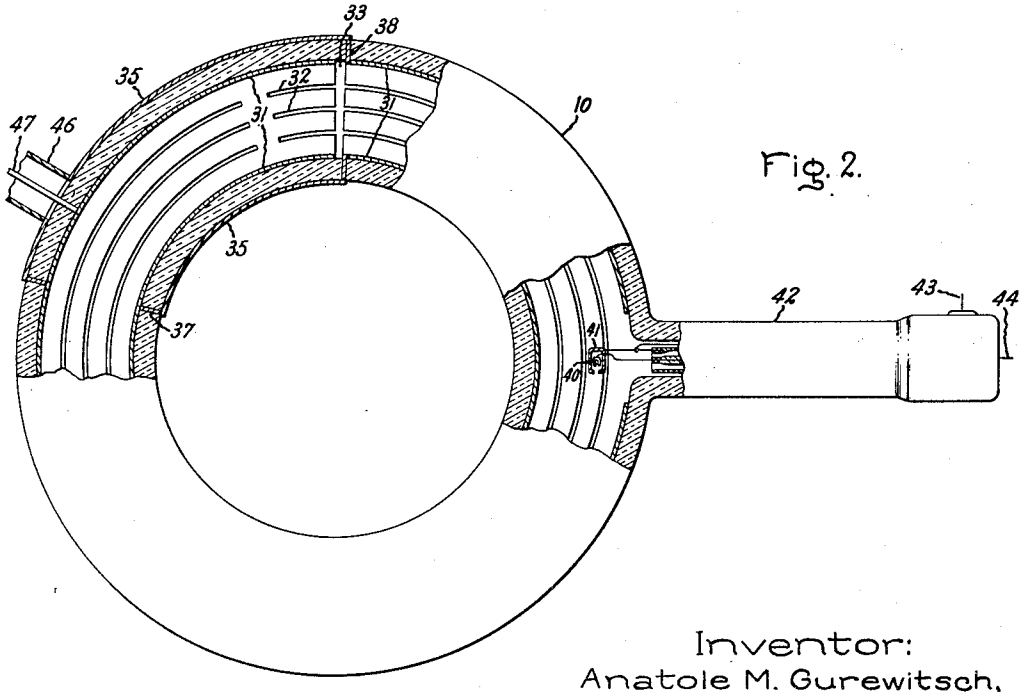


Fig. 2.

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Fig. 3.

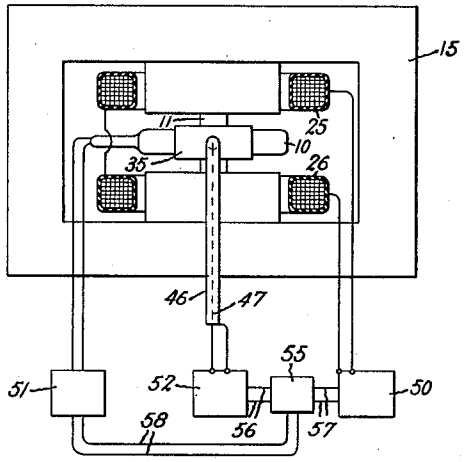


Fig. 4.

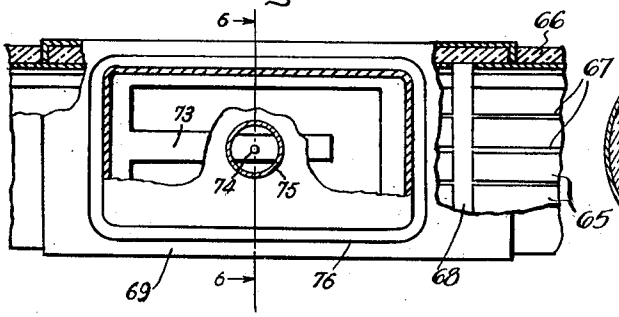


Fig. 6.

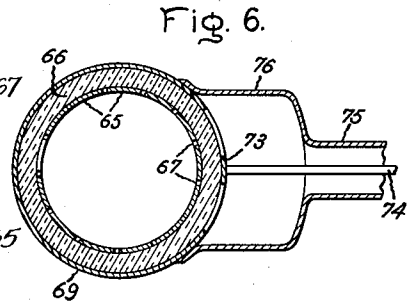
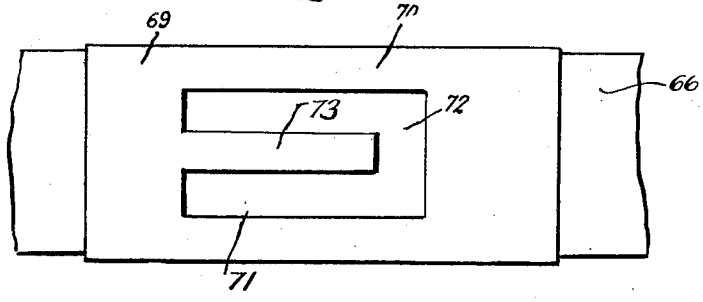


Fig. 5.



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APPARATUS FOR IMPARTING HIGH ENERGY TO CHARGED PARTICLES

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Fig. 7.

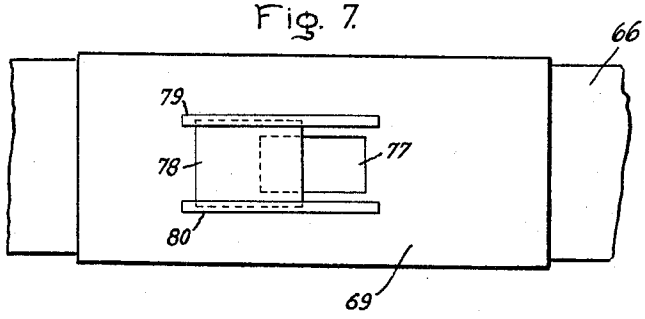

Fig. 8.

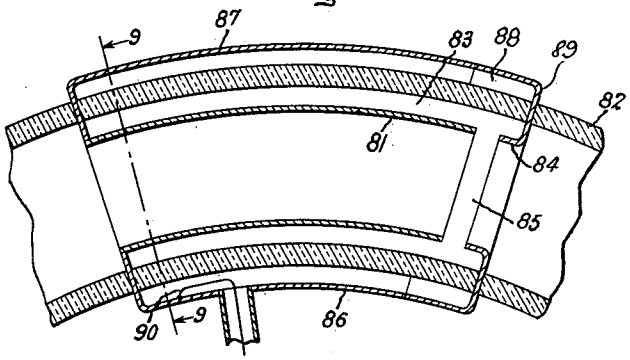

Fig. 9.

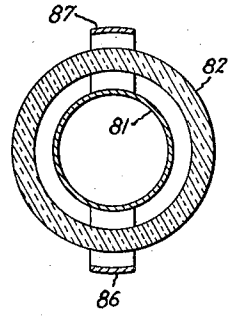

Fig. 10.

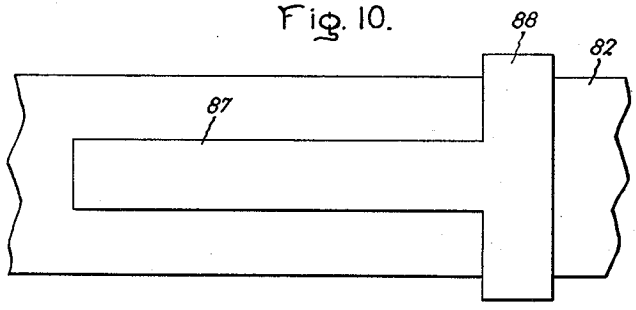

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Fig. 11.

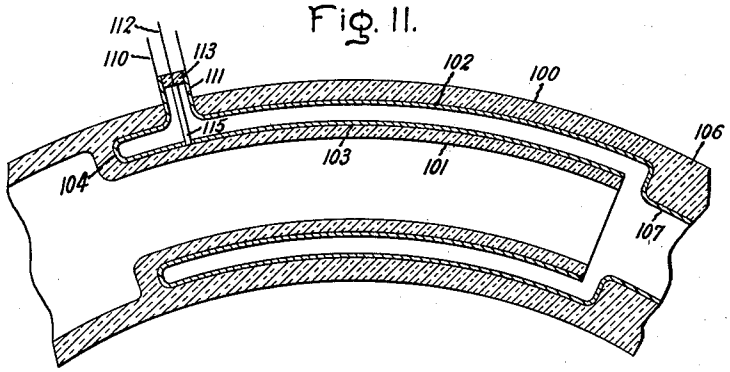


Fig. 12.

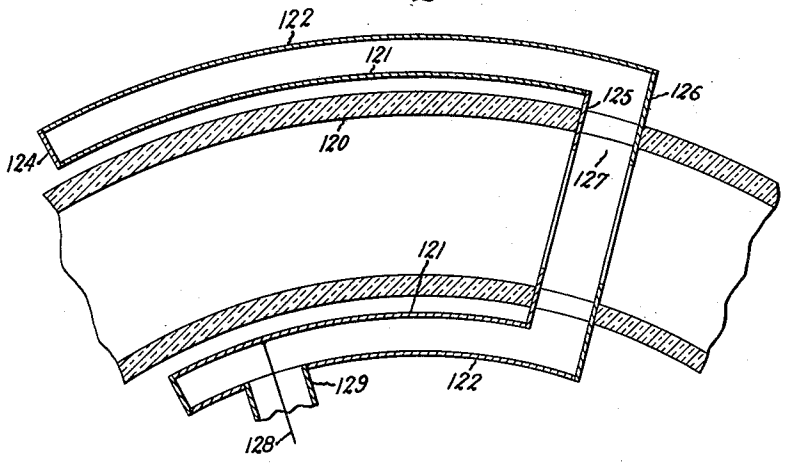
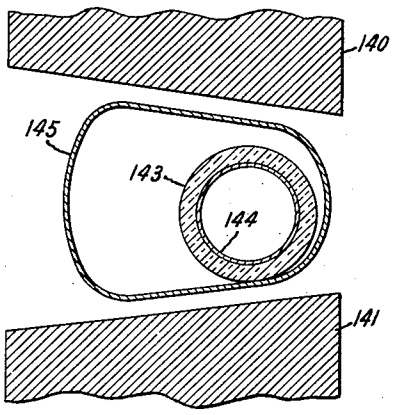


Fig. 13.



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Patented May 15, 1951

2,553,312

UNITED STATES PATENT OFFICE

2,553,312

APPARATUS FOR IMPARTING HIGH ENERGY TO CHARGED PARTICLES

Anatole M. Gurewitsch, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

Application August 17, 1946, Serial No. 691,293

16 Claims. (Cl. 250—27)

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The present invention relates to apparatus for imparting high energy to charged particles by repeated acceleration of such particles.

The invention is applicable in connection with apparatus of the type disclosed in United States patent application Serial No. 639,462, filed January 5, 1946, in the names of Herbert C. Pollock and Willem F. Westendorp, now U. S. Patent 2,485,409, and assigned to the General Electric Company, a corporation of New York. Such apparatus comprises means for initially accelerating charged particles by the action of a field produced by a time-varying magnetic flux and for thereafter producing continued acceleration of such particles by a localized electric field of cyclically varying character. My invention is primarily concerned with the performance of the last mentioned function, i. e., acceleration by a localized electric field, and comprises improved means for effectively and efficiently producing localized electric fields of the desired character.

One object of the invention comprises the provision of an electric field-producing system capable of meeting the peculiar space and electrical requirements of the application just mentioned. A more specific object comprises the provision of an advantageously constructed form of space resonator adapted to serve as an accelerating device for charged particles.

The features of the invention desired to be protected 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 accompanying drawings in which Fig. 1 is a partially sectionalized elevation of an accelerator suitably embodying the invention; Fig. 2 is an enlarged view of the discharge vessel of Fig. 1, shown partly broken away; Fig. 3 is a schematic representation of the excitation system employed in connection with the device in Fig. 1; Fig. 4 shows in partial section a preferred embodiment of the invention; Fig. 5 is an elevation view showing part of the structure of Fig. 4 removed; Fig. 6 is a cross section taken on line 6—6 of Fig. 4; Fig. 7 is an elevation showing a possible addition to the construction of Figs. 4, 5 and 6; Figs. 8 and 9 are orthogonal cross sectional views of a modified embodiment of the invention; Fig. 10 is an elevation view of the construction of Fig. 8 as seen from above; Fig. 11 is a cross sectional view of a further modification of the invention; Fig. 12 is a cross sectional view of still another modification of the invention; and Fig. 13 illustrates in section an alternative mode of application of the invention.

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Referring particularly to Fig. 1, there is shown in section a closed rotationally symmetrical glass vessel 10 which defines within its interior an annular chamber 10'. The vessel 10 provides a circular orbit in which charged particles, e. g., electrons derived from a source indicated generally at 41, may be accelerated to a high energy level. The vessel is preferably highly evacuated and is provided on its interior surface with a conductive coating, for example, a layer of silver, which has associated with it means enabling it to serve as a high frequency electrode system. The details of the electrode system do not appear in Fig. 1 but will be described at a later point.

The vessel 10 lies symmetrically around the axis of a laminated magnetic structure having a central flux path provided by an annular iron core 11. This core is supported at its extremities by attachment to the central portions of opposed pole pieces 12 and 13 which have planar circular areas 12' and 13' and tapered annular areas 12'' and 13''. These pole pieces are in turn supported by a rectangular frame 15 of laminated iron which surrounds and extends transversely to the vessel 10.

The ends of the core 11 are separated from the pole pieces 12 and 13 by narrow gaps 17 and 18 which are so proportioned as to cause the core to saturate at a predetermined level of the magnetic flux passing through it. The annular faces 12'' and 13'' of the two pole pieces each have a double taper as shown, the purpose of this configuration being explained at a later point. An opening 16 which extends continuously through the frame 15, the pole pieces 12 and 13 and the core 11 permits cooling air to be circulated through these parts.

The magnetic structure is excited by means of a pair of series connected coils 25 and 26 which surround the pole pieces and which may be energized in such a manner as to provide a cyclically varying flux in the magnetic circuit. Electrons produced within the desired vessel 10 are affected in two ways by the variations in magnetic flux thus obtained. In the first place, since the magnetic flux traversing the core 11 links the circular path provided by the vessel 10, any variation of such flux necessarily produces an electric field tending to accelerate electrons projected along such path. In this latter respect the apparatus is comparable to a transformer with a secondary comprising a circular path along which the various electrons are accelerated. In general, al-

though the voltage per turn in such a transformer may be low, within a practically attainable range of flux variation the electrons can be made to achieve very high energies, e. g. several million electron volts, because of the tremendous number of turns which they may execute during a single cycle of magnetic flux variation. In addition to the acceleration produced by flux linking the electron path, the flux produced by the annular pole pieces 12'' and 13'' in the region of the electron orbit tends to cause the electrons to follow an inwardly spiraling path. It has been shown that by a proper design of the magnetic structure the centripetal force produced by the magnetic field existing at the electron orbit may be caused to balance the centrifugal tendencies of the accelerated electrons. In general, this result requires that the following relationship be satisfied:

$$\varphi = 2\pi r^2 B_r$$

where φ is the flux included in the electron orbit, r is the radius of the orbit and B_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 B_r extending over the entire area enclosed by the orbital electron path. This condition may be realized by making the reluctance per unit of cross-sectional area of the magnetic path at the electron orbit greater by an appropriate amount than its average reluctance within the orbit. In order to maintain the desired proportionality between the enclosed flux and the guide field, i. e., the field B_r, at all times during an accelerating period, one may adjust the air gap existing between the pole pieces 12'' and 13'' to the appropriate value. It is readily practicable to control the dimensions of the gap from point to point over the pole piece in such a fashion as to effect the balanced relation of guide field and enclosed flux which is desired for the purpose specified above and which is further necessary for radial and axial stability of the electron orbit. This may be done, for example, by a construction such as that shown in Fig. 1 in which the pole pieces are doubly tapered. The principles governing the proper space distribution of the guide flux are more fully set forth in D. W. Kerst United States patent application Ser. No. 445,465, filed June 2, 1942, now matured into Patent No. 2,394,070 and assigned to the General Electric Company, a corporation of New York.

When all the conditions specified in the foregoing are fulfilled, electrons introduced into the chamber 10 in a period when the magnetic field is increasing may be expected to be drawn into the particular orbit in which a balance of centripetal and centrifugal forces exist and to be continuously accelerated along such orbit as long as the magnetic field increases in value. Assuming that the peak value of the magnetic field is sufficiently high, a total energy on the order of several million electron volts may be acquired by the accelerated electrons in a small fraction of a second.

It may be noted, however, that when an electron has obtained a velocity corresponding to an energy level of about 3 million electron volts, it is already within about 1% of the velocity of light. Accordingly, further gains in energy result primarily in an increase in the mass of the affected electrons and only insignificantly in a further gain in electron velocity, this result being

consistent with the Einstein mass-energy equivalence formula. Accordingly, electrons which have attained a velocity within a few percent of the velocity of light will gyrate with a relatively constant periodicity (at a fixed frequency) provided they can be confined to an orbit of relatively fixed radius. As is pointed out in the aforementioned application Serial No. 639,462 of Pollock and Westendorp, this consideration makes it possible to impart further energy to the electrons by means of a localized electric field of fixed frequency acting repetitively on the electrons as they continue their gyrations within the vessel 10. By this means extremely high energy levels can be reached through a mechanism which avoids mechanical difficulties associated with any attempt to achieve corresponding energy levels by a magnetic acceleration alone. With this in mind, the apparatus of Fig. 1 is so designed that saturation of the core 11 occurs after a sufficient acceleration of the electrons has been obtained by magnetic means, and an electric field accelerating system to be hereinafter described is brought into play. However, the guide field produced between the pole pieces 12'' and 13'' continues to increase as a result of continued energization of the coils 25 and 26 in order that the accelerated electrons may still be confined to the desired orbit.

Because of space limitations and the presence of a strong varying magnetic field, the effective application of an electric field to the electrons desired to be accelerated presents numerous difficulties in connection with an accelerator of the type here under consideration. In accordance with my invention, the most serious of these difficulties are overcome by utilizing a space resonant structure as the means for providing an electric field of proper frequency and orientation. One embodiment of this feature of the invention is shown in Fig. 2.

Referring to Fig. 2 there is shown an annular vessel 10 of glass or other suitable dielectric material, preferably highly evacuated, which is provided on its inner surface with a conductive metallic coating 31 consisting, for example, of silver. This coating is longitudinally subdivided by the provision of uncoated strips 32 which have the function of minimizing the circulating currents induced in the tube by the changing magnetic field to which the tube is subjected. A gap 33 formed between longitudinally spaced portions of the coating provides a region across which a high frequency electric field may be established.

On the outside of the discharge vessel 10 there is provided a second conductive metal coating 35 which extends over only a portion of the vessel. Coating 35 is electrically connected to the inner coating 31 by two metal rings 37 and 38 sealed into the wall of the discharge vessel. It is to be noted that the ring 38 connects directly with the portion of the coating 31 which forms the right-hand boundary of the gap 33 while the ring 37 is connected to the coating 31 at a point which is to the left of the gap 33 and appreciably spaced from it. Actually, the spacing of the ring 37 with reference to the gap 33 is chosen to represent electrically a quarter wave length at the desired frequency of the field to be established across the gap 33. With the correct selection of longitudinal dimensions, the space between the conductors 31 and 35 constitutes in effect a space resonant system comprising a quarter wave concentric transmission line section. Accordingly, if the struc-

ture thus provided is excited at the proper frequency, a cyclically reversible electric field of high intensity may be made to appear across the gap 33. By choosing the frequency of reversal of this field to correspond to the frequency of rotation of the electrons moving within the vessel 10, an increase in the energy level of such electrons may be effected in accordance with the principles previously outlined. Electrons may be introduced into the vessel by means of an electrode system comprising a cathode 40 and an accelerating electrode 41, both supported from a stem 42 and having lead-in connections 43 and 44, respectively.

Excitation of the space resonator formed by the conductors 31 and 35 is accomplished through a concentric conductor transmission line formed by the combination of a metal cylinder 46 which attaches to the conductive layer 35 and by an inner conductor 47 which extends through the wall of the discharge vessel 30 to contact with the inner conductive layer 31. The conductors 46 and 47 connect at their remote extremities with a high frequency power source as indicated in Fig. 3. The point of attachment of the conductors to the members 31 and 35 is chosen in such fashion as to accomplish an efficient power transfer from the power source to the resonator formed by 31 and 35, etc.

With the arrangement as so far described, it is evident that the conductive coating 35 is not required to extend over the entire outer surface of the discharge vessel 30. However, the inner coating should be essentially coextensive with the inner surface of the vessel in order to provide shielding and to prevent charging of the vessel walls.

It is obviously possible to employ two electrode systems such as that described in Fig. 2 operated in synchronism from a common power source and having their respective gaps located at opposite ends of a diameter of the discharge vessel. Moreover, the operating frequency of the resonant system may be made any integral multiple of the frequency of rotation of the accelerated electrons, and as a further alternative a half wave transmission line may be employed in lieu of the quarter wave system just described. Otherwise expressed, the effective electrical length of the line may be either

$$\frac{2n-I}{4}\lambda \text{ or } \frac{n\lambda}{2}$$

where $n=1, 2, 3, 4. \ldots$

The correlation of the various elements of the accelerator so far considered may be better explained by reference to Fig. 3 of the drawings which shows diagrammatically the accelerating structure as a whole in combination with schematically illustrated excitation equipment. In this figure, parts which have previously been described bear numbers corresponding to those by which they have already been identified.

Referring particularly to Fig. 3, there is shown a power source 50 adapted to supply excitation voltage of the desired frequency, for example, 60 cycles, to the coils 25 and 26 by which the magnetic system of the accelerator is energized. A second power source 51, which is assumed to be appropriately connected to the cathode 40 and the accelerating electrode 41 of Fig. 2, and which may be an intermittently energized circuit of the type described in Pollock and Westendorp U. S. Patent 2,485,409, serves to inject electrons into the discharge vessel 10 at appropriate intervals correlated with the cyclical reversals of the magnetic field. Finally, a high frequency power source 52 which may consist, for example, of an electronic oscillator, supplies high frequency potential, when energized, through transmission line conductors 46 and 47 (corresponding to the similarly numbered elements of Fig. 2) to the inner and outer conductors of a resonator 35 which is assumed to be identical with the resonator shown in Fig. 2. Properly correlated energization of the magnetic field, the electron injecting means and the high frequency power supply for the resonator is accomplished by means of a timing circuit indicated schematically by the block 55, it being indicated that the timing circuit is connected with the various power supplies by conductors 56, 57 and 58, respectively. Through the action of the timing circuit, the system as a whole is controlled in such fashion that initial acceleration of the injected electrons is accomplished by variation of the magnetic field up to the point where the electrons have attained an energy level of several million electron volts. Thereafter by saturation of the core 11 the accelerating effect of the magnetic field is substantially eliminated and subsequent acceleration of the electrons to high energy levels is accomplished by bringing into operation the resonator 35.

The resonator described in Fig. 2 has been found to present certain difficulties with reference to the means provided for introducing high energy excitation through the transmission line conductors 46 and 47, these difficulties being mainly associated with the problem of conducting high frequency energy condutively through the glass wall of the discharge vessel. In Figs. 4, 5 and 6 there is illustrated a form of resonator, usable in lieu of that of Fig. 2, which obviates these difficulties and which is considered to represent the preferred embodiment of my invention. In the construction illustrated in Fig. 4, the inner conductor of the transmission line system is formed in essentially the same manner as in Fig. 2. That is to say, it comprises a conductive film 65 applied internally to the wall surface of a discharge vessel 66 and divided longitudinally by uncoated strips 67 to minimize circulating currents caused by the magnetic field. An annular gap 68 is provided between longitudinally spaced segments of the coating 65 to provide a region across which a high frequency electric field may be developed for acting on electrons projected within the vessel.

The outer conductor of the resonator comprises a coating 69 applied to the outer surface of the discharge vessel, but in this case is provided with uncoated areas 70 and 71 (Fig. 5) which join at a region 72 to provide a longitudinally extending strip 73 which is relatively separate from the remainder of the conductive structure. Although the strip 73 is shown in Figs. 4 and 5 as being joined to the remainder of the coating 69 at its left-hand extremity, this conductive connection may in some cases be omitted. This construction appears most clearly in Fig. 5, which is a view in which certain of the elements included in Figs. 4 and 6 have been removed. As is indicated in Figs. 4 and 6, energy is supplied to the resonator by the combination of a conductor 74 which connects with the conductive strip 73 and a tubular element 75 surrounding the conductor and forming with it a concentric transmission line. At the point at which the conductor 75 approaches the resonator it merges into a channel-shaped enlargement 76 which is of sufficient

longitudinal and lateral extent entirely to cover the uncoated regions 70 and 71 (see Fig. 4) and thus to afford high frequency shielding. While the conductor 75 and the enlarged member 76 are shown as being of metallic cross-section, it will ordinarily be preferable to form them of a nonconducting dielectric internally coated with a thin metal layer in order to minimize currents induced by the magnetic field.

It is found that the coupling arrangements described in the foregoing are materially superior to those represented in Fig. 2 and are also superior to a direct capacitive coupling. By choosing the correct dimensions and an appropriate point of connection for the strip 73, it is possible to accomplish an excellent match of power from the concentric line 74, 75 into the resonator. The electrical system which is formed is essentially a two-wire transmission line contained in a shield, one of the lines being the strip 73 and the other the inner conductor 65. By exciting the stripline 73 in the manner specified, corresponding excitation of the inner conductor and of the resonator as a whole is effectively accomplished with no mechanical difficulties being introduced. The length of the strip 73 may be varied as desired to produce optimum tuning and matching of the system.

Auxiliary tuning and trimming of the resonator described in Figs. 4, 5 and 6 can be accomplished by providing a second window in the outer conductor 69 in the manner indicated in Fig. 7. In this figure there is shown an area of the conductor 69 which is assumed to be remote from (for example, diametrically opposite to) the strip 73. This area includes an uncoated region 77 which is covered by a sliding metallic or metallized shutter 78 adapted to move longitudinally along the conductor 69, being guided by appropriately positioned channels 79 and 80. By varying the proportion of the window 77 which is covered by the shield 78, the tuning of the resonator may be varied over a considerable range, thus facilitating optimum adjustment of the system.

Under certain circumstances the characteristic impedance and Q of a system such as that shown in Figs. 4, 5 and 6 may be somewhat low, resulting in a relatively high requirement of input power. This is due both to the inherent characteristics of a concentric transmission line system and to the relatively high dielectric constant and dielectric loss of the glass wall of the discharge enclosure as contrasted with air. Figs. 8, 9 and 10 illustrate a construction which permits avoidance of these difficulties in cases where this is considered important. In this case, there is shown a resonant transmission line section comprising a hollow cylindrical conductor 81 which is supported coaxially within a glass enclosure 82 which may be assumed to comprise a section of an annular vessel such as the vessel 10 of Figs. 1 and 2. It will be noted that the conductor 81 (which may alternatively comprise a thin metallic coating adhering to a shell of insulating dielectric) is spaced from the inner wall of the enclosing vessel 82 by an annular gap 83. A second cylindrical conductor 84 of abbreviated length is located in spaced relation with respect to the conductor 81 so as to form a gap 85 which may serve for the production of a localized electric field acting upon electrons traversing the vessel 82. Outside the vessel and spaced from its outer wall surface there are provided a pair of diametrically displaced strip conductors 86 and 87 joined at their right-hand extremities to an annular ring 88 which merges into a disk-like member 89 extending through the wall of the discharge vessel 82 and connecting with the conductor 84. At their left-hand ends the strip members 86 and 87 extend inwardly through the wall of the vessel and connect with the conductor 81. With the arrangement thus described, there is provided by the combination of the conductor 81 and the conductors 86 and 87 a resonator construction analogous to a parallel wire transmission line as distinguished from a concentric conductor line. By appropriate choice of the length of the respective conductors, the system may be made resonant at a desired frequency so that an alternating electric field of that frequency will appear across the gap 85.

Inherently, the characteristic impedance and Q of a parallel wire transmission line system such as that of Fig. 8 are higher than that of a concentric conductor system. Moreover, the fact that the conductors 81 and 87 are spaced from the wall of the vessel 82 means that the effective dielectric constant of the composite medium interposed between the conductors is lower than that which would be afforded by the glass wall alone, this circumstance tending further to increase the impedance and the Q of the system and thus to reduce the power necessary to maintain it in excited condition. Excitation of the structure shown in Fig. 8 is obtained by means of a concentric line terminating in loop 90 which is inductively coupled to the resonator space.

Referring to Fig. 11, there is shown in that figure a certain modification of the invention which realizes some of the advantages of the construction of Fig. 8 in that the dielectric constituting the wall of the discharge vessel is removed from the resonator space, thus leading to a higher characteristic impedance of the resonator. In this construction there is provided a discharge vessel 100 which supports from its interior wall a re-entrant tube 101 of similar dielectric material which extends concentrically along a portion of the discharge tube. The opposed wall surfaces which exist between the discharge vessel and the concentric tubulation 101 are provided with a thin metallic coating as indicated at 102 and 103, these coatings being conductively connected at 104. The length of the tubulation 101 is shown to be such that the opposed coatings 102 and 103 constitute a transmission line system resonant at the desired operating frequency of the accelerating system. A gap across which the field of the resonator may be concentrated in such fashion as to act effectively upon electrons traversing the discharge envelope is provided by thickening the wall of the discharge vessel as indicated at 106 and extending the coating 102 over the surface of the enlargement as shown at 107. It should be noted, however, that the use of the embossment 106 is not entirely necessary as a mere extension of the coating 102 along the normal surface of the discharge vessel will produce at the extremity of the tubulation 101 a field having a component which is directed circumferentially of the vessel. Power may be fed into the resonator just described by means of a concentric conductor arrangement having an outer conductor 110 which terminates in an eyelet 111 extending through the wall of the discharge vessel into contact with the coating 102 and an inner conductor 112 sealed through a glass bead 113 and connecting with the conductive coating 103 as indicated at 115.

A still further resonator construction which may be usefully employed under certain conditions is that which is shown in Fig. 12. In this figure, there is illustrated a short section of a discharge vessel 120 provided externally with a resonator constituted of a pair of concentric metal cylinders 121 and 122 (these may alternatively consist of dielectric shields coated with a metallic film, longitudinally subdivided if necessary, in order to minimize the effect of the magnetic field). The cylinders 121 and 122 are connected at one end by a conductive annulus 124 and at the other end connect with conductive rings 125 and 126, respectively, which extend inwardly through the wall of the discharge vessel. The inwardly projecting edges of the rings form a gap 127 at which acceleration of particles passing through the vessel 120 may be accomplished. Power is supplied to the resonator by a concentric conductor arrangement having an inner conductor 128 which connects with the cylinder 121 and an outer conductor 129 which connects with the cylinder 122.

In the constructions so far described, it has been assumed that the resonator elements are symmetrical about an axis running along the expected path of electrons passing through the discharge vessel. However, this is not an essential feature of the invention and in certain cases better space utilization may be obtained by other configurations, one useful configuration being shown in Fig. 13.

In the figure last referred to, there are shown schematically and in section magnetic pole pieces 140 and 141 which correspond to the pole pieces 12 and 13 of Fig. 1. These pole pieces are of tapered form so as to provide a wedge-shaped space between them. A discharge vessel of dielectric material lies in this space as indicated at 143. Within the vessel there is a conductor 144 of annular cross section (e. g., a metallic film formed on the inner wall of the vessel) and outside the vessel there is a further conductive element 145 of such dimensions in a direction perpendicular to the view shown as to form with the conductor 144 a resonator of the type previously described. (It may be assumed, for example, that a section taken in a vertical plane orthogonal to the section of Fig. 13 would disclose a construction similar in sectional appearance to that of Fig. 8). It will be noted, however, that the cross sectional configuration of the conductor 145 is non-cylindrical and is such as to utilize a good portion of the space available between the pole pieces 140 and 141.

Various other changes may be made without departing from the spirit of the invention. For example, in any of the constructions so far described, the portion of the enclosing vessel which is interposed between the conductors of the transmission line system may be constituted of a material having lower dielectric constant than glass such, for instance, as titanium. Moreover, while the system has been described primarily in connection with the acceleration of electrons, it may similarly be employed in the acceleration of other types of charged particles, such as positive ions.

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

1. An envelope defining an annular path for the gyration of charged particles, means for producing within the envelope charged particles traveling at a velocity sufficiently close to the velocity of light so that their frequency of gyration remains essentially constant irrespective of subsequent increments of energy, and means for further increasing the energy of said particles, said last-named means comprising a space-resonant system having inner and outer conductors which enclose a portion of said annular path and define between themselves a space through which a high frequency field may be directed to act on said particles to produce said further energy increase.

2. An annular envelope, means for producing within said envelope charged particles traveling at a velocity sufficiently high so that their frequency of gyration remains essentially constant in spite of subsequent increments of energy, and a transmission line resonator having inner and outer conductors adjacent a portion of said envelope and being resonant at an integral multiple including unity of the frequency of gyration of said particles, said conductors forming boundaries between which a high frequency field may be directed to act on said particles to increase their energy level.

3. An annular envelope, means for producing within the envelope charged particles annularly traversing the envelope at a velocity sufficiently high so that their frequency of gyration remains essentially constant in spite of subsequent increments of energy and a parallel element resonator extending along a section of said envelope and having an inner conductor within the envelope and an outer conductor outside the envelope, said resonator being resonant at an integral multiple including unity of the frequency of gyration of said particles and being effective to produce an electric field which acts upon said particles to increase their energy level.

4. An annular envelope forming an enclosure for the acceleration of charged particles and a concentric transmission line resonator having its inner conductor within said envelope and its outer conductor outside said envelope, there being a gap in the inner conductor across which a high frequency field may be developed so as to act on said charged particles in a direction adapted to accelerate them.

5. An annular envelope of dielectric material forming an enclosure for the acceleration of charged particles along a circular orbit and a concentric transmission line resonator extending along a section of said envelope and having its inner conductor supported on the interior wall of said envelope and its outer conductor on the exterior wall of said envelope.

6. An annular envelope of dielectric material forming an enclosure for the acceleration of charged particles, a concentric transmission line resonator having its inner conductor within the envelope and its outer conductor outside the envelope, there being an annular gap in the inner conductor through which a portion of the field of the resonator may act on charged particles within the envelope and there being longitudinal gaps in the outer conductor providing between them a conductive strip relatively separate from the remainder of the conductor, and a high frequency power source coupled to the strip for producing electric and magnetic fields between the strip and the remainder of the outer conductor, thereby to excite the resonator as a whole.

7. A resonator comprising an inner conductor, an outer conductor having longitudinal gaps in its structure which provide between them a conductive strip relatively separate from the remainder of the conductor, and means for conducting energy to said resonator comprising a

concentric transmission line having one end adapted for connection to a source of high frequency oscillations and the other end connected to said resonator, the outer conductor of said transmission line at said other end being connected to said remainder of the outer conductor of said resonator and the inner conductor of said transmission line at said other end being connected to said strip.

8. An envelope forming an enclosure for the acceleration of charged particles, and a parallel element resonator extending along a portion of said envelope, said resonator comprising a generally cylindrical conductor forming one element thereof and further comprising a conductive strip parallel to said conductor and adapted to resonate therewith, and a high frequency power source coupled to said resonator to produce an electric field which acts on particles traversing said envelope.

9. In apparatus for the acceleration of charged particles along an orbital path by the production of a time-varying magnetic flux which links the path to accelerate the particles to an initial energy level during an inceptive period and which establishes a magnetic field along the locus of the path to constrain the particles to the path during the inceptive period as well as during a subsequent period, the combination which comprises an annular envelope enclosing the path, a resonator which includes an inner conductor having a gap therein and enclosing a portion of the path and an outer conductor enclosing at least a portion of said inner conductor, and a high frequency power source coupled to said resonator whereby said resonator may be excited to produce an electric field across said gap which acts upon the particles to raise their energy level above the initial level during the subsequent period.

10. In apparatus for the acceleration of charged particles in an orbital path which is linked by a time-varying magnetic flux and traversed by a time-varying magnetic field, said apparatus having a source which is adapted to introduce charged particles into the path so that they may be accelerated to an initial velocity within said path by said field and flux; the combination which includes an annular envelope enclosing said path, a resonator comprising an inner conductor which encloses a portion of said path and has a gap therein and an outer conductor which encloses at least a portion of said inner conductor, and a high frequency power source coupled to said resonator whereby said resonator may be excited to produce an electric field across said gap which alternates at a frequency corresponding to an integral multiple of the initial velocity of said particles and acts to increase the velocity of said particles.

11. An annular envelope of dielectric material forming an enclosure for the acceleration of charged particles along an orbital path; a resonator comprising an inner hollow conductor disposed within said envelope having an annular gap in the periphery thereof and an outer hollow conductor disposed outside said envelope having one of its ends connected through said envelope to said inner conductor on one side of said gap and the other of its ends connected through said envelope to said inner conductor on the opposite side of said gap, said outer conductor having portions of its periphery removed to form a longitudinal conductive strip attached to the remainder of said outer conductor at only one end; and means for conducting high frequency power to said resonator comprising an inner conductor attached to said strip and an outer conductor having a channel-shaped enlargement attached to the remainder of said outer conductor of said resonator.

12. An annular envelope of dielectric material forming an enclosure for the acceleration of charged particles along an orbital path, and a concentric transmission line resonator extending along a section of said envelope having its inner conductor supported on the interior wall of said envelope and its outer conductor on the exterior wall of said envelope, said inner conductor having a gap therein whereby an alternating high frequency electric field may be caused to act on said particles in a direction adapted to accelerate them when said resonator is excited.

13. A resonator comprising a hollow cylindrical inner conductor, a hollow cylindrical outer conductor concentric with said inner conductor but having portions of its periphery removed to provide a longitudinal conductive strip attached to the remainder of said outer conductor at only one end thereof, and means for conducting high frequency energy to said resonator comprising a concentric transmission line having its inner conductor connected to said strip and its outer conductor connected to the remainder of said outer conductor of said resonator.

14. A concentric transmission line resonator comprising a first conductive coating supported upon the inner surface of a tubular section of dielectric material, a second conductive coating supported upon the outer surface of said tubular section and having portions of its periphery removed to provide a longitudinal conductive strip extending along said tubular section, and means for conducting high frequency energy to said resonator comprising a concentric transmission line having its inner conductor connected to said strip and its outer conductor connected to the remainder of said second conductive coating.

15. A concentric transmission line resonator comprising a first conductive coating being supported upon the inner surface of a tubular section of dielectric material and having a portion of its periphery removed to form an annular gap across which a strong electric field may be developed, a second conductive coating being supported upon the outer surface of said tubular section and having portions of its periphery removed to provide a longitudinal conductive strip extending along said tubular section, and means for conducting high frequency electrical energy to said resonator comprising a concentric transmission line having its inner conductor connected to said strip and its outer conductor connected to the remainder of said second conductive coating.

16. An envelope forming an enclosure for the acceleration of charged particles; and a parallel element resonator extending along a portion of said envelope comprising a first cylindrical conductor disposed within said envelope, a pair of conductive strips diametrically disposed adjacent the outer surface of said envelope and connected at one end through said envelope to one end of said first conductor, and a second cylindrical conductor disposed within said envelope and connected through said envelope to the remaining end of said pair of strips, said second conductor being spaced from the remaining end of said first conductor to form a gap across which a high

frequency electric field may be produced to act upon particles traversing said envelope.

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