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W. F. WESTENDORP
ACCELERATOR MAGNET STRUCTURE

2,491,345

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Fig. 1

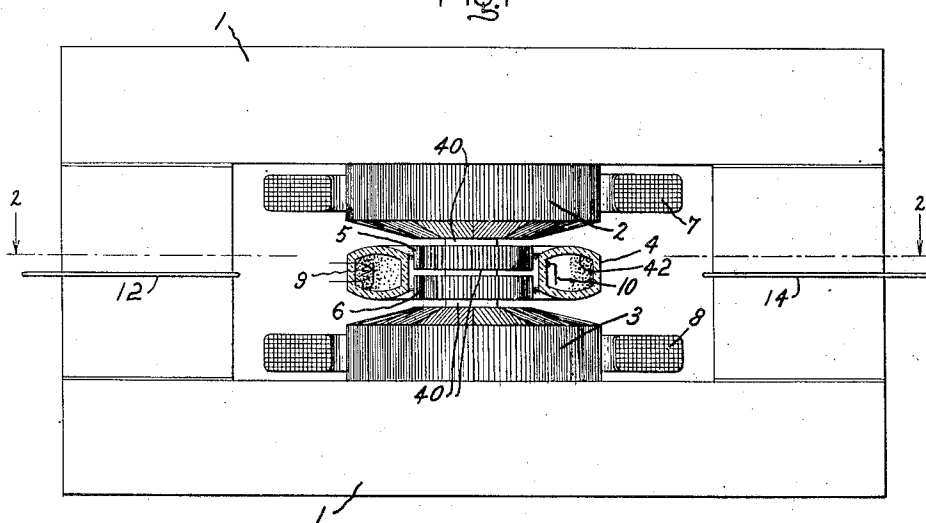


Fig. 2

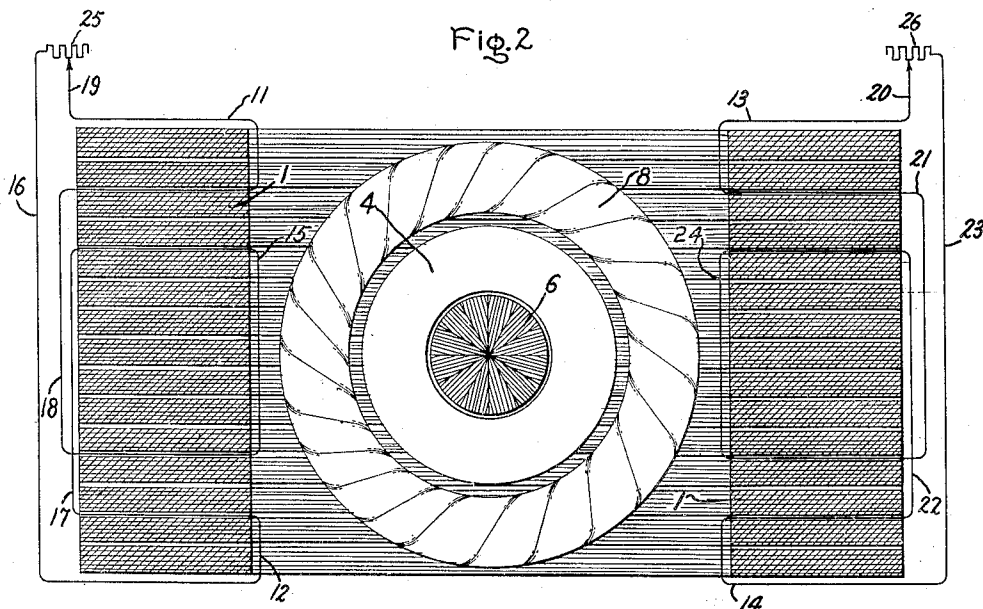


Fig. 4.

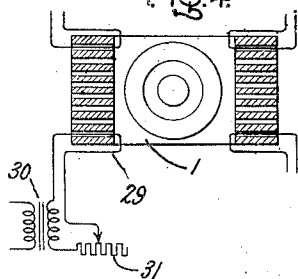
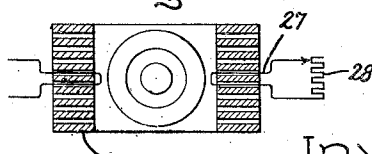


Fig. 3.



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ACCELERATOR MAGNET STRUCTURE

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7 Claims. (Cl. 250—27)

1

The present invention relates to devices in which a stream of charged particles is caused by a time-varying magnetic field to be accelerated in a circular path until they have attained a desired speed. They may be discharged finally upon a metal target resulting in the production of X-rays. Devices of this kind are described and shown in my prior Patents 2,394,071, 2,394,072 and 2,394,073 all of February 5, 1946.

The magnetic field in such devices as heretofore constructed has been undesirably non-uniform in phase, with the result that part of the injected electrons were deflected out of their course and caused to be prematurely discharged.

In a magnetic accelerator of former construction the paths of the magnetic lines of flux were of unequal length through the various parts of the magnetic structure. The magnetic flux which travelled a short path in the magnetic core of such accelerator resulted in less hysteresis and eddy current loss than the magnetic flux which traveled a longer path. The higher energy loss in the parts of the core remote from the center may be regarded as caused by electric currents which are in phase with the voltage and lag 90 degrees with respect to the main magnetizing current. Such currents would produce a non-uniform magnetic field at the electron orbit. This disturbing magnetic field is strongest at the critical part of the cycle of operation of the accelerator namely at the moment of injection of the electrons when the guiding magnetic field should be weak. It is the object of my invention to produce uniformity of the magnetic guiding field at the electron path, particularly at the instant of electron injection, which results in high efficiency of operation.

In accordance with my invention, compensating windings are provided for one or more sections of the core and these windings are either resistance loaded or are separately excited or are so inter-connected as to compensate for the inequality of magnetic flux in different parts of the core no matter what the cause may be.

The accompanying drawing shows in Fig. 1 a front elevation of an electron accelerator which is shown in simplified form; Fig. 2 is a partly sectional plan view of the lower half of an accelerator, shown as provided with interconnected compensating windings, the section being taken at the region indicated by dotted lines in Fig. 1, and Figs. 3 and 4 illustrate somewhat diagrammatically other embodiments of my invention.

An accelerator, as shown in Fig. 1 commonly comprises a magnetic core 1 having generally cir-

2

cular pole pieces 2, 3 which are coaxial with an annular evacuated accelerating chamber 4. The core 1 ordinarily consists of laminations as indicated in Fig. 2. The pole pieces 2, 3 of the core are tapered near their extremities which may be terminated by flat surfaces. Two laminated iron discs 5, 6 are supported by insulating disks 40 between the pole faces for the purpose of decreasing the reluctance of the magnetic path at this region.

The magnetic core is excited by a pair of series-connected windings 7, 8 which surround the pole pieces 2, 3 and which are energized by an alternating current source, (not shown) to provide a time varying cyclic flux in the magnetic circuit traversing the chamber 4.

Within the chamber 4 is provided a thermionic cathode 9 as a source of electrons, such cathode is only diagrammatically indicated as the above noted prior patents describe its construction. A cooperating anode 10 also is schematically indicated, the anode being connected to a conductive film 42 which lines the chamber 4. As the general construction of the magnetic core is described in my prior patents reference may be had to such patents for more detailed understanding.

As well understood, the time-varying magnetic flux enclosed by the annular chamber 4 causes the electrons emitted by the cathode 9 to be continuously accelerated as they execute repeated revolutions during a quarter of a cycle of magnetic flux variation. As a result the electrons may be caused to assume energies of many millions of electron volts as a consequence of the continuous acceleration. As described in prior patents the annular stream of electrons is contracted in diameter automatically when discharge of the electrons upon the target 10 is desired.

Distributional variations in field strength occurring for any reason, for example, as a result of the transverse difference of flux lengths of the elements of a rectangular core arranged about an annular accelerating chamber, as heretofore indicated, results in the magnetic flux at the transverse extremities of the core being out of phase with the flux near the center of the core where the core is more closely adjacent to the annular chamber.

As indicated in Fig. 2, I have provided in accordance with one embodiment of my present invention electric windings 11, 12 and 13, 14 which are magnetically interlinked respectively with the extremities of the core 1 as indicated. The windings 11, 12 are connected in series with a winding 15 interlinked with a center portion of the core 1

by the conductors 16, 17, 18 and 19. As will be evident from the drawing the windings 11, 12 are connected in opposition to the winding 15. The windings 13, 14 are connected by the conductors 20, 21, 22 and 23 to a center coil 24 also in opposition. The windings 11, 12 and 15 are connected by the conductors 16, 19 to an adjustable resistor 26. These resistors 25 and 26 are adjusted to load the windings the amount required to cause the necessary lag of the flux at the center of the core.

The loading required to produce the desired lag of the time-varying flux at the center of the core may be produced by one or more windings linked with the central part of the core as indicated in Fig. 3. Here the winding 27 is connected to an adjustable resistor 28 which loads the coil 27 in order to produce the desired lag. A similar loaded winding may be provided on the opposite leg of the core as indicated.

As shown in Fig. 4 a coil 29 at one of the extremities of the core 1 may be connected to an external source of energy. Here such a source is represented by the secondary of a transformer 30 the voltage of which is higher than the loop voltage and which is synchronized to be in phase with the main source of alternating current. The transformer 30, the secondary winding of which is connected in series with a variable resistor 31 to the winding 29, compensates for phase lag of a portion of the flux by introducing an auxiliary flux. Other coils may be provided as indicated.

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

1. Apparatus for the acceleration of charged particles along an orbital path comprising a source of alternating voltage; a source of charged particles adjacent the locus of said path and energized by said voltage source to inject said particles into said path; a laminated magnetically conductive structure including rotationally symmetrical pole piece means disposed on either side of said path to provide between them an annular gap containing said path, and core means magnetically coupled to said pole piece means; annular coil means embracing said pole piece means and energized by said voltage source to provide a time-varying magnetic flux, said flux being directed by said pole piece means and said core means to act upon said particles whereby they are inductively accelerated along said path; and winding means interlinking the laminations of said core means and arranged to compensate for eddy-current loss effects produced by said time-varying flux in said core means.

2. Apparatus for acceleration of charged particles along an orbital path comprising a source of alternating voltage; a source of charged particles adjacent the locus of said path and energized by said voltage source to inject said particles into said path; a laminated magnetically conductive structure including rotationally symmetrical pole piece means disposed on either side of said path to provide between opposing pole faces an annular gap containing said path, and a substantially rectangular core means partially enclosing and in magnetically conductive relation with said pole piece means; annular coil means embracing said pole piece means and energized by said voltage source to provide a time-varying magnetic flux, said flux being directed by said pole piece means and said core means to act upon said particles whereby they may be inductively accelerated along said path; and winding means

interlinking the laminations of said core means and arranged to reduce phase inequalities existing among portions of said time-varying magnetic flux directed by said structure.

3. Apparatus for the acceleration of charged particles along an orbital path comprising a source of alternating voltage; a source of charged particles adjacent the locus of said orbital path and energized by said voltage source to inject the particles into said orbital path; a laminated magnetically conductive structure including rotationally symmetrical pole piece means disposed on either side of said orbital path to provide between them an annular gap containing said orbital path, and a substantially rectangular core means partially enclosing and in magnetically conductive relation with said pole piece means; annular coil means embracing said pole piece means and energized by said voltage source to produce a time-varying flux within said structure whereby said particles may be inductively accelerated along said orbital path, portions of said flux following paths of different length in said structure; and winding means connected in electrical circuit with resistor means and interlinked with the laminations of said core means whereby said time-varying flux may induce currents in said winding means to reduce phase inequalities existing among the portions of said time-varying flux which follow paths of different lengths in said structure.

4. Apparatus for the acceleration of charged particles along an orbital path comprising a source of alternating voltage; a source of charged particles adjacent the locus of said orbital path and energized by said voltage source to inject the particles into said orbital path; a laminated magnetically conductive structure including rotationally symmetrical pole piece means disposed on either side of said orbital path to provide between them an annular gap containing said orbital path, and a substantially rectangular core means partially enclosing and in magnetically conductive relation with said pole piece means; annular coil means embracing said pole piece means and energized by said voltage source to produce a time-varying flux within said structure whereby said particles may be inductively accelerated along said orbital path, portions of said flux following paths of different lengths in said structure; and winding means interlinking the laminations of said core means and energized by said voltage source to provide an auxiliary flux within said laminations whereby phase inequalities existing among the portions of said time-varying flux which follow paths of different lengths in said structure may be reduced.

5. In apparatus for the acceleration of charged particles in an orbital path by the production of a time-varying flux which links the path to accelerate the particles and simultaneously establishes a magnetic field at the locus of the path to constrain the particles to the path, the combination which comprises a laminated magnetically conductive core means partially surrounding the path to provide a magnetic circuit for the time-varying flux and a winding interlinking the laminations of said core means to produce within said laminations an auxiliary flux which counteracts eddy-current fluxes generated in said laminations by the time-varying flux.

6. In apparatus for the acceleration of charged particles in an orbital path by the production of a time-varying flux which links the path to accelerate the particles and simultaneously estab-

5

lishes a magnetic field at the locus of the path to constrain the particles to the path, the combination which comprises a laminated magnetically conductive core means partially surrounding the path to provide a circuit for the time-varying flux, and winding means connected in electrical circuit with resistor means and interlinked with the laminations of said core means whereby the time-varying flux may induce currents in said winding means to compensate for phase inequalities existing among portions of the time-varying flux.

7. In apparatus for the acceleration of charged particles in an orbital path by the production of a time-varying flux which links the path to accelerate the particles and simultaneously establishes a magnetic field at the locus of the path to constrain the particles to the path, the combina-

6

tion which comprises a laminated magnetically conductive core means partially surrounding the path to provide a circuit for the time-varying flux, and winding means interlinking the laminations of said core means and energized by an alternating voltage source to provide an auxiliary flux which counteracts eddy-current fluxes generated in said laminations by the time-varying flux.

WILLEM F. WESTENDORP.

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The following references are of record in the file of this patent:

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