

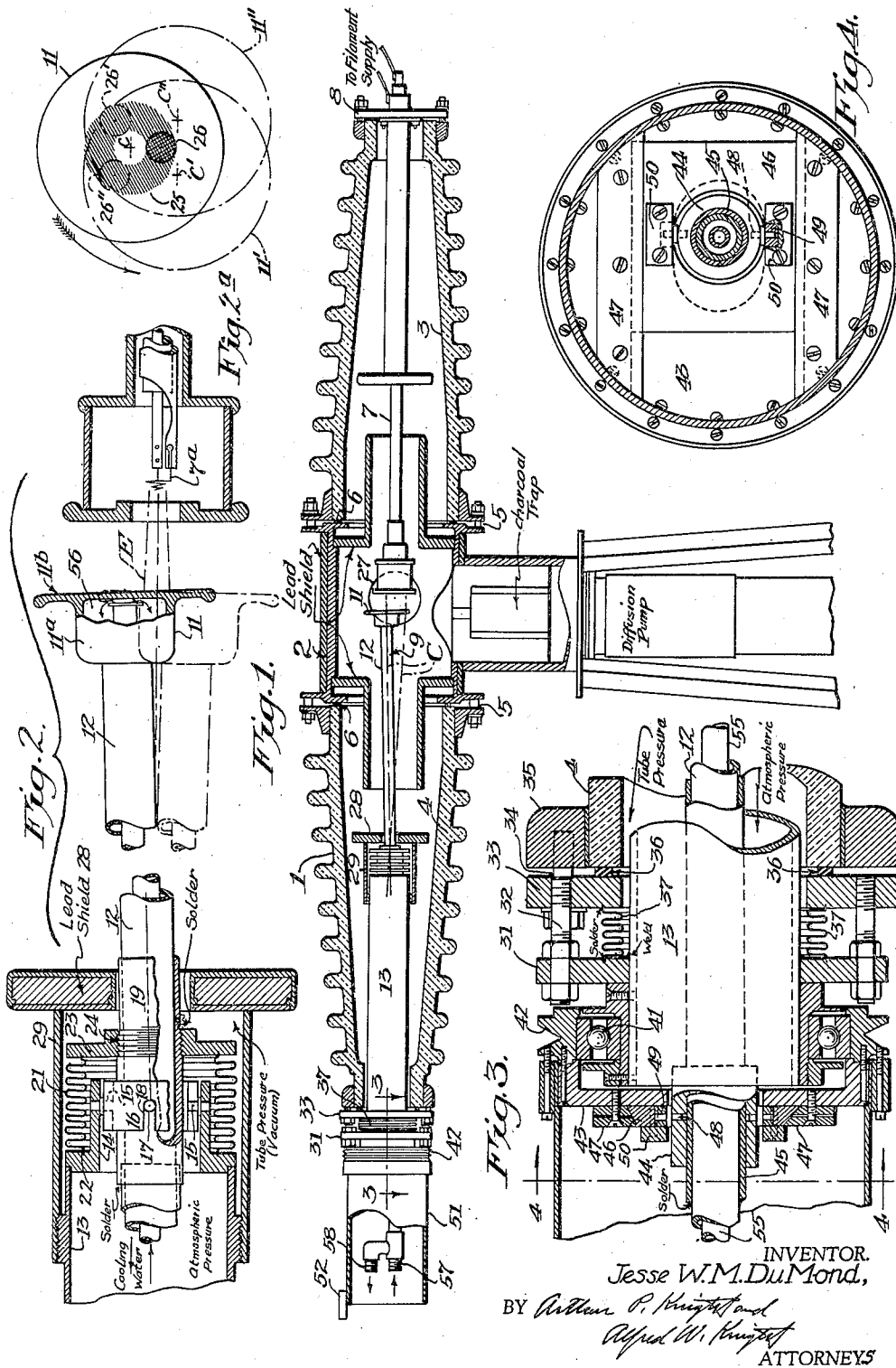
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X-RAY GENERATING DEVICE

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X-RAY GENERATING DEVICE

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This invention relates to X-ray generating devices and pertains particularly to a device provided with a mobile target and adapted for sustained high power input and high X-ray output.

One of the particular objects of the invention is to provide an X-ray generating device provided with a continuously moving anode surface.

A further object of the invention is to provide a device of the character described, provided with an anode member of extended area which is adapted for continuous movement with reference to the cathode whereby the area of the anode which receives electrons from the cathode is caused to continuously shift in order to keep the surface density of electron impingement below a desired maximum over the entire effective area of the anode.

A further object of the invention is to provide a high power X-ray generating device having a continuously moving anode surface, in which an effective vacuum seal may be preserved between the relatively movable parts of the device while permitting free effective circulation of a cooling medium to the anode member.

A further object of the invention is to provide an X-ray generating device having a target member which continuously moves so that new regions of its surface are continuously being presented under the focal area of electron bombardment without variation in the position of the focal spot with respect to other stationary objects in the room.

X-ray generating devices have heretofore been suggested in which either the focal spot moves over the face of a stationary target or the target surface is moved with respect to a stationary focal spot, for the purpose of permitting high power input over short periods of time. In constructions in which the target is stationary and the focal spot is caused to move with respect thereto, the adequate cooling of the target presents no particular difficulties, but the position of the source of the resulting X-rays is caused to continuously shift which renders such constructions substantially useless for many purposes. In constructions where the focal spot is caused to remain motionless and a continuous movement of the target is provided, considerable difficulty has heretofore been experienced in providing for continuous and rapid removal of the relatively large quantities of heat from the target which result from high kilowatt input. As far as is known to applicant all such constructions have either involved intermittent bombardment and relied upon the provision of a

target having a relatively high heat capacity sufficient to permit absorption of the thermal energy for a very brief time, the target being subsequently cooled over a comparatively protracted period in the absence of bombardment before a second exposure to the focal spot is made, or have relied upon a rotating structure in which vacuum-sealing glands are required. This latter conception requires the use of structures in which the sealing surfaces are in constant sliding engagement with one another, thus limiting the relative rotation of the parts to slow speeds if a high degree of evacuation of the tube is desired. In such constructions, owing to the cooling difficulties, the average safe rate of power input over any protracted time is very restricted.

The device of the present invention comprises, essentially, a continuously bombarded movable target member of extended area mounted in such manner as to undergo approximately a circular motion of translation in which any particular portion of the target is exposed to electron bombardment for a short enough period so that that portion does not become overheated, and is maintained out of exposure to the bombardment for a sufficient time to become cooled through the agency of an associated fluid or other cooling means before reexposure to the bombardment, whereby a dynamically steady cyclic thermal state is established in the face of the target, while maintaining the focal spot in a fixed position.

According to the herein disclosed embodiment, the objects of the present invention are attained by a construction in which the target member is mounted on an elongated support arm which is provided with pivotal attachment to a fixed portion of the tube assembly in such manner that the axis of the support arm may be caused to revolve or gyrate about a center line intersecting the axis of the arm at the point of pivotal support, whereby said axis will be caused to sweep out a cone having its apex at the center of pivotal support of said arm. The face of the target is thus provided with a circular and nearly translatory motion, without producing an actual rotation of the target member or support arm. The support arm is preferably extended both sides of the center pivotal support to provide for operative association of the device with a suitable driving means for producing the desired revolving motion, and a flexible sealing means is provided adjacent to the point of pivotal attachment to establish the desired vacuum

seal for the tube. Cooling means are provided for the device, which may conveniently extend within the aforesaid support arm into position to establish positive fluid circulation to the internal rearward surface of the target member as close as possible to the region of electron bombardment.

For the purpose of simplicity of description, the above-described revolving movement of the target member and the associated support mechanism will be referred to as a "gyratory" movement, in view of the fact that no more accurately descriptive term is available. It is appreciated that the term "gyratory" is ordinarily applied to the movement of rotating bodies, while in the present case the target and support assembly do not undergo rotation, but in view of the fact that the actual movement which is particularly involved in the operation of the specific form of apparatus herein disclosed for the purpose of providing the desired nearly translatory movement of the target member so closely resembles the movement through space of a spinning body such as a top, the term "gyratory" is believed properly descriptive.

Other objects and features of the invention will be brought out in the following description, or will be apparent therefrom. A preferred embodiment of the invention is shown in the accompanying drawing, and referring thereto:

Fig. 1 is a longitudinal section of a complete X-ray tube constructed according to the present invention;

Fig. 2 is a partly fragmentary sectional detail of the cathode, anode, and pivotal mounting construction;

Fig. 2a is a partly diagrammatic representation of the movement of the target member with reference to the focal spot;

Fig. 3 is an enlarged sectional view taken on line 3—3 in Fig. 1, showing the construction of a form of driving means which may be employed for producing the desired substantially circular translatory movement of the target face; and

Fig. 4 is an end elevation thereof taken on line 4—4 in Fig. 3.

Referring to the drawing, a tube body portion or envelope is indicated at 1, said body portion comprising a center section 2 and two end sections 3 and 4. The end sections 3 and 4 may comprise suitable tubular members such as porcelain insulators secured to the center section 2 in any suitable manner as through the agency of bolted flange constructions as indicated at 5, suitable rubber gaskets or the like being provided between the flanges and the members 3 and 4 as at 6. The cathode assembly 7 is provided with a filament 7a, the cathode assembly being mounted to the end of the portion 3 through the agency of a suitable bolted flange construction 8. The anode assembly is indicated generally at 9, being shown more fully in Figs. 2 and 3.

The anode assembly 9 may comprise a target 11 secured to a tubular support arm 12 pivotally mounted on a standard 13 which is fixed to the outer end of the member 4. The standard 13 is of tubular construction, and extends within the end section 4 and cooperates with the tube body as a whole to provide a fixed housing structure, said standard being provided at its inner end with a collar member 14 carrying two diametrically opposed pivot pins 15 adapted to receive a gimbal ring 16. The tubular support arm 12 is provided with diametrically opposed pivot pins 17 adapted to extend within slots 18 in the

gimbal ring 16 disposed at positions 90° removed from the positions of the respective pins 15. The pins 17 are preferably secured to a separate sleeve 19 which is soldered or otherwise hermetically attached to the support arm 12. The gimbal ring 16, in conjunction with pins 15 and 17, serve to mount the support arm 12 for pivotal movement about a point which is conveniently located in the axis of said arm. Hermetic sealing between the interior of the standard 13 and the interior of the body portion 1 of the tube is provided by flexible sealing means disposed adjacent the point of pivotal support of arm 12 and secured to said arm and to a fixed part of the housing structure, such as standard 13. Such sealing means are shown as comprising a "syphon" bellows 21, one end of which is secured to the collar 14 as at 22 as by means of solder or the like, and the other end of which is secured to a collar 23 which is in turn sealed to the sleeve 19 as by means of coactingly threaded portions 24 which are preferably hermetically sealed as by means of solder.

The standard 13 is fixedly mounted within the outer end of the tube section 4 as by means of a flange 31, which is preferably welded to the standard 13 to provide a hermetic seal, said flange 31 being bolted as at 32 to a compression flange 33 which is secured to the tube section 4 in any suitable manner as by means of cap screws 34 extending into a reinforcing ring 35 which is cemented or otherwise secured to the tube section 4. A suitable gasket such as of rubber, lead, or the like is provided as at 36 between the outer end of the tube section 4 and the compression flange 33, and a flexible sealing member such as a "syphon" bellows 37 is provided between the flanges 31 and 33, the respective ends of which are hermetically sealed to the respective flanges 31 and 33 as by means of soft solder or the like.

When the tube is evacuated to establish the desired operating pressure, the whole of the tube exteriorly of the standard 13 is thus established at the tube pressure (or vacuum) while the interior of the standard 13 is at atmospheric pressure. The double flange construction at 31 and 33 provides for alinement of the standard 13 within the tube, by variation of the direction of the longitudinal axis of the tubular standard 13 with respect to the cathode filament 7a through adjustment of the bolts 32, and the desired seal against atmospheric pressure is provided between the flange 33 and the outer end of the tube section 4 through the agency of the bellows 37 as above described.

Any suitable means may be provided for producing the desired gyratory movement of the support arm 12 and thus cause the desired nearly translatory movement of the target face 11b. In view of the fact that relatively high speeds of gyration are desirable in order to permit a sustained high power input, it is very desirable, if not essential, to provide means for counterbalancing the gyratory assembly. I have illustrated one form of driving means, which is subject to the desired counterbalancing, in which a suitable bearing member 41 such as a ball bearing is mounted on the outer end of the standard 13, said bearing member carrying a grooved pulley 42 to which a driving head 43 is secured. The pulley 42 and the associated driving head 43 are preferably disposed concentric with the standard 13 and radially adjustable connecting means are provided on the head 43 through which the support arm 12 may extend, such adjustable

means serving to position the outer end of the support arm 12 at any desired radial displacement from the center of rotation of the head 43, so that upon rotation of the pulley 42 the outer end of the support arm 12 will be given a circular and nearly translatable movement of any desired radius.

The eccentric driving means may comprise a journal bearing 44 slidably and rotatively engaging a sleeve 45 which is disposed about the tubular support arm 12, being preferably soldered to the sleeve 19 adjacent the point of pivotal attachment of the arm 12 and standard 13 and soldered or otherwise secured to the arm 12 rearwardly of the head 43 to facilitate assembly of the device and to provide an effective seal between the sleeve 19 and tubular support arm 12. The bearing 44 is pivotally mounted on a plate 46 which is slidably secured to the head 43 as by means of suitable dove-tailed guides 47 which provide for adjustment of the plate 46 in a radial direction along the face of head 43. The bearing 44 is pivotally mounted to the plate 46 in any suitable manner as through the agency of diametrically opposed trunnions 48 whose axes lie perpendicular to the direction of adjustment of the plate 46. These trunnions are preferably carried in trunnion blocks 49 which are loosely mounted in suitable sockets in the plate 46 and retained in place through the agency of caps 50. The loose mounting of the trunnion blocks 49 is desirable in order to prevent the introduction of any strains due to slight misalignment of the parts.

The desirable dynamical counterbalancing of the revolving gyratory assembly may be secured by the disposition of a suitable weight on the rotating assembly in such manner as to counteract the dynamic forces set up by the revolving masses, and for this purpose I provide a balance tube 51 secured to and extending rearwardly of the head 43, on which a suitable counter weight 52 is mounted. The calculation of the forces set up by the gyration of the arm 12 and its accessory elements and the target 11, and by rotation of the head 43 carrying the eccentric load of the plate 46, etc., and the proper disposition of the counter weight 52, will be apparent to one skilled in the art.

The target 11 is preferably provided with cooling means, which may comprise a circulating system for supply of a cooling fluid to the target, such as a water supply tube 55 extending concentrically within the tubular support arm 12 and communicating with a chamber 56 located within the body portion 11a of the target 11, the return circulation of water being effected through the space between the exterior of the tube 55 and the interior wall of the support arm 12. Fluid connections such as indicated at 57 and 58 in Fig. 1 are provided for supply and discharge of the cooling fluid, suitable rubber hoses or other flexible conduits being connected thereto.

In the operation of the device a rotation of the pulley 42 at a suitable speed is secured through the agency of a belt drive or the like, causing a gyratory movement of the support arm 12, the radius of gyration being determined by the setting of the plate 46 and the bearing 44 with respect to the center of rotation of the head 43.

The radius of gyration, or, more properly, the half apex angle of the cone of gyration, is such that the radius of the circular path of translation of the center of the target face 11b is consider-

ably greater than the radius of the area of electron bombardment on the target, so that any particular portion of the target face which is scanned by the electron stream is cyclically exposed to electron bombardment for a relatively short period and is maintained out of electron bombardment for a relatively long period. Owing to the fact that the gimbal ring 16 and the pins 15 and 17 prevent actual rotation of the arm 12 with respect to the tube housing, there is no rotative strain placed upon the bellows 21, said bellows serving to provide the desired vacuum seal between the standard 13 and the arm 12 while permitting free relative angular movement between these parts during the gyrating or revolving movement of said arm 12.

In Fig. 2a I have illustrated the target 11 in full lines corresponding to the full line position thereof shown in Fig. 2 and have shown in dot-dash lines at 11' and 11'' the corresponding positions of the target when the support arm has been moved to positions 120° successively removed from the position shown in full lines. The electron stream indicated in dot-dash lines at E in Fig. 2 is fixed in space, and hence the "focal spot" (where the electron stream impinges upon the target surface) may be caused to be fixed in space (with respect to other stationary objects in the room in which the X-ray tube is located). Due to the nearly translatable movement of the face 11b of the target 11, the target is moved with reference to the focal spot in such manner that said focal spot is swept over an annular surface represented by the shaded ring 25 in Fig. 2a, the focal spot being indicated by the double cross-hatched circle 26. The center point of the target 11 is indicated by the dot-dash cross at c, c', and c'' for the several positions shown at 11, 11', and 11'', and the positions occupied by the focal spot 26 are indicated by the dot-dash circles 26' and 26'' within the shaded area 25, showing the effective progression of the focal spot 26 over the target 11 as said target moves through the positions shown at 11' and 11'', respectively.

The rate of gyration of the target 11 will depend upon the power input and the ratio of areas of the focal spot and the annulus traversed thereby, and will in general be so established with respect to a given power input that the circulated cooling fluid will keep the inside wall of the target cool enough so that the heat produced at a given position of the focal spot with respect to the annulus 25 will be conducted away from the outer surface of the target in one gyration of the target assembly, without exceeding safe values of temperature on the target surface, i. e., by the time the focal spot is again impinging upon the same portion of the target. It will be appreciated that focal spots are not uniform over their entire area, due to the emission characteristics of the cathode filament, and local hot spots are very frequently present. For this reason the target is preferably gyrated at a somewhat faster rate than that theoretically called for by a focal spot which is uniformly loaded, to provide a factor of safety. The theoretical considerations and mathematical treatment of the thermal problem involved in X-ray assemblies which provide a mobile focal spot either by actual movement of the anode or by movement of the cathode, are set forth in July 1935 issue of the "Review of Scientific Instruments," published by the American Institute of Physics, of which I am a co-author.

The tube sections 3 and 4 are above described as of porcelain, and the tube body is formed in three sections. It will be appreciated that this construction is not essential to the invention and was merely a matter of practical expediency in the actual construction of the device, in which ready assembly and dismantling of the structure was desirable. It will be comprehended that the tube body may be formed as an integral envelope, of glass or other suitable material. The device is preferably provided with adequate shielding means whereby only such X-rays as are to be used are allowed to escape from the envelope, such shielding means being indicated about the cathode-anode assembly in Fig. 2, and a suitable aperture 27 being left in a portion of the shielding which encompasses the center section 2 to serve as a window for the useful X-rays. Similarly, in order to prevent escape of X-rays through the end of the tube, as well as to prevent undue heating of the soldered joints located adjacent to the pivotal mounting of the arm 12, I preferably provide an annular lead shield 28 about the arm 12 forwardly of such pivotal mounting, said shield being conveniently carried on the standard 13 through the agency of an extension 29 secured thereto. Fig. 1 also illustrates the provision of a diffusion pump for maintaining the desired condition of reduced pressure within the tube body, and under some circumstances I prefer to use a suitable adsorbing medium such as a charcoal trap for the purpose of adsorbing vapors which may be emitted from the gasket material or the diffusion pump. The electrical connections to the cathode filament and to the anode are in accordance with the conventional practice in the art.

The length of the support arm 12 from the center of pivotal support thereof to the target face 11b is preferably so selected with respect to the extent of translatory movement required at the target face that the angle which the target face makes with the electron stream E does not vary to a large extent, although said target face may conveniently be formed as a spherical cap whose center is located at the pivotal center of the arm 12. The use of a small apical angle of the cone swept out in the gyrating movement also avoids excessive reversing stresses on the bellows 21, thus lengthening its life before failure by fatigue.

While I have delineated but a single form of pivotal mounting for the anode support arm 12 and a single form of driving means for producing the desired nearly circular translatory movement of the target face, it will be apparent to one skilled in the art that modifications may be made in these specific considerations without departing from the spirit and contemplation of the invention. It will further be appreciated that the device may be caused to extend vertically, or at any other desired angle to the horizontal, depending upon the particular construction desired. When particularly heavy target structures are employed, it may be desirable to dispose the axis of the target support arm in a generally vertical direction, whereby the translatory motion produced in the target will be more symmetrical owing to the absence of distorting forces resulting from the force of gravity.

I claim:

1. An X-ray generating device which comprises: an evacuated envelope; a tubular standard secured to said envelope and extending interiorly thereof, said tubular standard cooperating with said evacuated envelope to define a housing structure for said device; a target member dis-

posed within said envelope; an elongated target support arm carrying said target member and pivotally secured to said standard at a point outwardly removed from said target member; flexible metallic sealing means hermetically secured to said standard and said support arm adjacent the point of pivotal attachment of said support arm; a cathode member disposed within said envelope and adapted to produce a stream of electrons directed toward and against said target member; driving means for producing gyratory movement of said support arm to cause the axis thereof to describe a cone having its apex at the center of pivotal support of said arm and thereby cause said target to undergo approximately a circular motion of translation, in the absence of actual rotation, while remaining in position to receive said electron stream, whereby the focal spot produced by said electron stream on said target is caused to describe a cyclic path on the surface of the target; and fluid circulating means associated with said target member for conducting heat therefrom.

2. An X-ray generating device which comprises: an elongated envelope; a tubular standard secured to said envelope adjacent one end thereof and extending interiorly thereof in the direction of the length of said envelope; a target member disposed within said envelope; an elongated target support arm carrying said target member and extending within said tubular standard; pivotal supporting means for said support arm mounted on said tubular standard adjacent the inner end thereof; flexible sealing means disposed adjacent said pivotal supporting means and connected to said tubular standard and to said support arm and cooperating with said envelope and said tubular standard and support arm to seal the interior of said envelope from the atmosphere and from the space within said tubular standard; a cathode member disposed within said envelope and adapted to produce a stream of electrons directed toward and against said target member; driving means for producing gyratory movement of said support arm to cause the axis thereof to describe a cone having its apex at the center of pivotal support of said arm and thereby cause said target to undergo approximately a circular motion of translation, in the absence of actual rotation, while remaining in position to receive said electron stream, whereby the focal spot produced by said electron stream on said target is caused to describe a cyclic path on the surface of the target; and fluid circulating means associated with said target member for conducting heat therefrom.

3. The structure set forth in claim 2, and comprising in addition, counterbalancing means associated with said driving means and located exteriorly of said envelope in position to establish a dynamic balance in said driving means and said elongated target support arm.

4. An X-ray generating device which comprises: an evacuated envelope; a tubular standard secured to said envelope and extending interiorly thereof, said tubular standard cooperating with said evacuated envelope to define a housing structure for said device; a target member disposed within said envelope; an elongated target support arm carrying said target member and pivotally secured to said standard at a point outwardly removed from said target member; flexible metallic sealing means hermetically secured to said standard and said support arm adjacent the point of pivotal attachment of said

support arm; a cathode member disposed within said envelope and adapted to produce a stream of electrons directed toward and against said target member; driving means for producing gyratory movement of said support arm to cause the axis thereof to describe a cone having its apex at the center of pivotal support of said arm and thereby cause said target to undergo approximately a circular motion of translation, in the absence of actual rotation, while remaining in position to receive said electron stream, whereby the focal spot produced by said electron stream on said target is caused to describe a cyclic path on the surface of the target; fluid circulating means associated with said target member for conducting heat therefrom; and means for varying the direction of the longitudinal axis of said tubular standard with respect to the position of said cathode member and including a flexible metallic sealing member hermetically secured to said standard and to said envelope at the position of attachment of said standard to said envelope.

5. An X-ray generating device which comprises: an evacuated envelope; a tubular standard secured to said envelope and extending interiorly thereof, said tubular standard cooperating with said evacuated envelope to define a housing structure for said device; a target member disposed within said envelope; an elongated target support arm carrying said target member and pivotally secured to said standard at a point outwardly removed from said target member; flexible metallic sealing means hermetically secured to said standard and said support arm adjacent the point of pivotal attachment of said support arm; a cathode member disposed within said envelope and adapted to produce a stream of electrons directed toward and against said target member; driving means for producing gyratory movement of said support arm to cause the axis thereof to describe a cone having its apex at the center of pivotal support of said arm and thereby cause said target to undergo approximately a circular motion of translation, in the absence of actual rotation, while remaining in position to receive said electron stream, whereby the focal spot produced by said electron stream on said target is caused to describe a cyclic path

on the surface of the target; and fluid circulating means associated with said target member for conducting heat therefrom, said driving means comprising driving head means rotatably secured to said housing structure adjacent the outer end of said tubular standard and provided with a radially adjustable journal bearing in rotative sliding engagement with said elongated target support arm.

6. An X-ray generating device which comprises: an evacuated envelope; a tubular standard secured to said envelope and extending interiorly thereof, said tubular standard cooperating with said evacuated envelope to define a housing structure for said device; a target member disposed within said envelope; an elongated target support arm carrying said target member and pivotally secured to said standard at a point outwardly removed from said target member; flexible metallic sealing means hermetically secured to said standard and said support arm adjacent the point of pivotal attachment of said support arm; a cathode member disposed within said envelope and adapted to produce a stream of electrons directed toward and against said target member; driving means for producing gyratory movement of said support arm to cause the axis thereof to describe a cone having its apex at the center of pivotal support of said arm and thereby cause said target to undergo approximately a circular motion of translation, in the absence of actual rotation, while remaining in position to receive said electron stream, whereby the focal spot produced by said electron stream on said target is caused to describe a cyclic path on the surface of the target, said driving means comprising driving head means rotatably secured to said housing structure adjacent the outer end of said tubular standard and provided with a radially adjustable journal bearing in rotative sliding engagement with said elongated target support arm; counterbalancing means secured to said driving head means in position to establish a dynamic balance in the rotative and gyratory portions of said device; and fluid circulating means associated with said target member for conducting heat therefrom.

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