June 5, 1956 A. M. GUREWITSCH ET AL 2,749,438

RESONATOR STRUCTURE

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Fig. 1.

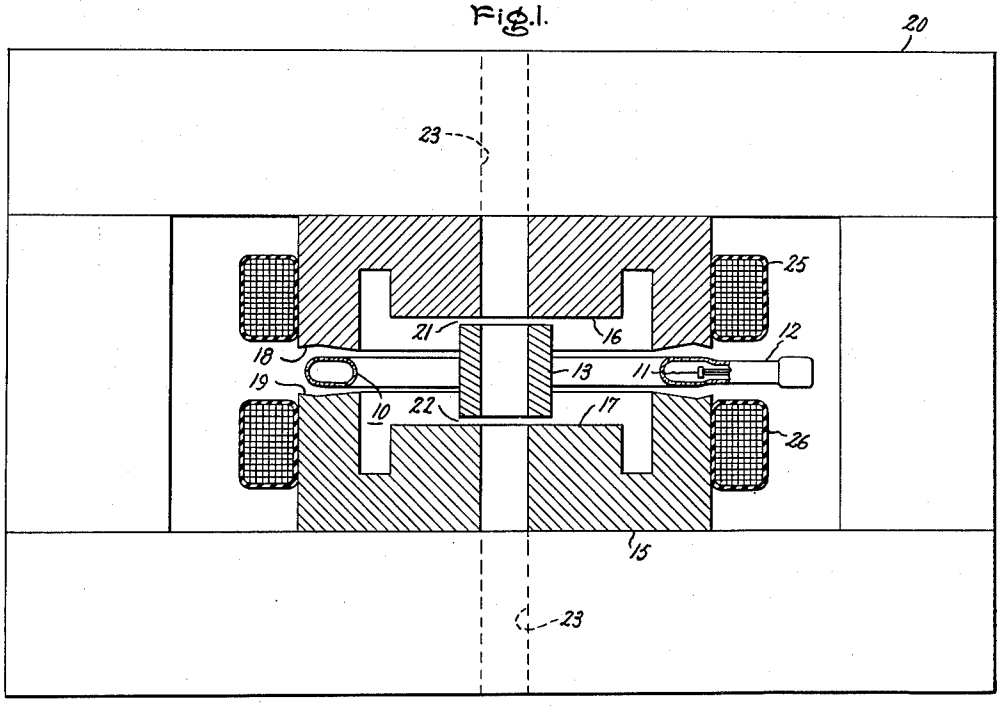
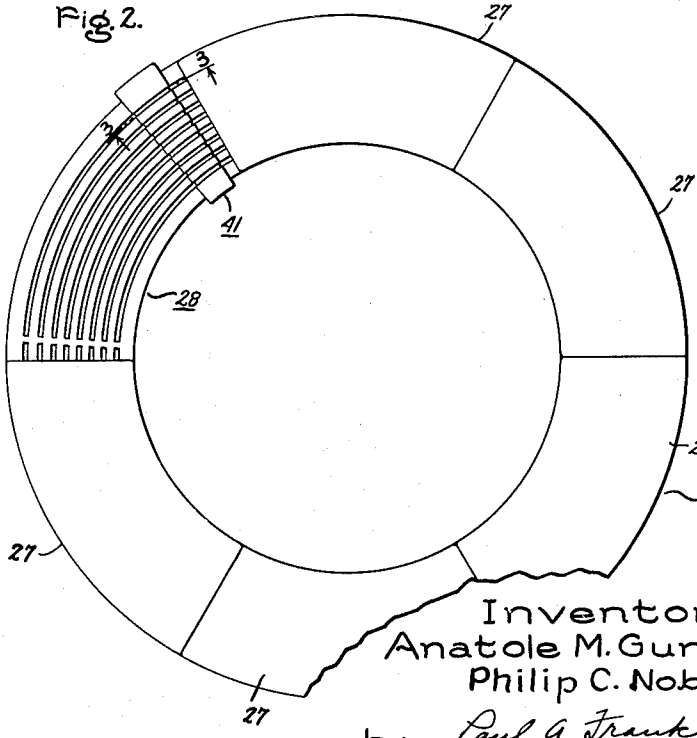


Fig. 2.



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Fig. 3.

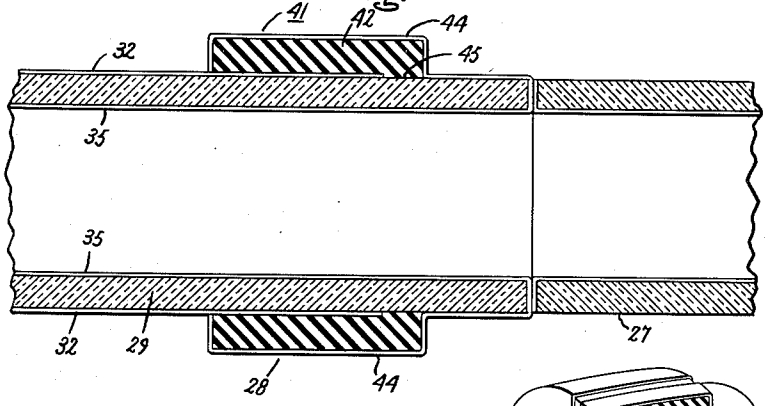


Fig. 4.

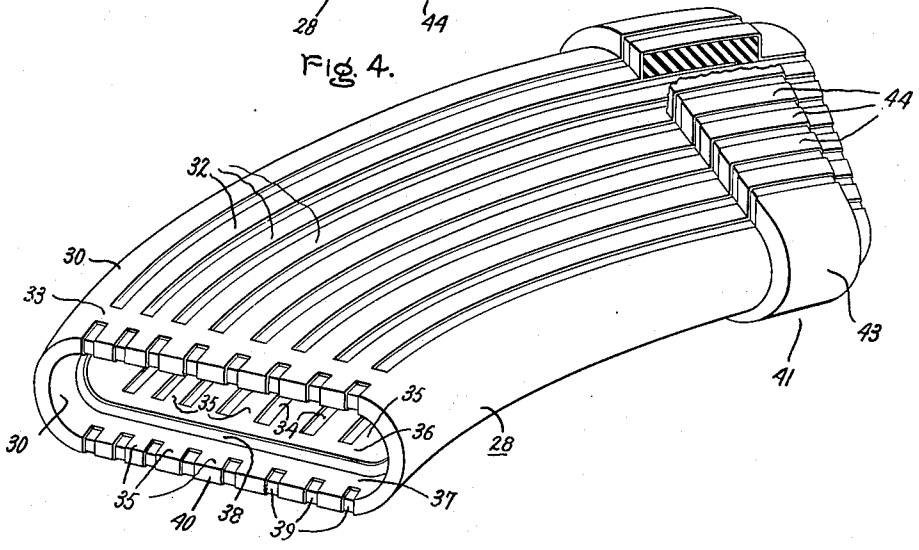
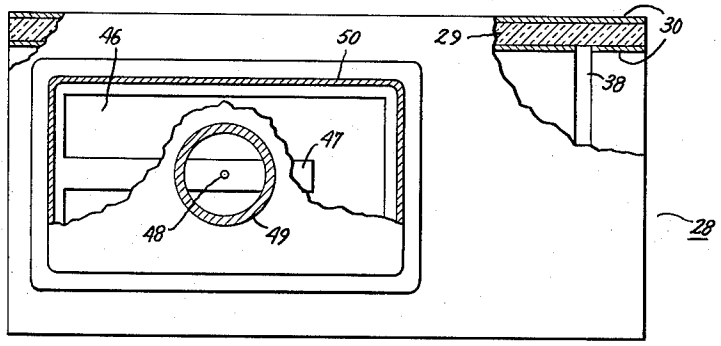


Fig. 5.



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RESONATOR STRUCTURE

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Fig.6.

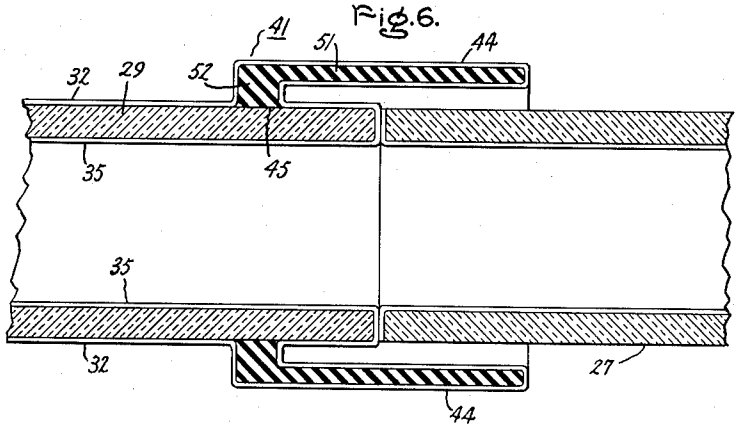


Fig.7.

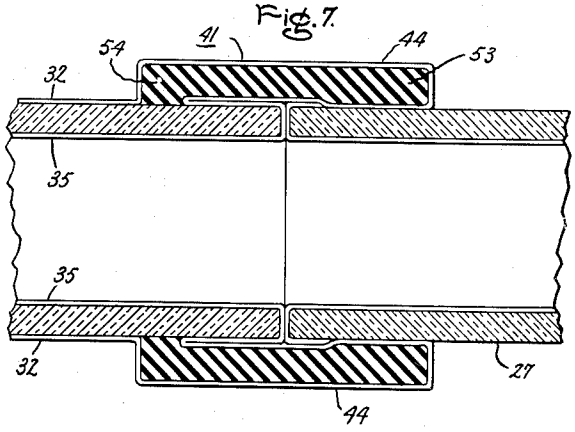
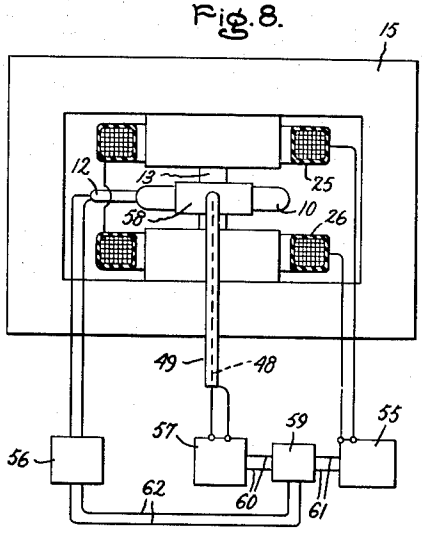


Fig.8.



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United States Patent Office

2,749,438

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2,749,438

RESONATOR STRUCTURE

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Application August 21, 1952, Serial No. 305,632

10 Claims. (Cl. 250—27)

The present invention relates to high frequency resonators and, more particularly, to resonators finding useful application in apparatus for imparting high energy to charged particles.

The invention is applicable in connection with apparatus of the type disclosed in United States Patent No. 2,485,409, patented October 18, 1949, by Herbert C. Pollock and Willem F. Westendorp, and assigned to the assignee of the present invention. Such apparatus comprises means for initially accelerating charged particles within an evacuated annular envelope by the action of a field, produced by a time-varying magnetic flux, and for thereafter imparting additional energy to the particles by a localized electric field of cyclically-varying character.

In one form of this charged particle accelerating apparatus, the means employed for producing the localized electric fields comprises a space resonant structure or resonator suitably located along the path of the charged particles within the region of the time-varying magnetic flux. To facilitate the assembly of a vacuum-tight envelope enclosing the particle path and the desired close coupling of the electric fields with the path of the charged particles, the space resonant structure or resonator is formed as a sector of the annular envelope which itself is divided into sectors of equal length. Since the physical length of the resonator is thus determined, it very often occurs that the resonant frequency of the resonator does not correspond to that required for the successful acceleration of charged particles within the apparatus.

Accordingly, it is a principal object of the present invention to provide a novel space resonant structure or resonator in which the resonant frequency may be varied without altering the physical length thereof.

It is another object of the invention to provide a novel space resonant structure or resonator which is adapted for employment with charged particle accelerator apparatus and which may be tuned without any alteration in its physical length.

It is still another object of the invention to provide novel means for tuning a resonator without altering its physical length and without disturbing the electrical symmetry of the structure.

It is yet another object of the invention to provide novel means for tuning a resonator without deleteriously affecting the shielding of the electromagnetic oscillations produced therewithin.

In accordance with one aspect of the invention more fully described hereinafter, there is provided a resonator formed of a tubular section of dielectric material upon the outer and inner surfaces of which are supported layers of conductive material. These layers respectively constitute the inner and outer conductors of the resonator. By the provision of a non-conductive gap around the inner periphery of the tubular section, high frequency electric fields are caused to appear within the inner conductor of the resonator when it is excited with high frequency energy. In order to enable tuning of the resonator, the outer conductor is made discontinuous along at least a portion of the periphery of the tubular section, and an inductive member including a layer of conductive material is connected across the discontinuous portion. The inductive member is arranged to have a desired length longer than the discontinuous portion of the outer conductor whereby the resonant frequency of the resonator may be varied without changing its physical length.

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 a plan view of the annular envelope or discharge vessel shown in Fig. 1; Fig. 3 is a section view taken along lines 3—3 of Fig. 2; Fig. 4 is an enlarged perspective view of the resonator structure of Fig. 2; Fig. 5 is a partially sectionalized view of a preferred arrangement for exciting the resonator structure of the invention; Fig. 6 is a fragmentary sectionalized view of alternative resonator structure according to the invention; Fig. 7 is a fragmentary sectionalized view of another alternative embodiment of resonator structure according to the invention; and Fig. 8 is a schematic representation of excitation apparatus employed in connection with the device of Fig. 1.

Referring particularly to Fig. 1, there is shown in section a closed rotationally symmetrical envelope **10** which defines within its interior an annular chamber. The envelope **10**, which is preferably constructed of glass or ceramic material, provides a circular orbit in which charged particles, e. g., electrons derived from a suitably energized source **11** supported from a side arm **12**, may be accelerated to a high energy level. The envelope **10** is preferably highly evacuated and is provided on its interior surface with a high resistivity, conductive coating (not shown), for example, a layer of a metallic salt, in order to reduce the effect of wall charging. Forming a sector of envelope **10** is a resonator structure which does not appear in Fig. 1, but which will be shown and described at a later point.

The envelope or vessel **10** lies symmetrically around the axis of a laminated magnetic structure having a central flux path provided by an annular iron core **13**. This core is supported at its extremities by attachment to the central portions of opposed pole pieces **14** and **15** which have planar circular areas **16** and **17** and tapered annular areas **18** and **19**. The pole pieces **14** and **15** are, in turn, supported by a rectangular frame **20** of laminated iron which surrounds and extends transversely to the envelope **10**.

The ends of the core **13** are separated from the pole pieces **14** and **15** by narrow gaps **21** and **22** which are so proportioned as to cause the core to saturate at a predetermined level of the magnetic flux passing through it. Preferably gaps **21** and **22** are filled by washers of nonmagnetic material (not shown) for the purpose of assisting in the proper support of core **11**. The annular faces **18** and **19** 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 **23**, which extends continuously through the frame **20**, pole pieces **14** and **15**, and core **13**, 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 time or cyclically-varying flux in the magnetic circuit. Electrons produced within the envelope **10** are affected in two ways by the variations in magnetic

flux thus obtained. In the first place, since the magnetic flux traversing core **13** links the circular path provided by envelope **10**, any variation of such flux necessarily produces an electric field tending to accelerate electrons projected along such paths. 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, although 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 the magnetic flux variation. In addition to the acceleration produced by the time-varying magnetic flux linking the electron path, the flux produced by the annular pole pieces **18** and **19** in the region of the electron orbit tends to cause the electrons to follow an inwardly spiraling path. It has been shown that with 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:

$$\phi=2\pi r^2 B_r \tag{1}$$

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 indicates that the flux incuded in or linking the orbit 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 conditon 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 pole pieces **18** and **19** 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 field are more fully set forth in United States Patent 2,394,070, granted February 5, 1946, to D. W. Kerst.

When all the conditions specified in the foregoing are fulfilled, electrons introduced into envelope **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 exists 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 three million electron volts, it is already within about 1 percent 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 further gain in electron velocity, this result being consistent with the Einstein mass-energy equivalence formula. Therefore, electrons which have attained a velocity within a few percent of the velocity of light will gyrate with a relatively constant periodicity, or at a relatively fixed

frequency, provided they can be confined to an orbit of relatively fixed radius. As is pointed out in the aforementioned United States Patent No. 2,485,409 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 envelope **10**. By this means, extremely high energy levels can be reached through a mechanism which avoids 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 constructed that saturation of core **13** occurs after a sufficient acceleration of the electrons has been obtained by magnetic means, and an electric field accelerating device to be hereinafter described is brought into play. In order that the accelerated electrons may still be confined to the desired orbit, however, the guide field produced between pole pieces **18** and **19** continues to increase as a result of continued energization of coils **25** and **26**.

As is illustrated in Fig. 2, envelope **10** is formed of a plurality of sectors **27** of dielectric material which may be joined together in vacuum-tight relation by means of suitable rubber gaskets (not shown) in a manner well known to those skilled in the art. To assure the maintenance of an evacuable space within envelope **10**, the surfaces of juncture of the rubber gasket and the envelope may be coated with a desired adhesive material, for example, an alkyd resin prepared by reacting a polybasic acid and a polyhydric alcohol, such as a resin being prepared from glycerol and phthalic anhydride. Alternatively, the rubber gaskets may be omitted and the abutting surfaces of sectors **27** coated with the adhesive material. The ease with which envelope **10** may be constructed is assisted by making each of the glass or ceramic sectors **27** of equal lengths, inasmuch as this permits the manufacture of the sectors such that closely matched end surfaces are obtained without an excessive expenditure of effort. Formed as a sector of envelope **10** is a space resonant structure or resonator **28** which will be more fully described later.

In connection with the description of the apparatus of Fig. 1, it has been stated that the electrons introduced into envelope **10** are first accelerated to within about 1 percent of the velocity of light by a time-varying magnetic flux, and then are further raised in energy level by means of a localized electric field of fixed frequency acting repetitively on the electrons as they continue their gyration within the envelope **10**. In order to obtain repetitive acceleration of the electrons, the frequency of the localized electric field must satisfy the following relation:

$$f=\frac{c}{2\pi r} \tag{2}$$

where c is the velocity of light, r is the radius of the orbit, and f is the frequency. It is apparent from Equation 2 that, once a desired orbital radius is selected, the frequency of the localized electric field is immediately determined. It will be observed, however, that resonator **28**, which supplies the localized electric field according to the invention and which comprises inner and outer conductors supported upon a tubular section of dielectric material, has a resonant frequency which is a function of the length of the resonator and the dielectric constant ϵ of the material employed. Its resonant frequency is given by

$$f_1=\frac{c}{4L\sqrt{\epsilon}} \tag{3}$$

where f_1 is the resonant frequency and L is the central arcuate length of the structure. Therefore, as may be seen from Equation 3, for a given dielectric material, the resonant frequency f_1 of resonator **28** is determined by its length L which, in turn, is fixed by the above-

mentioned construction of envelope 10 from sectors of equal length. Accordingly, if the resonant frequency f_1 of resonator 28 does not correspond to the frequency f required by Equation 2, further energy cannot be successfully imparted to the electrons by the localized electric field within resonator 28.

The present invention supplies an advantageous and efficient solution to this problem by the provision of the novel resonator 28, the frequency of which may be varied without altering its physical length. As is more clearly shown in Figs. 3 and 4, space resonant structure or resonator 28 forms a sector of envelope 10 and comprises a tubular section 29 of dielectric material having an approximately elliptical cross section which conforms to the cross section of envelope 10. Since it is preferable to utilize a dielectric material having a small high-frequency loss coefficient, tubular section 29 may be formed of a material such as fused quartz or ceramic and shaped similarly to the sectors 27 of envelope 10. In order to provide means for conducting high frequency currents, tubular section 29 is coated upon all its exposed surfaces with a layer 30 of conductive material, such as silver. Portions 31 of coating 30 are removed from the exterior surface of section 29 to form a plurality of approximately evenly spaced conductive strips 32 extending longitudinally along both sides thereof. Portions 31 are discontinuous adjacent one end of section 29 in order to provide a peripheral conductive strip 33. In a like manner, portions 34 are removed from coating 30 on the inner surface of section 29 to form a plurality of conductive strips 35 extending longitudinally therealong. Portions 34 are discontinuous to provide peripheral conductive strips 36 and 37. A peripheral gap 38 is provided by removing a portion between strips 36 and 37. Portions 39 are removed from the end surfaces (one of which is not shown) of section 29 to produce a plurality of conductive strips 40. Portions 31, 39 and 34, removed respectively from the coating upon the exterior surface, end faces, and inner surface of section 29, are spatially interrelated so that each strip 32 is conductively connected to the oppositely disposed strip 35 upon the adjacent inner surface of section 29.

One convenient way of forming conductive layer 30 is as follows. A layer of silver paint is placed upon the inner surface, outer surface and end faces of section 29 and subsequently baked to secure adherence thereto. The thickness of this layer may be increased by means of electroplating, or by repeated painting and baking, for the purpose of obtaining a layer having a thickness greater than the depth of penetration of the high frequency current which flows therein when resonator 28 is excited. As an order of magnitude, the layer may have a final thickness of about 1 to 1½ mils when the resonator is to be excited at 160 mc. The various portions removed from the conductive layer as above described may be made by masking during the painting operation, or by burning in grooves, after the painting and electroplating, with a tungsten disc which is rolled along the conductive surface carrying a heavy current through the contact area.

As is disclosed in United States Patent No. 2,579,315, patented December 18, 1951, and assigned to the assignee of the present invention, the subdividing of coating 30 into longitudinal strips provides a convenient and direct means of reducing eddy currents induced in resonator 28 by the time-varying magnetic flux which traverses the structure when the accelerator apparatus of the invention is in operation. With the particular interconnection of the longitudinal strips by peripheral conductive strips 33, 36 and 37 in the manner illustrated, nearly complete compensation of induced eddy currents may be obtained whereby undesirable heating of the strips is avoided. Moreover, this interconnection of the strips increases the coupling therebetween and prevents the oscillation of resonator 28 in undesirable modes. It will be observed that the longitudinal subdivision of coating 30 need not be continued adjacent the inner and outer circumference of resonator 28 inasmuch as such portions are nearly parallel to the direction of the time-varying flux and therefore will not have appreciable eddy currents induced therein.

With the longitudinal dimensions determined in the above-described manner by the construction of the envelope 10 from sectors of equal length, resonator 28 operates as a quarter-wave, closed concentric line resonator at a particular excitation frequency. The space between the conductive coating on the exterior surface of section 29 and the coating on the interior surface constitutes in effect a space resonant system comprising a quarter-wave transmission line section. Accordingly, if resonator 28 is excited at its resonant frequency, a cyclically reversible electric field of high intensity appears across gap 38. If the resonant frequency of resonator 28 as expressed by Equation 3 corresponds to the frequency of rotation of electrons moving within envelope 10 and section 29 as expressed by Equation 2, an increase in the energy level of such electrons may be effected in accordance with the principles previously outlined.

Since the physical length of resonator 28 as determined by the constructional requirements of envelope 10 very seldom provides a resonant frequency which corresponds to the frequency of rotation of electrons within envelope 10, the present invention contemplates means for tuning or varying the resonant frequency of resonator 28 without altering its physical length. In general, it is feasible to increase the resonant frequency of resonator 28 by moving gap 38 along section 29 away from the end which it is adjacent. However, when it is necessary to lower the resonant frequency of resonator 28, severe difficulties arise because gap 38 obviously cannot be moved beyond the end of section 29 which it is adjacent. According to the present invention, therefore, there is provided an inductive member 41 which is positioned adjacent the end of section 29 remote from gap 38. Inductive member 41 comprises an annular band 42 of dielectric material supported upon section 29 about the exterior surfaces of strips 32. Extending along the exposed sufaces of band 42 is a layer of conductive material 43 which is subdivided into strips 44 corresponding in peripheral position to conductive strips 32. If conductive coating 43 and strips 44 are formed upon band 42 separate from the formation of conductive coating 30 and strips 32 upon section 29, conductive connection therebetween may be assured by soldering the adjoining surfaces. Conductive coating 30 and strips 32 are made discontinuous to form a peripheral gap 45 whereby conductive coating 43 and strips 44 constitute in effect a longitudinal extension of conductive coating 30 and strips 32. Thus, conductive layer 43 and strips 44, which are connected across gap 45, add inductance to resonator 28 and lower its resonant frequency without requiring any alteration in the physical length of resonator 28.

It will be observed that inductive member 41 is positioned adjacent the end of resonator 28 where the high frequency currents are large and the electric fields within the dielectric are small. Therefore, the choice of dielectric material required for band 42 is not critical. Conveniently, it may consist of an organic material such as polystyrene. Alternatively, band 42 may be constructed by impregnating strips of glass cloth with a solventless varnish such as a resin synthesized from diethylene glycol maleate and diallyl phthalate, distributing the impregnated glass cloth within a suitable mold, and curing in accordance with principles well known to those skilled in the art. If the dielectric material selected for band 42 is not capable of withstanding the heat necessary for the application of a conductive coating of silver in the manner heretofore described, conductive coating 43 and strips 44 may be formed of thin, conductive material such as copper secured to the surface of band 42 by means of a suitable adhesive, e. g., the above-men-

tioned alkyd resin. If desired, conductive layer **30** and strips **32** may likewise be formed of thin conductive material secured to the surfaces of section **29**.

In Fig. 5, wherein like reference characters are employed to designate elements hereinbefore presented, there is illustrated a suitable means for exciting resonator **28** with high frequency energy. A portion **46** is removed adjacent the outer circumference of section **29** to provide a longitudinally extending conductive strip **47**. Although strip **47** is shown as being joined at its lefthand extremity to the remainder of layer **30**, it may in some cases be made entirely separate therefrom by extending portion **46**. Energy may be supplied to resonator **28** by the combination of a conductor **48** which connects with the conductive strip **46** and a tubular element **49** surrounding the conductor to form with it a concentric transmission line. At the point where conductor **49** approaches resonator **28**, it merges into a channel-shaped enlargement **50** which is of sufficient longitudinal and lateral extent entirely to cover removed portion **41** and thus to afford high frequency shielding. While conductor **48** and the enlarged member **49** are shown as being of metallic cross section, it will ordinarily be preferable to form them of a non-conducting dielectric internally coated with a thin metal layer in order to minimize currents induced by the time-varying magnetic field. By choosing the correct dimensions and an appropriate point of connection to strip **47**, it is possible to accomplish an excellent match of power from concentric line **48**, **49** into the resonator. The length of strip **47** may be varied as desired to produce optimum tuning and matching of the system.

In some installations of the apparatus of Fig. 1, it may be inconvenient because of spatial requirements to extend inductive member **41** along the exterior surface of resonator **28** toward the gap **38**. In the embodiment of Fig. 6, wherein like numerals are employed to designate similar elements described hereinbefore, inductive member **41** is shown as extending away from gap **38** over the juncture of the end of resonator **28** and the adjoining sector **27**. Layer **43** and strips **44** extend along a substantial portion of the inner and outer surfaces of a flanged annular band **51** of dielectric material. The flange **52** of annular band **51** may be attached to section **29** by means of a suitable adhesive, thereby assuring adequate support of the inductive member. As will be seen, the construction of the inductive member illustrated in Fig. 6 provides a larger added inductance to resonator **28** for a given circumferential or longitudinal extension of band **51**.

In Fig. 7, where like numerals are also utilized to designate similar elements, inductive member **41** comprises an annular band **53** of dielectric material having a flange **54** of smaller radial extent than the flange **52** of Fig. 6. This construction possesses the advantage of obtaining relatively large added inductance to resonator **28** without the requirement of a large air gap volume in the apparatus of Fig. 1. Furthermore, band **53** is given additional support by the adjacent sector **27**.

The operational correlation of the resonator structure and the other various elements of the accelerator heretofore considered may best be understood by reference to Fig. 8 which shows diagrammatically the accelerating structure as a whole in combination with schematically illustrated excitation equipment. In this figure, parts which have been described bear numbers corresponding to those by which they have already been identified.

Referring particularly now to Fig. 8, there is shown a power source **55** adapted to supply excitation voltage of the desired frequency, for example, 60 cycles, to windings **25** and **26** by which the magnetic system of the accelerator is energized. A second power source **56** which is assumed to be appropriately connected to source **11** of Fig. 1, and which may be an intermittently energized circuit of the type described in the aforementioned Pollock and Westendorp patent serves to inject electrons into the envelope **10** at appropriate intervals correlated with the cyclical reversals of the magnetic field. Finally, a high frequency power source **57** which may consist, for example, of an electronic oscillator, supplies when energized, high frequency potential through transmission line conductors **48** and **49**, to the inner and outer conductors of a resonator **58** which is identical with one of the resonator structures shown in the preceding figures. 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 illustrated schematically by the block **59**, it being indicated that the timing circuit is connected with the various power supplies by conductors **60**, **61** and **62** 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 a 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 core **13**, 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 **58**.

In each of the embodiments, inductive element **41** has been illustrated as extending completely around the periphery of section **29**. This construction is preferred because the electrical symmetry of resonator **28** is thereby essentially unaffected. However, in some instances it may be desirable to extend inductive element **41** around only a portion or portions of section **29** and such is within contemplation of the present invention.

While the invention has been described by reference to particular embodiments thereof, it will be understood that numerous changes may be made by those skilled in the art without actually departing from the invention. We 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 we claim as new and desire to secure by Letters Patent of the United States is:

1. In apparatus for the acceleration of charged particles along a path which is enclosed by an envelope of dielectric material; a resonator forming a section of the envelope comprising an inner conductor which includes a conductive layer supported upon the inner surface of said section, and an outer conductor which includes a conductive layer supported upon the outer surface of said section and being discontinuous around at least a portion of the periphery of said section which discontinuous portion extends in spaced relation around a portion of the inner conductor; and an inductive member for tuning said resonator including a conductive layer connected across the discontinuous portion of said outer conductor, said last-mentioned conductive layer having a length greater than the length of the discontinuous portion of said outer conductor.

2. In apparatus for the acceleration of charged particles along a path which is enclosed by an envelope of dielectric material; a resonator forming a section of the envelope comprising an inner conductor which includes a conductive layer supported upon the inner surface of said section and being discontinuous to provide a non-conductive gap extending around the periphery of said section adjacent one end thereof, and an outer conductor which includes a conductive layer supported upon the outer surface of said section and being discontinuous around at least a portion of the periphery of said section which discontinuous portion extends in spaced relation around a portion of the inner conductor adjacent the end remote from said gap; and an inductive member for tuning said resonator including a conductive layer connected across the discontinuous portion of said outer conductor, said last-mentioned conductive layer having a length greater

than the length of the discontinuous portion of said outer conductor.

3. In apparatus for the acceleration of charged particles along an orbital path which is enclosed by an annular envelope of dielectric material and traversed by a time-varying magnetic field; a resonator forming a sector of said annular envelope and comprising an inner conductor including a conductive layer supported upon the inner surface of said sector of said envelope and having portions thereof removed to form a plurality of spaced apart conductive strips extending longitudinally along said sector, and an outer conductor including a conductive layer supported upon the outer surface of said sector of said envelope and having portions thereof removed to form a plurality of spaced apart conductive strips extending longitudinally along said sector, said outer conductor being discontinuous around at least a portion of its periphery which discontinuous portion extends in closely spaced relation around a portion of said inner conductor; and an inductive member for tuning said resonator comprising a conductive layer connected across the discontinuous portion of said outer conductor, said last-mentioned conductive layer having a length greater than the length of the discontinuous portion of said outer conductor.

4. In apparatus as in claim 3 in which said last-mentioned conductive layer is supported upon a band of dielectric material extending around at least part of the periphery of said sector, said last-mentioned layer having portions thereof removed to form a plurality of conductive strips extending along said band.

5. In apparatus for the acceleration of charged particles along an orbital path which is enclosed by an annular envelope of dielectric material and traversed by a time-varying magnetic field; a resonator forming a sector of said annular envelope and comprising an inner conductor including a conductive layer supported upon the inner surface of said sector of said envelope and having portions thereof removed to form a plurality of spaced apart conductive strips extending longitudinally along said sector, said conductive layer having adjacent one end a gap extending around the periphery theerof, and an outer conductor including a conductive layer supported upon the outer surface of said sector of said envelope and having portions thereof removed to form a plurality of spaced apart conductive strips extending longitudinally along said sector, said outer conductor being discontinuous adjacent the end of said sector remote from said gap in said inner conductive layer to form a gap extending around at least a portion of the periphery of said outer conductor which gap is spaced by said envelope from a portion of said inner conductive layer; and an inductive member for tuning said resonator comprising a conductive layer connected across the gap in said outer conductor, said last-mentioned conductive layer having a length greater than the length of the discontinuous portion.

6. In apparatus as in claim 5 in which said last-mentioned conductive layer is supported upon a band of dielectric material extending around at least part of the periphery of said sector, said last-mentioned layer having portions thereof removed to form a plurality of conductive strips extending along said band.

7. A resonator comprising an inner conductor which includes a conductive layer supported upon the inner surface of a tubular section of dielectric material, an outer conductor which includes a conductive layer supported upon the outer surface of said section and being discontinuous around at least a portion of the periphery of said section which discontinuous portion is spaced by said envelope from said inner conductive layer and an inductive member for tuning said resonator including a conductive layer connected across the discontinuous portion of said outer conductor, said last-mentioned conductive layer having a length greater than the length of the discontinuous portion of said outer conductor.

8. A resonator as in claim 7 in which said last-mentioned conductive layer is supported upon a band of dielectric material extending around at least part of the periphery of said section, and all of said conductive layers are longitudinally subdivided to form a plurality of conductive strips extending along said section.

9. A resonator as in claim 8 in which the discontinuous portion of said outer conductor is adjacent one end of said section and said inner conductor has a peripheral gap adjacent the end of said section remote from the discontinuous portion.

10. A resonator as in claim 9 in which said band of dielectric material and said last-mentioned conductive layer extend beyond said one end of said section.

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