

Aug. 17, 1948.

D. W. KERST ET AL  
MAGNETIC INDUCTION ACCELERATOR  
WITH SMALL X-RAY SOURCE

2,447,255

Filed May 4, 1944

3 Sheets-Sheet 1

Fig. 1.

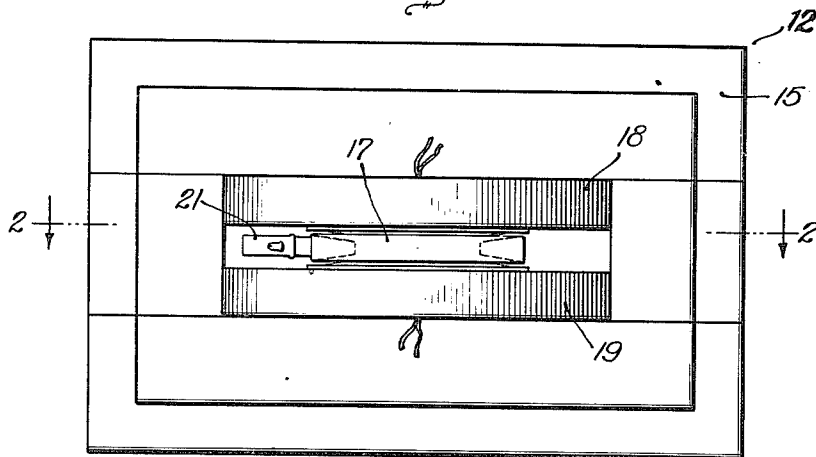


Fig. 2.

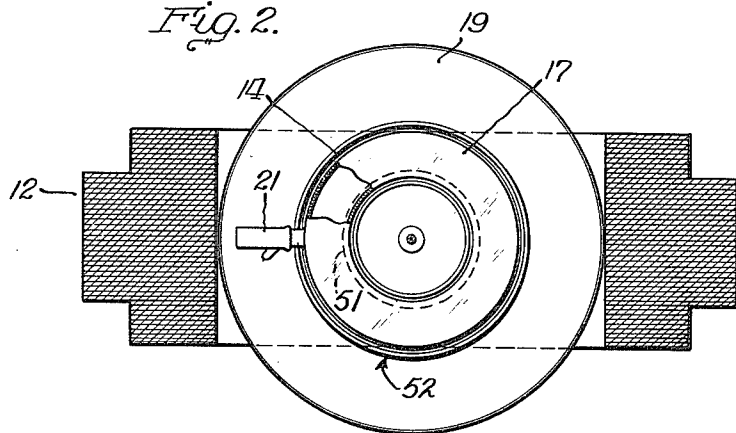


Fig. 3.

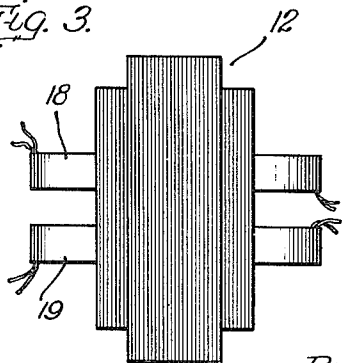
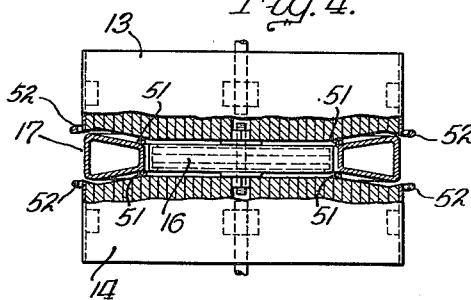


Fig. 4.



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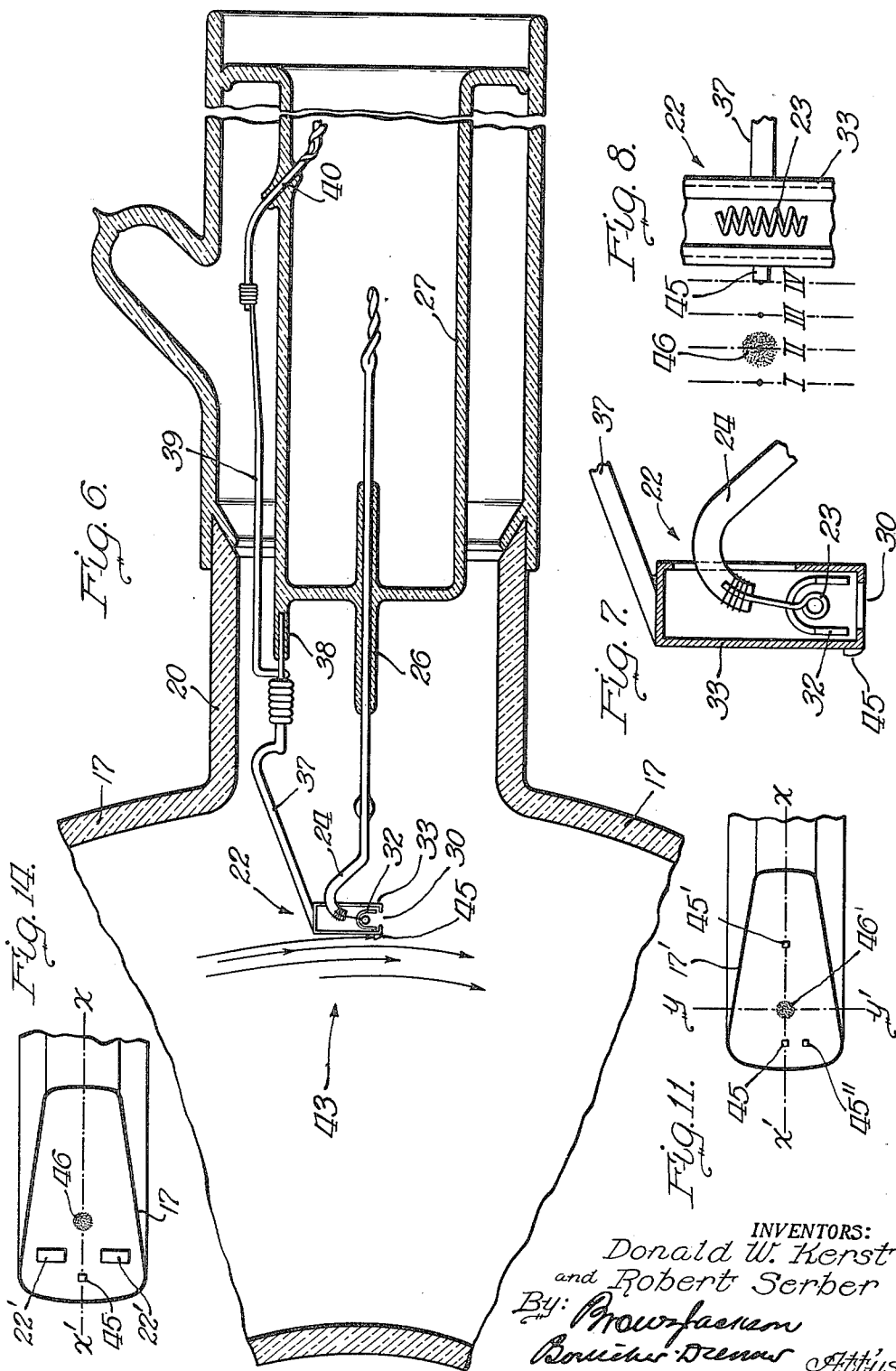
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Filed May 4, 1944

3 Sheets-Sheet 2



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Aug. 17, 1948.

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3 Sheets-Sheet 3

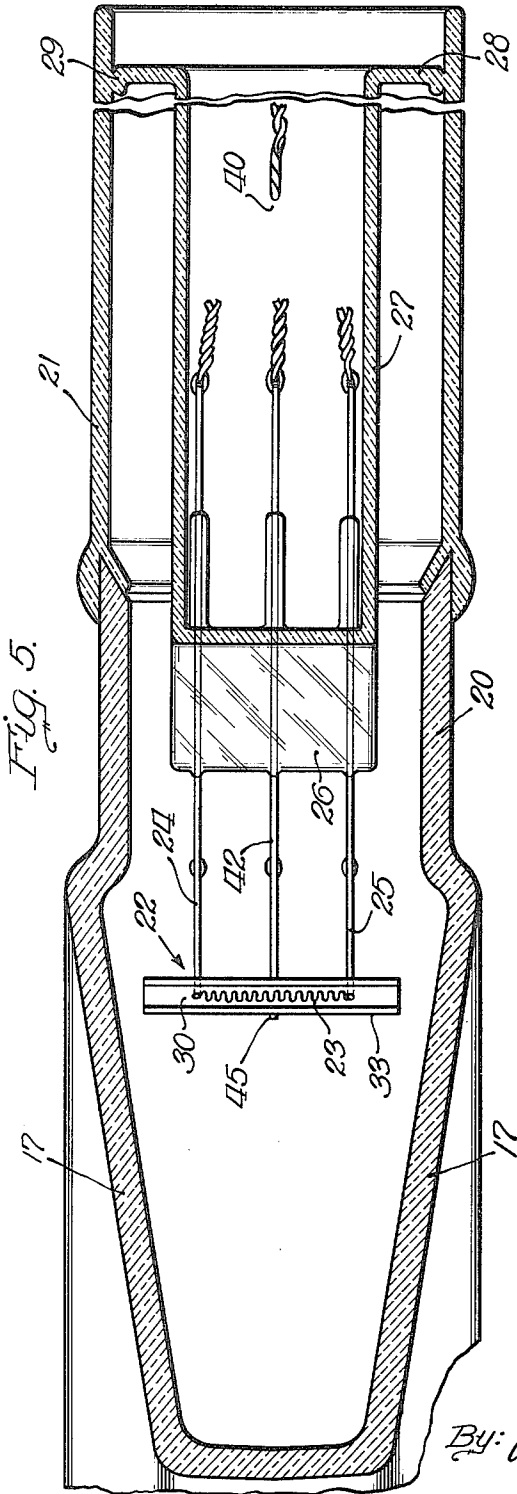


Fig. 10.

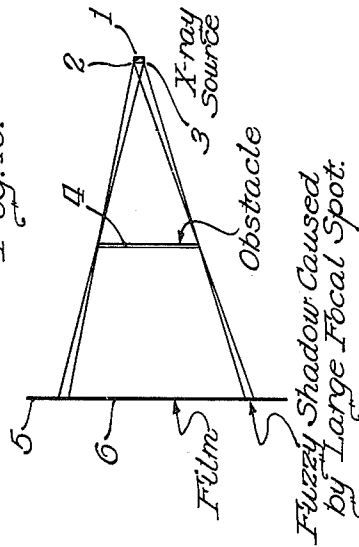
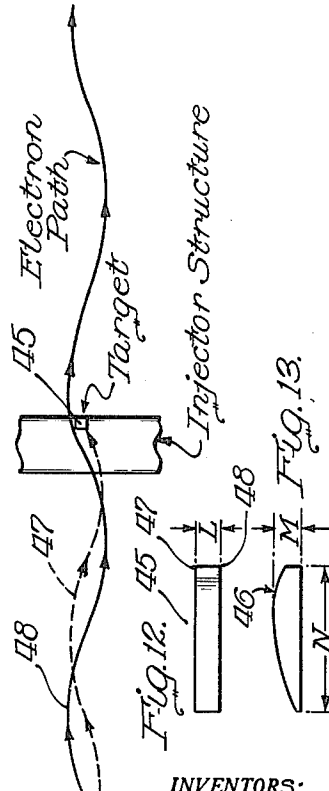


Fig. 9.



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## UNITED STATES PATENT OFFICE

2,447,255

MAGNETIC INDUCTION ACCELERATOR  
WITH SMALL X-RAY SOURCEDonald W. Kerst and Robert Serber, Urbana, Ill.,  
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Application May 4, 1944, Serial No. 534,060

18 Claims. (Cl. 250—99)

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This invention relates to an accelerator of the induction type (betatron), and is more particularly concerned with a method of and means for restricting or confining the area of impingement of an electron beam or a beam of charged particles upon a target.

The primary object of the invention is to provide an X-ray source of small area. In radiography a small focal spot source of X-rays is desirable for several reasons. The smaller the area of the focal spot or source of X-rays, the sharper the image and the better the definition. Also with a small focal spot or source of X-rays the photographic plate may be disposed farther behind the object while still securing the desired sharpness and definition of the image. Thus, with substantially a point source of rays the plate may be disposed farther behind the object and a magnified image of satisfactory definition obtained. Fine detail is thereby more easily made out.

Other and subsidiary objects will be apparent from the following specification and claims.

The theory of acceleration of charged particles by induction has been theoretically developed by Wideroe, by Walton, and by Kerst and Serber, and the practical operation of a successful electron accelerator has been described by Kerst in "The Physical Review," vol. 60, No. 1, pages 47-53; "The Physical Review," vol. 58, page 841; "The Physical Review," vol. 59, page 110; and "The Review of Scientific Instruments," vol. 13, No. 9, pages 387-394; and by Kerst and Serber in "The Physical Review," vol. 60, No. 1, pages 53 to 58. See also Kerst Patent No. 2,297,305 for a disclosure of such an accelerator.

The utility of acceleration of charged particles in the production of X-rays of great penetrating power is known. The production of an electron beam of as high as 20,000,000 electron volts is described in the above papers, and in the above patent, to which reference is made for a full exposition of the method of establishing the electron beam, accelerating it in its orbit, and of expanding or contracting the orbit for the purpose of directing the accelerated electrons upon a target, the impingement upon which of the high speed electrons, or other charged particles, releases X-rays projected mainly in the direction of the electron travel. The travel of the electrons in the beam is confined to an orbit controlled in radial extent by the radial distribution of the magnetic field (air gap) in which acceleration is produced.

The beam tends to be confined to the median

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plane of the gap in which the orbit of travel is laid by the axial disposition of the magnetic forces in the air gap, but the straying electrons in their orbital travel oscillate above and below the plane of the orbit by virtue of the restoring force of the said magnetic field.

The forces holding the beam in or confining it to a predetermined radial position are responsible for the radial oscillation of straying electrons about the average orbit radius. The beam may be controlled to spiral radially inwardly or outwardly as desired in order to strike the target accordingly disposed radially inside or outside the mean orbit, as the case may be, and thus secure the consequent X-ray emission.

The attainment of a sharp substantially point source of X-rays did not, in our earlier work, appear to be feasible under the circumstances, since the electrons in the beam although oscillating in a damped manner about the mean orbit, still formed a beam and focal spot of an undesirable size. A method of focusing the impingement of the stream of oscillating electrons upon a confined spot or substantially a point constituted a desideratum, the attainment of which presented a problem which the present invention solves.

We conceived the possibility of utilizing a target of minute area disposed outside the orbit (inwardly or outwardly or above or below), and then spiralling the orbit of the beam to approach the position of the target. This would appear to confine the impact to only those electrons which were traveling in line with the target area. But we conceived that by the oscillations of the electrons above and below the position of the target, for example, substantially in the median plane of the orbit, the electrons would, if sufficient revolution were allowed to occur, eventually strike the target. Likewise, any oscillation radially would have the same effect of eventually striking the target.

By spiralling the beam radially toward or in radial register with the target, and taking advantage of the oscillation of the electrons above and below the median plane, it was found possible to cause substantially all the electrons in the beam to strike the target. While obviously this involved a striking of the target later by some than others, the difference in the time factor and in the energy content of the later striking electrons was of no practical moment in the use to which this concept was put, i. e., for an X-ray exposure. The value of this concept has proven itself in practical tests.

The beam may be spiraled above or below the normal plane of acceleration to strike a target suitably located. Any combination of axial and radial shifts of the orbit to accomplish impact upon a correspondingly located target may be employed.

While we refer herein, in reference to the specific embodiment, to the generation of X-rays by the employment of electrons, it is to be understood that any charged particles which are responsive to the magnetic field, or for that matter to an electrostatic field, may be utilized. We employ the term "charged particles" to include broadly electrons and such other sub-atomic particles as exhibit an electric charge whether negative or positive.

Now in order to acquaint those skilled in the art with the manner of constructing and operating a device embodying our invention, we shall describe, in connection with the accompanying drawings, a specific embodiment of our invention and the preferred method of constructing and using the same.

In the accompanying drawings:

Figure 1 is a side elevational view of an electron accelerator embodying our invention;

Figure 2 is a transverse, horizontal section, taken on the line 2, 2 of Figure 1;

Figure 3 is an end elevation of the accelerator shown in Figure 1;

Figure 4 is a fragmentary elevation, partly in section, showing the location of the evacuated tube between the pole pieces and the shape of the pole pieces;

Figure 5 is an enlarged vertical section through the electrode arm showing the electron gun;

Figure 6 is a horizontal sectional view of the same parts shown in Figure 5;

Figure 7 is an enlarged, horizontal cross section of the parts of the electron gun, showing the target on a larger scale;

Figure 8 is a face view of the electron injector or gun showing a diagram of the location of the electron beam;

Figure 9 is a diagram showing the nature of the oscillation of the electrons in their orbital path, and the manner of engaging the target;

Figure 10 is a diagram illustrating the value of a point source of X-rays;

Figure 11 is a diagram to explain the various ways in which the electrons may be brought into register with the target through variations in the method of shifting the orbit;

Figure 12 is a side elevation of the target;

Figure 13 is a plan view of the same; and

Figure 14 is a diagrammatic view like Figure 11, showing an arrangement of electron injectors on each side of the median plane, with the target disposed on substantially the median plane, and at a greater radius than the electron injectors.

Reference is now made to our prior Patent No. 2,297,305, of September 29, 1942, for a description of the general features of construction and mode of operation of the present device, the particular improvement herein disclosed having mainly to do with the securing of substantially point emission of X-rays by limiting the area of engagement between the impinging charged particles, such as electrons, and the target against which they strike, to a focal spot small enough to serve substantially as a point source within the limits in which the apparatus is employed in practical operation.

The value of a point source of X-rays is illus-

trated in Figure 10. Assume an emission target 1 of a substantial area, the face of the same extending from the corner 2 down to the corner 3, and that X-rays are emitted from or through the said face. The X-rays we will assume are emitted uniformly across the face of the source 1 to cast a shadow of the obstacle 4 upon the screen or film 5. Where the source of X-rays is a large focal spot the edges of the image cast by the obstacle 4 will be fuzzy because of the overlapping rays emitted from the large focal spot. This fuzziness will be magnified where the screen 5 is disposed a substantial distance back of the obstacle 4. This is generally the case where the subject of which an X-ray picture is to be taken has substantial depth or dimension in the direction of the rays, so that the plate is a considerable distance away from the structure or obstacle in question.

We have conceived the possibility of securing substantially a point focal spot for X-rays of high intensity. With the attainment of a point focal spot sharp images are attainable even where the subject has substantial depth; and if desired the screen or film may be purposely placed a suitable distance away to secure magnification.

According to our invention, we provide an accelerator of the magnetic induction type with a target of minute dimensions in the direction of oscillations of the electrons in their orbits and secure impingement of the electrons upon the minute surface of the target by spiralling the electrons while oscillating into register either radially or axially or both radially and axially with the target, whereby on successive rotations the electrons in their oscillations will fall into register with the target and impinge thereupon and produce their effect. The concept involves a target of a dimension in the direction of the lateral oscillation of the charged particles less than the amplitude of oscillation with successive impingement of particles upon successive rotations whereby substantially the entire beam of traveling particles is caused to impinge upon an area of less width than that of the beam. The dimension may be much smaller than the amplitude of oscillation and thereby produce an exceedingly sharp focal point. While the time of impingement is thereby strung out, nevertheless the entire operation occurs in so short a period that the time element is not of consequence.

The accelerator shown in Figure 1 comprises the magnetic frame 12, having upper and lower polepieces 13 and 14, see Figure 4, disposed centrally of the rectangular yoke 15. The yoke 15 and the polepieces 13 and 14 are suitably laminated. The polepieces 13 and 14 are preferably formed of sector shaped laminated components. A magnetic control suitable for controlling the flux density through the central part of the polepieces is disposed at 16. This preferably consists of a pair of spaced laminated disks. The flux brought through these disks maintains the equilibrium orbit of particles in the evacuated electron tube 17. The separation of the disks controls the shape of the magnetic field in the vicinity of the small gap between the disks, but the thickness of the disks determines the size of the equilibrium orbit. This control structure 16 is constructed separate from the polepieces 13, 14, so that adjustment in manufacture may readily be made.

Circular exciting coils 18 and 19 surround the polepieces 13 and 14, and are disposed above and below the tube 17. Control coils 51 and 52 are disposed about the central and outer parts, re-

spectively, of the polepieces 13 and 14. The flattened annular vacuum tube 17 is preferably formed as a one-piece hollow, doughnut-shaped vessel. The walls of the tube, and the base of the laterally extending neck indicated at 20 in Figures 5 and 6, are preferably constructed of a unitary piece of porcelain, suitably formed and fired, to constitute a vacuum vessel within which the electron beam is accelerated.

The formation of this vacuum vessel, and the sealing of the electron gun thereinto is not per se of our invention. Suffice it here to say that the vacuum vessel 17 may be of a truncated wedge shape in cross section as indicated in Figures 4 and 5, and is provided with the tubular neck 20 to which there is sealed a glass extension 21. The said extension 21 comprises both a support and a seal through which conducting leads for the elements of the electron gun are conducted in suitably gas tight relation. The gun 22 comprises a tungsten filament 23 supported upon terminal leads 24 and 25, these leads passing out through the pinched glass seal 26 formed on the inner end of the inner tube 27. The tube 27 is flanged out at 28 and is sealed at 29 to the outer tube 21. This outer tube 21 is made of glass, and it is fused to the outer end of the neck or extension 20 of the doughnut tube 17. Various other ways of supporting the electron injector structure may be employed and various forms of tubulation may be utilized. A channel shaped molybdenum grid 32, which under operating conditions can be negatively charged, serves to focus the discharge of electrons from the filament 23 through the slot or opening 30 in the front wall of the rectangular box-shaped molybdenum plate 33. The molybdenum plate 33 is supported upon the molybdenum lead 37 which in turn is fixed in a portion 38 of the inner glass tube 27, as shown in Figure 6, and is electrically connected to a lead 39 extending through the inner wall 27 at 40. The negatively charged focusing grid 32 is supported upon a central electrode lead 42 which passes through the pinched glass seal 26 to an external lead. The inside of the tube is preferably silvered or otherwise given a high resistance conductive coating which is connected to earth.

In operation, the main magnetizing coils 18 and 19 are excited by current flowing as the result of an impressed alternating voltage of suitable frequency. The shape, excitation, and disposition of the magnetic field in the air gap between the magnetic poles 13 and 14 is such as to provide an equilibrium orbit for electrons in the vacuum chamber a short distance radially inside the electron gun 22. Electron gun 22 is disposed within the magnetic field, so that the electrons emitted by the same are as promptly as possible drawn into the orbit and accelerated by the change in the magnetic field occurring through the rising quarter cycle of magnetism. The filament is shock excited as by the discharge of a thyratron circuit in time with the rising curve of magnetization of the core. The electrons may swing widely off the mean orbit, but are presently drawn into the orbit and are meanwhile accelerated by the rising magnetization. The electrons are held in their orbit radially by a relatively high stabilizing force, by the radial distribution of the magnetic field. The field is strong at the center and diminishes outwardly radially in known manner. Following discharge of the electrons and during the initial acceleration there is a tendency for the electrons to oscillate radially, but this oscillation is damped,

and hence radial oscillation in the course of acceleration tends to die out. The curvature of the magnetic field in the median plane provides a restoring force axially of the orbit of rotation.

Oscillation above and below the median plane is also damped. During the later stages of acceleration the flow of charged particles, in this case electrons, is confined to a fairly concentrated beam. In a typical installation the beam reaches a dimension of from one to two millimeters in the axial dimension, and is confined fairly closely to a circular orbit in the median plane of the air gap. Figure 6 illustrates diagrammatically the beam of electrons 43 as following a circular orbit in the plane of the paper, but oscillating above and below the said plane. There may also be some oscillation radially. Various imperfections in the structure of the apparatus and the presence of residual gas in the vacuum tube may be responsible for the lack of focusing the beam to a fine linear orbit.

The electrons emitted from the gun 22 tend to spiral with more or less oscillation radially into the orbit, and those emitted from above and below the plane of the orbit obviously tend to be centered by the restoring force of the curvature of the magnetic field and spiral with more or less oscillation axially into the orbit. As the magnetization of the core approaches maximum, the electron beam is then caused to spiral into a different position which may be radially inwardly or radially outwardly of the normal orbit. That is to say, the orbit may be spiraled to contract, or spiraled to expand for the desired purpose of striking the target which is located accordingly. The orbit may be raised or depressed to cause engagement of the beam with the target which is located in appropriate position above or below respectively. In the present instance, the target is located radially outside the orbit. The target consists of a minute solid body of a heavy metal, such, for example, as tungsten, platinum, gold, thorium or uranium. These are all metals of a high atomic number and high density. Materials of high atomic number produce X-rays more abundantly than lighter materials. Hence, we prefer to use a material of a high atomic number and high density. In the present construction the target 45 is attached to the outer wall of the plate 33, substantially in the median plane of the tube, although as will be shown later this is not essential. The plate and the attached target are preferably connected to ground.

In the embodiment illustrated and in one form which we have successfully operated, the target is a minute piece of tungsten of substantially the shape shown in Figures 12 and 13, where the dimension L, that is, the vertical width normal to the plane of the paper shown in Figure 6, is ten one thousandths of an inch (.10"). The dimension M, namely, the extent of projection outwardly from the face of the plate 33, is .020", and the length or dimension N, is substantially .050". The corner, as indicated at 46, is preferably obtuse or rounded, that is, it is slightly more than a right angle, thereby presenting no thin line of metal which would tend to give a less effective target for some of the electrons striking the same. It appears to be desirable to provide a substantial depth of metal back of the face of the target. Likewise, the edges 47 and 48 may be rounded or obtuse, i. e., made slightly larger than a right angle, for the same purpose.

In order further to concentrate the area of engagement of the charged particles and the tar-

get the edge of the target where it is presented to the beam is convex. For example, it may consist of a semi-cylindrical piece of metal with the convex side tangent to the orbit as the orbit is expanded. The form of the target permits of variation within the mode of cooperation with the electron beam as herein taught.

Referring now to Figures 8 and 9, and assume that the electron beam indicated at 46' occupies the position II in its outward spiralling toward the target 45. As the beam approaches the target 45, the individual electrons in the beam tend to oscillate up and down above and below the median plane. The rate of expansion of the orbit compared with the very high rate of rotation of the particles permits the particles moving in oscillating paths to be given successive opportunity to strike the target. Thus, as the beam 46' is moved to the right in Figure 8 approaching the target 45, assume that the path of one electron is as indicated at 47 in Figure 9, and that it will impinge upon the target 45. Another electron following the path 48, will miss the target 45, but sooner or later will arrive in register with and impinge upon the target 45, because of the enormous number of revolutions per second in the orbital path. The result is that outward spiralling of the orbital path will bring the electrons successively into register and impingement with the target 45 to give the desired emission of X-rays. Obviously, the oscillations may not be as rapid as herein diagrammatically illustrated. In fact, the rate of oscillation may be so slow that an oscillation will not be completed within a rotation, but the effect is the same for our purposes. It is to be observed that in general the more revolutions made by the electrons while following a shifting orbit, the more certainly will they all be brought into register and impingement with the target. In other words, the higher the rate of rotation of the electrons, the more rapid may be the rate of expansion of the orbit with the reasonable certainty of the impingement of substantially all or a very large percentage of the electrons upon the target, or, conversely, the more rapidly may the electrons be caused to impinge upon the target.

While we have described the disposition of the target 45 as being radially outwardly of the acceleration orbit, it is obvious that the target may be disposed radially inwardly of the acceleration orbit, and the electrons spiralled inwardly into contact with the target if so desired. The method of spiralling the electron orbit inwardly as well as outwardly is known to those skilled in the art and need not here be described in detail. Suffice it to say that for inward spiralling, saturation of the central part of the core as the magnetization proceeds will result in inwardly spiralling. Provision of expansion coils upon the upper and lower faces of the polepieces may be made for superposing expansion producing flux upon the air gap to change the gradient of the magnetic field, as disclosed in the above paper of D. W. Kerst in "The Review of Scientific Instruments," volume 13, No. 9, pages 387-394, for producing outward spiralling.

Expansion coils 51 are disposed on the faces of the poles 13 and 14 to embrace the central part of the pole inside the evacuated tube 17. Companion coils 52 wound in a direction opposite the winding of the coils 51 and of fewer turns than the latter are disposed so as to embrace the entire polepiece, so that when these two sets of coils 51 and 52 are simultaneously energized, the addi-

tional flux created in the center and superposed on the main field will be matched with decreased flux around the outside of the polepieces. This modification of the distribution of the flux in the air gap expands the orbit of the rotating beam of electrons in known manner (see Kerst Patent No. 2,297,305) to produce the desired interception of the beam by the target lying outside the normal orbit.

It is not essential that the beam 46' be spiralled radially outwardly to the target 45, but, as indicated in the diagram of Figure 11, the beam may be spiralled inwardly to contact a like target 45' at a smaller radius. In the diagram of Figure 11, the vacuum tube is shown diagrammatically at 17' for disposal between the polepieces, the magnetic field of which stabilizes and accelerates the electron beam in the orbit at 46'. By suitable alteration of the magnetic field, the electron beam 46' may be depressed below the plane X', X, and may thereupon be spiralled outwardly to bring the electrons into engagement with the target 45', which is disposed below the median plane X', X and radially outwardly of the circular orbit. Obviously, the electron gun may be disposed at any suitable position out of the way of the rotating beam of electrons during acceleration and during spiralling into engagement with the suitably positioned target.

In Figure 14 we have shown diagrammatically a pair of electron guns 22', 22' disposed above and below the median plane X', X, and closely adjacent the orbit of the rotating electron beam 46. The beam may be spiralled outwardly in substantially the plane X, X' of the orbit to impact the target 45, which is supported independently between the electron guns 22', 22'. Various other arrangements of the electron injector means and the target may be made. The target may be supported independently of the injector structure. Preferably it should be located out of the way of the electrons while they are emitted and being stabilized and accelerated.

In the spiralling of the beam towards the target, whether the same be radially inwardly or outwardly, in or parallel to the mean plane of the orbit, the beam spirals toward the target so slowly that the straying electrons, that is, those which oscillate out of register with the target, may execute many oscillations across the plane of the orbit and hence arrive on the level of the target while the beam as a whole shifts toward the target. Consequently, it is assured that the beam will not have shifted so far that the particles hit the support for the target before all of the electrons oscillating across the plane of the orbit have been intercepted. Where, as in the specific instance above given, the target is only .010" in height, it is obvious that all of the X-rays originate from a source only .010" high. The other dimension of the X-ray source is determined by the distance between successive spirals of the electron beam as the beam expands. Since this distance is very small, almost all of the electrons strike the most protruding edge of the target, and the focal spot can, where the edge of the target is straight, therefore be very much more narrow than it is high. In the example given, the area of the source is therefore substantially a line .010" long.

In the case of radially outward expansion herein specifically described and illustrated, the effective height of the target in a direction axially of the orbit should, in order to gain the advantages of the present invention, be less than

the amplitude of oscillation. The practical construction to secure this restricted engagement is shown herein as a target of less axial height than the amplitude of oscillation. The axial thickness of the beam in a typical operation is of the order of one to two millimeters just prior to spiralling into engagement with the target. Hence, the effective face which the target presents should be somewhat less in height than the minimum axial thickness of the beam, i. e., approximately 1 mm. to secure a concentration of the electrons upon an area of impact less than the cross sectional area of the beam.

This concentration of the area of impact may be gained by presenting a limited portion of a target of larger dimensions, as by relative movement of the beam transversely of the edge of a larger target which, however, is so spaced relative to the mean orbit that it presents interception with the beam across only a portion of the cross section of the beam. The particles of the beam would on successive revolutions become interrupted as they come into registration by oscillation. In brief, the combined action of relative traverse of the beam with a target which does not allow impingement across the full cross section of the beam and the oscillation of the particles within the cross section of the beam produces a concentration of the area of impact by gathering in impacts due to oscillation of the particles across the cross section of the beam. Thereby the advantages of a limited area of X-ray emission of high intensity is secured. Thus a target presented to the upper half of the beam would produce impingement of all particles oscillating up and down. The height, axially of the orbit, of the effective target face to gain the advantages of the present invention should be less than the amplitude of oscillation.

While presentation of a larger target to only a portion of the cross section of the beam is theoretically capable of concentrating the impact upon an area having a dimension less than the cross sectional diameter of the beam, the practical difficulty of securing such accurate limited registration is overcome by using a target as herein shown of a height less than the cross sectional diameter of the beam. Then accurate registration relative to the plane of the orbit is not necessary for the disposal of this size of target at almost any point on the vertical height of the cross section of the beam will secure good practical results.

Such a small source of high energy X-rays has been the goal of X-ray engineers for many years, since a point source of X-rays enables radiographs to have extremely sharply defined contours. This sharp definition assists in the detection of imperfections in industrial objects, which is one of the main uses of radiography. The images which we have obtained by the use of our invention are so sharp that one can place the photographic film far behind the object which is casting a shadow, and still obtain satisfactory results. In such an arrangement, the image is enlarged, and fine detail may be more easily seen. For radiography of very thick sections, such a minute focal spot is essential.

It is to be understood that the small target need not be attached to the electron injector, but may be supported in any suitable manner, where it can be intercepted by the beam, by either expansion or contraction of the orbit, or by displacing of the orbit above or below its normal plane.

While we have specifically referred to the dis-

charge of electrons into the evacuated vessel for acceleration by the magnetic field, it is to be understood that positively charged particles may be injected, and utilized in the production of X-rays, or in the production of radioactive samples. Also, it is to be understood that a wide variety of magnetic structures, vacuum chambers and injectors, may be employed. The essential feature of the present invention resides in the restricted character of the impingement or concentration of impingement of the charged particles upon the target by the peculiar interaction of oscillation of the electrically active elements, such as electrons or other charged particles, impinging upon a restricted area of the target, by virtue of the rotation of the same until they come into registration and impact with the target. The principle of securing interception between the accelerated oscillatory particles and the restricted effective area of the target applies equally well for oscillation in any direction. For example, assume that the particles had an oscillation in and out of the mean circular path, in addition to an oscillation in and out of the plane of the orbit, spiralling of the beam towards the target would still produce the desired interception of electrons by the target. In general the shifting or spiralling of the beam in or out provides the means for bringing the particles successively into registration with the radius of the target and the oscillations above and below the plane of the orbit serves to cause those electrons to come axially into registration to be intercepted.

We do not intend to be limited to the details shown and described, the extent of such modifications being determined by the limitations of the appended claims.

We claim:

1. Method of producing X-rays from a substantially point source which comprises discharging electrons into a magnetic field, accelerating said electrons by increase of intensity of said magnetic field to rotate in a circular orbit in a median plane normal thereto, applying a stabilizing force by said magnetic field tending to confine said electrons to the median plane of the orbit whereby said electrons tend to oscillate above and below said median plane as they rotate in said orbit, disposing a target of an effective linear dimension less than the amplitude of oscillation adjacent said orbit, and by operation of said magnetic field changing the orbit to bring about impact of the electrons with the target successively as they oscillate upon successive rotations into register with the target so that on failure to strike the same during the first revolution they strike it during a succeeding revolution whereby substantially all of said electrons strike said target.

2. Method of claim 1 wherein the change of the orbit comprises change of the radius of the same.

3. Method of claim 1 wherein the change of the orbit comprises a lateral shift lengthwise of the axis of rotation.

4. Method of producing impact of minute focal area between a target and a beam of charged particles travelling in a circular orbit with oscillating motion above and below said orbit and utilizing the resultant rays, which comprises disposing adjacent said orbit a target of a dimension less than the amplitude of oscillation in the direction of the axis of the orbit, traversing the rotating and oscillating beam radially with respect to the target to permit said particles which oscillate out of register with the target upon one

rotation to continue to rotate and oscillate whereby they impinge the target upon a succeeding rotation, and utilizing the rays projected from said target in about the same direction that said particles had in impinging upon it.

5. Method of producing impact of restricted area between a target and a beam of electrically charged particles and utilizing the resultant rays which comprises discharging a beam of electrically charged particles, moving said particles in a predetermined closed path, accelerating said elements in their travel along said path, said elements oscillating above and below the median plane of said path, traversing said path with a target of width in a direction transverse to the path of travel less than the amplitude of oscillation at a rate which permits elements which initially have oscillated axially out of register with the target, to travel in radial register with the target until they oscillate into impingement with the target, and utilizing the rays projected from said target in about the same direction that said particles had in impinging upon it.

6. Method of producing a restricted area of impact between a target and a beam of electrons and utilizing the resultant X-rays which comprises discharging a beam of electrons, moving said electrons in a predetermined generally circular path, accelerating said electrons in their travel along said path, said electrons oscillating above and below a median plane, producing relative traverse substantially in or parallel to the plane of the circular path of the traveling electron beam with a target of an axial dimension less than the amplitude of oscillation, said traverse being at a rate which allows impact with said target after successive revolutions, of electrons which have initially oscillated axially out of register with the target, but radially in register with the same, and utilizing the X-rays that are projected from said target in about the same direction that said electrons had in striking it.

7. In a device of the class described having an evacuated electron chamber comprising walls providing an annular space for an electron orbit, means for intermittently discharging electrons into said space, magnetic accelerating means for accelerating said electrons angularly in said orbit, said means comprising magnetic polepieces substantially concentric with said orbit, and having an air gap providing a magnetic field holding the electrons in an orbit of predetermined radius, said rotating electrons oscillating in said field above and below the mean plane of the orbit, the combination of a narrow target disposed in or adjacent the plane of the orbit and radially spaced from the orbit, and means for changing the position of the orbit to cause the orbit to intersect with the target, said target being of a dimension axially of the orbit substantially less than the amplitude of oscillation of the rotating electrons.

8. In a device of the class described, an evacuated tube having an annular evacuated chamber, a magnetic core having polepieces adjacent the tube for influencing electrically active particles therein to pursue an orbital path of oscillation, and a target supported in said tube adjacent the orbital path of said electrically active particles, said target having a length in the direction of oscillation of the said particles substantially less than the amplitude of oscillation of said particles.

9. The combination of claim 8 wherein the active particles are electrons and the oscillation

of the same is chiefly axially of the annular chamber, and the dimension of the target in a direction axially of the tube is of the order of .010" or less.

10. In a device of the class described, an annular evacuated chamber, an injector in said chamber comprising a filament for electron discharge, a shielding plate, a grid for driving electrons in a predetermined direction away from the filament in a planar orbit relative to which they oscillate, and a target of width less than the amplitude of oscillation of said electrons on said plate, said target projecting radially clear of the plate to permit it to be impinged by electrons spiraling circumferentially in said annular chamber.

11. In a device of the class described, an annular evacuated chamber in which a rotating and oscillating electron beam is adapted to be established in a generally circular orbit, an electron gun disposed adjacent the orbit and laterally of the plane of the orbit, and a target of width less than the amplitude of oscillation of said electrons disposed substantially in the plane of the orbit.

12. In a device of the class described, an annular evacuated chamber in which a rotating and oscillating electron beam is adapted to be established in a generally circular orbit, electron injectors disposed on opposite sides of the plane of the orbit, and a target of width less than the amplitude of oscillation of said electrons disposed substantially in the plane of the orbit.

13. Method of generating fine focus X-rays which comprises: accelerating electrons in a circular planar orbit with the electrons oscillating relative thereto, causing said accelerated and oscillating electrons to strike a target having an effective linear dimension less than the amplitude of their oscillations so that on failure of an electron in said orbit to strike said target during its first revolution it strikes the same during a successive revolution, and utilizing the X-rays that are emitted from said target in about the same direction that the electrons had in striking it.

14. Method of claim 13 wherein the electrons are accelerated by a magnetic field and their orbit is in a plane normal thereto.

15. In a device of the class described, the combination of an evacuated hollow annular container, means for discharging free particles into the evacuated space in said container, magnetic means for accelerating the particles in a circular orbit and confining them to a beam wherein the individual particles oscillate about a mean path, a target of a dimension in the direction of the oscillation of said particles less than the amplitude of said oscillation, and means for shifting the orbit of the beam across the target whereby impingement of said particles upon the target is confined to an area which approximates a point.

16. The combination of claim 15 wherein the effective height of the target is of the order of ten one thousandths of an inch (0.010).

17. In a magnet induction accelerator having means for emitting groups of particles in an evacuated space, means comprising a magnet having a field for accelerating the particles in a circular direction, said magnet having means to confine the particles of a group in a substantially circular common orbit about the axis of said magnet, the confining force of the field producing oscillations of the particles in said orbital path above and below the plane of said path, a target of heavy metal disposed radially outside the said orbital path, said target presenting a

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face for impingement by said rotating and oscillating particles of axial and radial dimensions less than the corresponding cross section of the orbital path of said group of particles, and means for expanding the orbital path of said particles to produce intersection with said target across a portion of the cross section of said orbital path, the rotation and oscillations of said particles in said path tending to bring substantially all of the particles of the group ultimately into register with the target. 10

18. Method of producing substantially point focal spot impact of free particles upon a target which comprises projecting free particles into an evacuated space, accelerating the particles angularly in a circular orbit in a magnetic field by variation of the field strength, confining the particles radially by distribution of magnetic flux in the field, confining the particles axially by the shape of said magnetic field, whereby the particles oscillate above a mean in said orbit, dispos-

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ing a target of a height less than the amplitude of oscillation adjacent said orbit, and progressively shifting the magnetic flux in said field to progressively move the orbit across the face of said target, the oscillations of said particles tending to bring substantially all the particles in the beam into impact with the target.

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