Aug. 6, 1940.

J. W. M. DU MOND

2,209,963

X-RAY GENERATING DEVICE

Filed June 18, 1938

4 Sheets-Sheet 1

Fig. 1

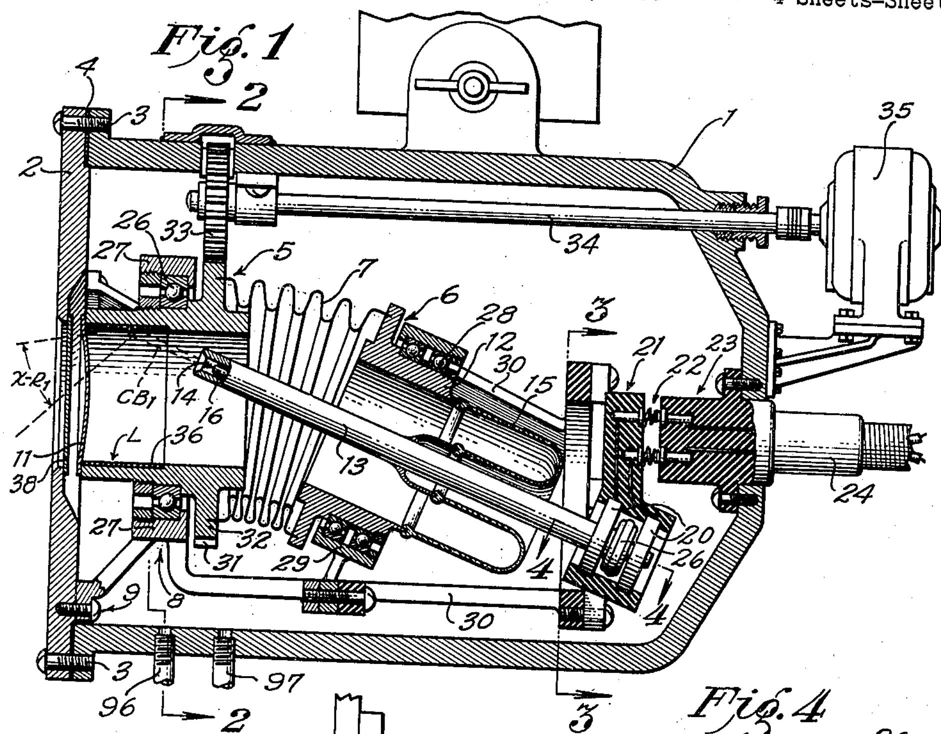


Fig. 2

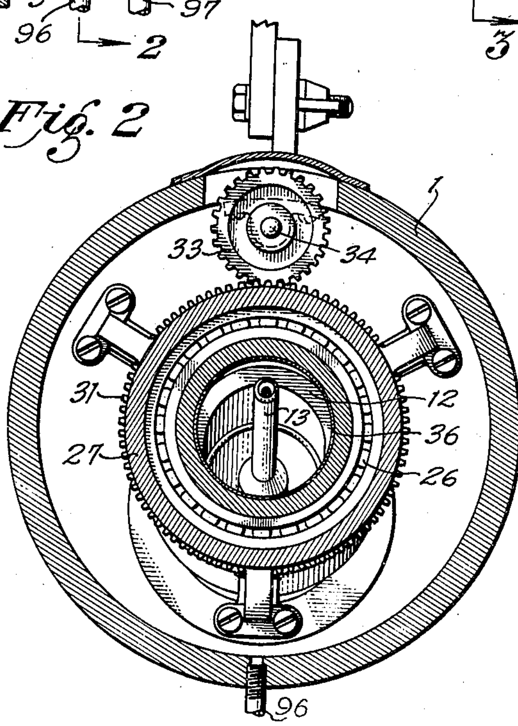
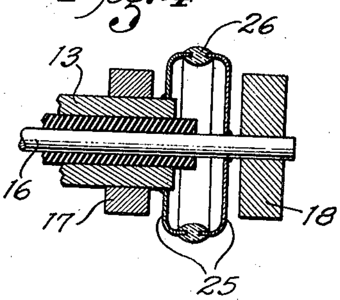


Fig. 4



JESSE W. M. DuMOND,
INVENTOR.

BY Arthur P. Knight and Alfred W. Knight
ATTORNEYS

Aug. 6, 1940. J. W. M. DU MOND **2,209,963**

X-RAY GENERATING DEVICE

Filed June 18, 1938 4 Sheets-Sheet 2

Fig. 8

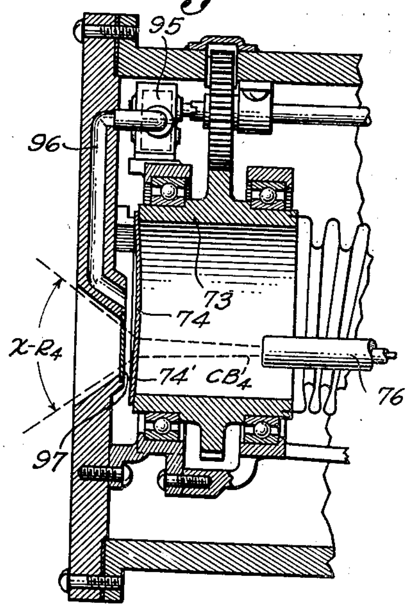


Fig. 9

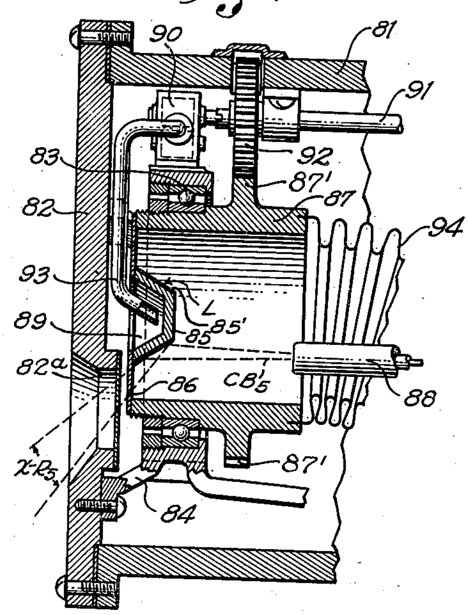
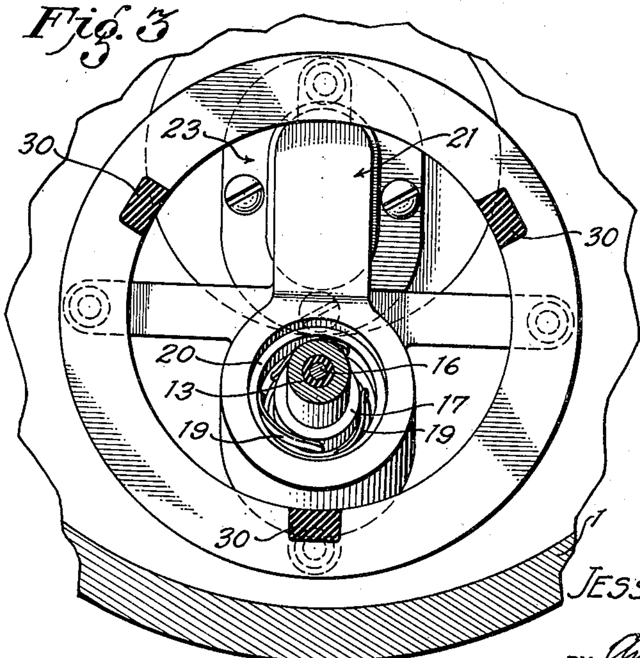


Fig. 3



JESSE W. M. DUMOND,
INVENTOR.

BY Arthur P. Knight and Alfred W. Knight
ATTORNEYS

Aug. 6, 1940. J. W. M. DU MOND 2,209,963
X-RAY GENERATING DEVICE
Filed June 18, 1938 4 Sheets-Sheet 3

Fig. 5

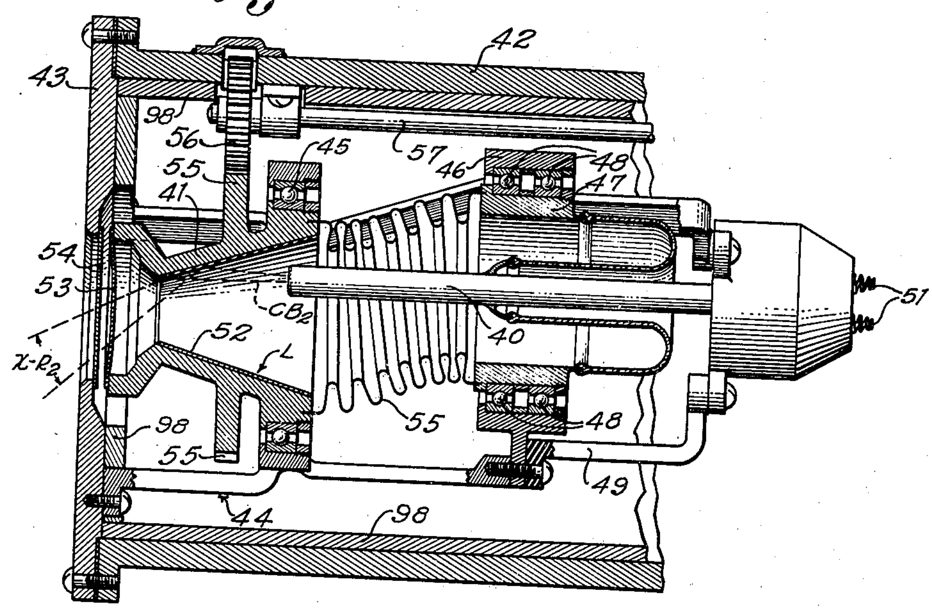


Fig. 10

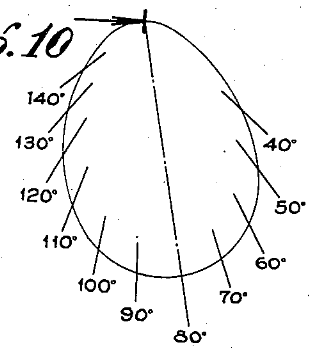
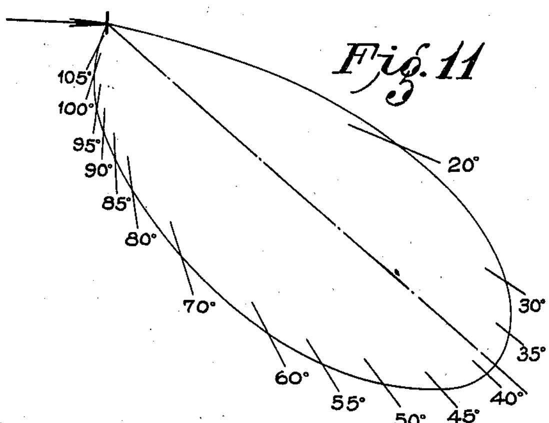


Fig. 11



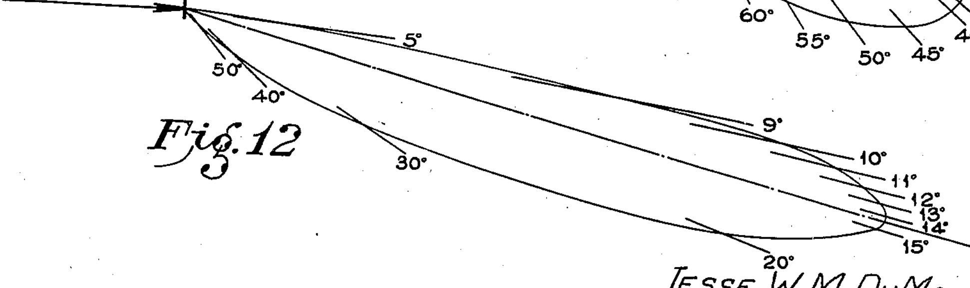


Fig. 12

JESSE W. M. DUMOND,
INVENTOR.
BY Arthur P. Knight and Alfred W. Knight
ATTORNEYS

Aug. 6, 1940.

J. W. M. DU MOND

2,209,963

X-RAY GENERATING DEVICE

Filed June 18, 1938

4 Sheets-Sheet 4

Fig. 6

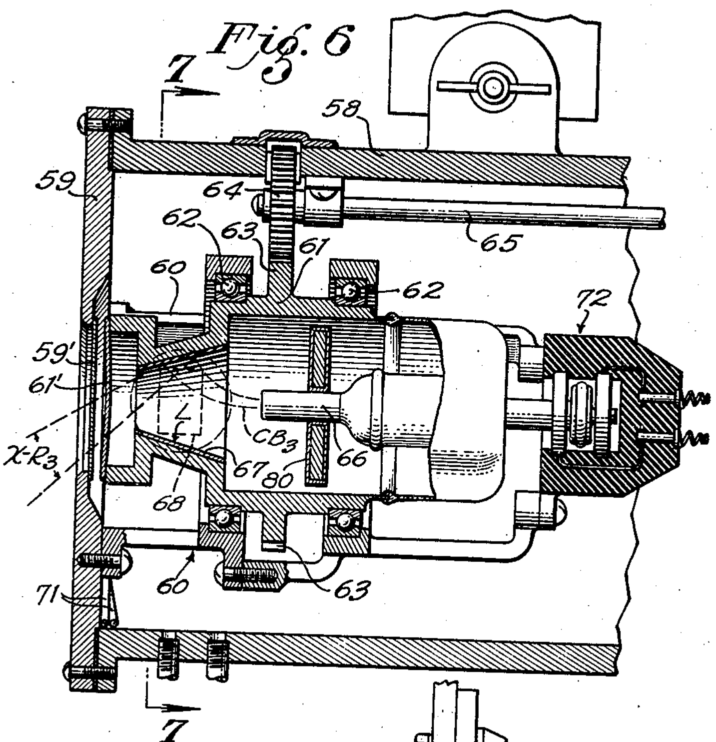
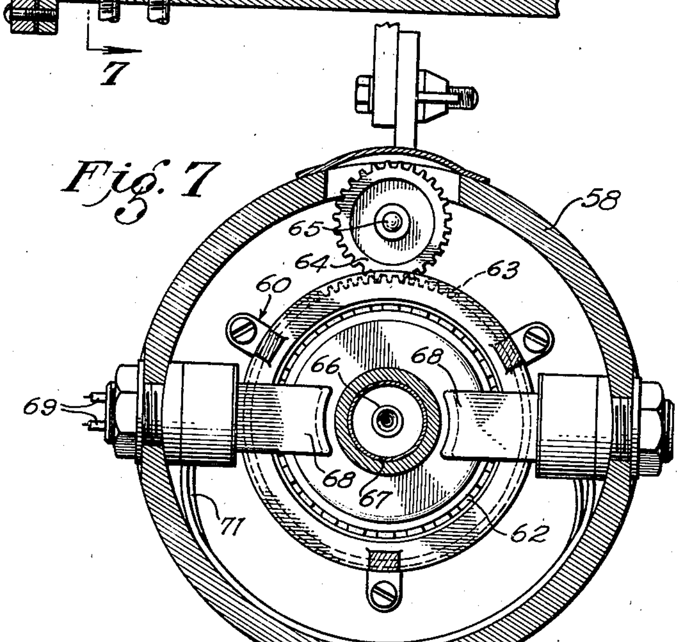


Fig. 7



JESSE W. M. DU MOND,
INVENTOR.

BY Arthur P. Knight and
Alfred W. Knight
ATTORNEYS

Patented Aug. 6, 1940 2,209,963

UNITED STATES PATENT OFFICE

2,209,963

X-RAY GENERATING DEVICE

Jesse W. M. Du Mond, Pasadena, Calif., assignor to California Institute of Technology, Pasadena, Calif., a corporation of California

Application June 18, 1938, Serial No. 214,483

17 Claims. (Cl. 250—148)

This invention relates to X-ray tube constructions, and pertains more particularly to X-ray tube constructions in which continuous relative movement is obtained between the target surface and the focal spot of the electron beam from the cathode.

One of the particular objects of the present invention is to provide an X-ray tube adapted for operation under very high power input conditions, over extended periods, without detriment.

A further object of the invention is to provide an X-ray tube employing a focal spot of smaller projected size than has been hitherto possible in high power X-ray tubes, whereby radiographs of greater definition are obtained, due to a reduction in the geometrical unsharpness of the radiographic images formed by the tube.

A further object of the invention is to provide an X-ray tube structure in which the emission of X-rays from the target is obtained in a direction such as to utilize the maximum quantity of generated X-rays in radiography.

A further object of the invention is to provide a movable anode X-ray tube which is completely shielded internally against the escape of unwanted X-rays.

A further object is to provide a tube construction in which the relatively movable parts are mounted in bearing means located externally of the exhausted area, wherefore bearing troubles may be reduced to an absolute minimum. A further object of the invention is to provide a movable anode X-ray tube construction which is of shock-proof design.

A further object of the invention is to provide a rotatable X-ray tube construction mounted within an enclosed housing on bearing means disposed wholly outside the evacuated structure, such enclosed housing being adapted to contain a body of fluid of high dielectric strength which will serve as an insulating medium, a cooling medium, and as a lubricating agent for the bearing means.

A further object is to provide a structure characterized by a complete freedom from vibration due to unbalanced rotating parts.

A further object of the invention is to provide an X-ray tube construction embodying a rotating target member in which positive and continuous circulation of cooling fluid is provided adjacent all portions of the construction which are subjected to heating, wherefore the operating temperature of the device may be kept at an advantageously low value under materially greater power input values than have hitherto been obtained.

A further object of the invention is to provide an X-ray tube construction having a rotatable anode member provided with a target surface portion of extended area located at points radially removed from the axis of rotation of said anode member and movable therewith in a fixed annular path, together with a cathode structure adapted to generate an electron beam of small cross-sectional area which is directed into impingement upon the target surface portion from one side of said path of rotation as a small "focal" spot", resulting in the production of X-rays directed away from the point of such impingement at the other side of the path of rotation. The electron impingement in the small "focal spot" on the rotating target portion of the anode results in a "scanning" of the entire target surface portion, and, inasmuch as the "focal spot" remains substantially fixed in space and the target surface portion rotates in its fixed annular path under impingement by the cathode beam, this "scanning" by the focal spot results in a distribution of the heating effect of the electron stream upon a relatively extended area of the target while restricting the projected area of the focal spot (which affects the geometrical sharpness of the structure for radiography) to a minimum.

The previously suggested forms of moving anode X-ray tubes have, in general, provided an anode construction comprising a large mass of metal capable of absorbing a relatively large quantity of heat, and have relied upon a short enough exposure to the electron beam so that any one portion of the target surface will not be allowed to reach a dangerous operating temperature. This form of device has relied upon bearing members disposed wholly within the evacuated space, and it has been found that the useful life of these particular tubes is unpredictable. It will be appreciated that if the bearings should stick, and the electron beam be allowed to impinge upon the target for any significant length of time, the allowable operating temperature will be exceeded almost instantaneously and serious damage to the equipment will result. An additional defect has resulted from the difficulty of cooling the target member at a sufficiently rapid rate to permit the device to be used for any protracted period. The conventional cooling arrangement provided is that of telescoping heat-exchange devices which depend upon loss of heat from the target member by radiation into a fixed member which may be subjected to water cooling. The problem of causing any quantity of heat to be transmitted across the evacuated space, at the small temperature differences which are experienced, is apparent.

Several features are now felt to be needed in commercial radiography, both of human bodies and for the examination of massive castings, and the like. Among these requirements may be enumerated:

(*a*) The provision of a smaller focal spot (to decrease the geometrical unsharpness of the images formed by the X-rays);

(*b*) The provision of sufficient intensity of radiation as to make possible short exposure times compared to the movement of body organs, that is, to take care of movements on the order of centimeters per second;

(*c*) The provision of a moving anode structure which will allow the target to move its surface over a distance many times the diameter of the focal spot during the time of exposure;

(*d*) The focal spot must be stationary in space (relative to objects in the room), especially as regards motions that would blur the radiographic image;

(*e*) Increased high long-time average heat dissipation capacity from the target, whereby sustained high input energies may be secured;

(*f*) Low first cost and long life.

The above features are secured according to the present invention by provision of a rotatable anode structure carrying a target face of extended area formed as a surface of revolution, removed from the axis of rotation of said anode, and adapted to be moved in an annular path, together with means for generating and directing an electron stream into impingement with the target face at a position substantially fixed in space and wholly from one side of said path, resulting in the production of X-rays directed away from said target face at the other side of said path.

Other features and objects of the invention will be brought out in the ensuing description of certain preferred embodiments, or will be apparent therefrom. Referring to the accompanying drawings:

Fig. 1 is a longitudinal vertical section of one form of the present X-ray tube, showing the use of a cylindrical target member, the cathode member being so established as to direct the cathode beam against the interior surface of the anode member and at an angle to the axis of rotation of said member;

Fig. 2 is a transverse section thereof taken on line 2—2 in Fig. 1;

Fig. 3 is a transverse detail thereof taken on line 3—3 in Fig. 1;

Fig. 4 is a detail sectional view of a portion thereof, taken on line 4—4 in Fig. 1;

Fig. 5 is a view corresponding to Fig. 1, showing a further modification of the invention in which the anode member is of conical configuration and the cathode member is mounted for rotation about an axis extending parallel to, but offset with respect to, the axis of rotation of the anode member;

Fig. 6 is a partly broken-away longitudinal section, corresponding to that shown in Fig. 1, illustrating a modified form of construction in which the conical anode and the cathode supporting structures are mounted for rotation upon a common axis, and means are provided for deflecting the electron beam into impingement against the internal surface of the anode member;

Fig. 7 is a transverse section taken on line 7—7 in Fig. 6;

Figs. 8 and 9 are fragmentary views corresponding to the left-hand end of Figs. 1, 5, or 6, showing further modifications of an X-ray tube structure according to the present invention; and

Figs. 10, 11, and 12 illustrate the classical theoretical law of X-ray (continuous spectrum) emission at low, medium, and high voltages, respectively, for electrons decelerated along their original direction of motion.

Referring to Figs. 1 through 4, one embodiment of the invention is illustrated as comprising a housing **1** provided with a removable cover member **2** secured to the housing **1** in any suitable manner as through the agency of screws **3**, a fluid-tight joint being preferably provided as through the agency of a gasket member **4**. The X-ray tube construction comprising a rotatable anode member **5** and a rotatable cathode assembly **6**, which in this instance are joined by a flexible gas-tight tube member **7** such as a "Sylphon" bellows, is mounted on a framework **8** which is independent of housing **1** and is preferably mounted upon the cover **2** as at a plurality of spaced points **9**. This construction provides for removal of the X-ray tube assembly from the body of the housing for inspection or repair, the electrical connection to the cathode member being provided with male and female contact elements as more particularly described hereinafter.

The X-ray tube proper is defined by the anode member **5**, which is of generally conical or cylindrical construction and includes a thin window or diaphragm **11** secured at the outer end thereof, the flexible tube member **7** and the cathode assembly **6**, which includes a hub member **12** carrying the cathode stem **13** provided with a filament **14** at its inner end, the stem **13** being suitably insulated from the hub **12** as through a glass seal **15**. The necessary electrical connection to the filament **14** may be provided by making the stem **13** of tubular construction and providing a central conductor **16** extending along the length of the stem **13** and insulated therefrom. The stem **13** and conductor **16** may be connected to the filament supply energy through the agency of contact rings **17** and **18** secured to the stem **13** and conductor **16** and engaged by suitable contact fingers such as are shown at **19** in Fig. 3, which are electrically connected to conductor rings **20** mounted in an insulating support **21** terminating in a plug connector **22** adapted to mate with a connecting socket **23** mounted on the housing **1** and suitably associated with a high tension lead-in cable **24**. A vacuum seal may be provided between the tube **13** and the member **16** according to conventional practice, as by providing thin metal diaphragm members **25** hermetically sealed to the respective members **13** and **16** and hermetically joined as by means of a glass sealing ring **26**, this construction being more particularly illustrated in detail in Fig. 4.

The anode member **5** is mounted for rotation in the housing **1** as through the agency of a bearing member **26** mounted on a support frame **27** which is secured to the framework **8**. The hub member **12** of the cathode assembly is similarly mounted in bearing means **28** carried by a supporting ring **29** mounted on a rearwardly projecting portion of the interior framework. The conductor rings 20 and the connector member 21 may be carried on the rearward projection 30 of the frame assembly, as is more particularly illustrated in Fig. 3, such portion being preferably formed of non-conductive material such as "Bakelite."

Suitable means are provided for effecting rotation of the X-ray tube construction, as by providing a gear member 31 located on a flange portion 32 of the anode member 5, engaged by a driving gear 33 carried on a shaft 34 and driven by a suitable motor 35, which may be located exteriorly of the housing 1.

According to this construction, the cathode assembly is mounted for rotation about the axis which intersects the axis of rotation of the anode member 5, in position to direct the cathode beam CB_1 upon the inner wall 36 of the hollow anode, and the resulting X-rays $X\text{-}R_1$ will be directed outwardly through the window 11, another window being provided in the cover 2 as at 38 to facilitate the transmission of a useful portion of such X-rays.

The provision of the bearing means 26 and 28 wholly exteriorly of the evacuated envelope, and the disposition of the rotating assembly within the housing 1 provide for continuous lubrication of such bearing means by the submerging fluid contained within the housing. This fluid is relied upon for (1) insulation of the high-tension portions of the device from the housing, which is grounded, (2) lubrication of the bearing means, and (3) cooling of the X-ray tube and particularly the anode portion thereof. Suitable inlet and outlet connections may be provided, as at 96 and 97, if desired, for continuous supply and withdrawal of the submerging fluid, in association with an external heat-exchange or cooler device, although in general sufficient cooling of the fluid body is obtained by direct radiation from the housing.

The construction illustrated in Fig. 5 is comparable to that shown in Figs. 1 to 4, with the exception that the cathode 40 is mounted for rotation about an axis which is parallel to, but offset from, the axis of rotation of the anode member 41. This construction may comprise a housing 42 provided with a removable cover 43 corresponding to the cover 2 above, which carries a supporting structure 44 on which the anode member 41 is rotatably mounted as through means of bearings 45, and a second supporting construction is provided as at 46 on a rearwardly extending portion of the support 44, carrying the cathode assembly 47 through the agency of bearings 48. A further extension of the supporting construction may be provided as at 49, preferably of insulating material, such as "Bakelite," for example, on which is mounted a connector ring assembly such as that shown at 17 through 20 in connection with Fig. 1. This portion of the device may terminate in a male plug connector corresponding to the member 22 above, and provided with spring contact members 51 which are adapted to engage with a suitable female connector which may be mounted on the housing 42 in accordance with the teaching in connection with the first form of the invention.

The anode member 41 is shown as having a conical internal face 52 having portions lying along the projection of the axis of the cathode member 40 in position to receive the cathode beam therefrom, as indicated at CB_2. A suitable window member is provided as at 53 across the forward end of the anode member, through which the X-rays are projected, as at $X\text{-}R_2$ and a correspondingly positioned window 54 is provided in the cover 53. A flexible tube connector will be provided between the anode 41 and the cathode hub 47, as at 55, corresponding to the flexible tube 7 shown in the first form of the device, and suitable driving means for the rotatable tube assembly will also be provided, as through the agency of gear members 55 and 56, the latter mounted on the shaft 57 as in the first-described form of the invention.

The form of device shown in Figs. 6 and 7 may comprise a housing 58 provided with a cover member 59 carrying a support 60 on which the anode member 61 is mounted for rotation as through the agency of bearings 62, the anode member being suitably driven through the agency of gears 63 and 64 and shaft 65. The cathode member 66 is disposed for coaxial rotation with the anode 61, and the electron beam CB_3 resulting therefrom is deflected into engagement with the target surface 67 of the anode 61 through the agency of opposed magnet means 68 adapted to establish a magnetic field substantially intersecting the axis of rotation of the cathode and anode.

The magnet means 68 may be formed as permanent magnets, if desired, although I have illustrated the use of electromagnets provided with external connecting leads 69 and interconnecting conductors 71. The necessary connection of the filament supply current may be provided as at 72 through the agency of a connector means of the type shown at 17 through 20 in Figs. 1 to 4. Suitable windows will be provided as at 61′ and 59′ at the end of the anode 61 and on the cover 59 respectively, for transmission of the generated X-rays $X\text{-}R_3$.

The type of tube construction illustrated in Fig. 8 is structurally comparable to that shown in Fig. 5, with the exception that the anode member 73 is made substantially cylindrical in shape and the inner substantially plane surface 74′ of the window 74 is employed in the role of target member, the cathode beam CB_4 from the cathode 76 being directed parallel to the axis of rotation of the anode but displaced therefrom, as shown, so as to sweep out an annular path on the surface 74′, or, alternatively, the cathode beam may be directed at an angle to such axis after the manner shown in the first form of the invention.

The form of the invention shown in Fig. 9 may comprise a housing 81 provided with a removable cover member 82 carrying the anode-end bearing 83 and the corresponding cathode-end bearing (not shown) through the agency of a suitable supporting frame 84, corresponding to the frame 8, above. The anode 85 is shown as a truncated cone-shaped member, mounted concentrically of the bearing 83 through the agency of an electrically-conductive X-ray-permeable window member 86 and an anode support member 87 mounted on the bearing 83. A cathode is shown at 88, which may be mounted in a manner comparable to that shown and described in connection with Fig. 5, or alternatively and equivalently, after the manner of the cathode 13 in the first form of the invention. The cathode 88 is adapted to produce a cathode beam CB_5, which is directed into impingement with the inclined annular wall 85′ of the anode, resulting in the generation of an X-ray beam $X\text{-}R_5$ through the window member **86**. The cover **82** is provided with a window member **82**a in position to permit the passage of the beam X-R_5 exteriorly of the housing **81**, as will be apparent to one skilled in the art.

The anode **85** is preferably hollowed out at its outer side, to form a recess **89**, and the cooling fluid provided about the X-ray structure may be positively circulated into cooling contact with such anode, as by means of a gear pump **90** mounted on the frame **84** and driven by the same member which effects rotation of the X-ray structure, such as a driven shaft **91** carrying a gear **92** meshing with a gear portion **87'** integral with the anode support member **87**. The intake supply line (not shown) for the pump **90** will preferably communicate with a lower portion of the housing **1** so as to insure a continuous supply of cooling fluid thereto, and the discharge line **93** for the pump **90** may be directed into the recess **89** adjacent the axis of rotation of the anode.

The cathode supporting structure will be hermetically joined to the anode support structure **87** through the agency of a flexible tube **94**, corresponding to the tube **7** in the first form of device and the balance of the tube structure, including the current supply connections, may be comparable to that shown in Fig. 5.

The target window **74** in the form of structure illustrated in Fig. 8 may be cooled by a stream of cooling fluid, if desired, in a manner comparable to that employed in connection with Fig. 9, as through the agency of a gear pump **95** mounted on the bearing support framework and operatively associated with the driven shaft member provided for rotation of the anode assembly **73**. The pump **95** may discharge through a passage **96** in the cover portion of the housing, at approximately the center of the window **74**. The cover is preferably provided with an X-ray-permeable window member **97** in position to transmit the X-ray beam X-R_4.

Positive circulation of cooling fluid to any desired portion of the anode structure may be provided for the forms illustrated in Figs. 1 through 7, if desired, as will be apparent.

In Figs. 10, 11, and 12 I have illustrated, graphically, the classical theoretical angular distribution law of continuous spectrum X-ray emission resulting from electrons suddenly decelerated in the direction of their motion, as by impingment upon a thin target member, at various electron speeds obtained by the use of various voltages. These curves represent, respectively, the distribution pattern of X-rays produced by electrons at three different speeds, Fig. 10 illustrating that obtained at comparatively low voltages, that shown in Fig. 11 illustrating the pattern obtained at approximately 50,000 volts, and the curve in Fig. 12 illustrating the pattern obtained at approximately 500,000 volts. These curves are obtained from the classical theoretical formula:

$$I=\frac{1}{4\pi}\,\frac{a^2e^2}{r^2C^3}\cdot\frac{\sin^2\theta}{[1-(v/C)\cos\theta]^6}$$

In this formula: I=the intensity in ergs per cm^2 per second, measured at distance r and time r/C seconds later than the time when a occurs; a=the acceleration or deceleration of the electron; e=the charge of the electron; C=the velocity of light; θ=the angle between the cathode ray (direction of original motion of the electron) and the X-ray direction; and v=the velocity of the electron. In this equation, the expression $[1-(v/C)\cos\theta]^6$ is responsible for the forward tilting of the direction of maximum emission as the electron speed is increased.

The actual emission from X-ray targets actually deviates from this formula because the electrons are not all decelerated exactly in the direction of their original motion; this formula does, however, account for the increased forward intensity as the cathode rays (electrons) approach the velocity of light.

From these curves it may be seen that at high electron voltages the direction of maximum emission of the X-ray approaches more and more the original direction of the generating electron. Advantage is taken of this physical fact in the X-ray tubes of the present invention, wherein the target surface to be impinged by the electrons is caused to move in an annular path radially displaced from the axis of rotation of the anode member, and the electron beam is brought into impingement upon the target surface from one side of said annular path while the utilized X-ray beam resulting from such impingement is directed away from the target surface at the other side of said path and in the direction in which the maximum emission occurs. This feature makes it possible to cause the X-ray radiation to leave the X-ray tube construction at the end of the tube rather than at the side of the tube according to conventional construction, and makes possible the provision of anode members which may constitute a portion of the X-ray tube envelope and which, consequently, may be directly exposed to the cooling action of a fluid body. In each form of apparatus herein described, the anode member may be completely immersed in a body of fluid of high dielectric strength such as oil, contained within the housing structure, and this submergence, taken with the circulatory effects produced by the rapid rotation of the tube structure, results in the rapid dissipation of heat from the anode body.

The form shown in Figs. 6 and 7 is more adapted to the production of X-rays at comparatively low electron velocities, while the form illustrated in Fig. 8 is adapted to utilize the maximum voltage practicable in X-ray tubes, inasmuch as the X-ray beam resulting from the impingement of the cathode beam **75** may extend coaxially with such beam, if necessary, without absorption by shadowing portions of the anode body.

The forms illustrated in Figs. 1, 5, and 9 are adapted for intermediate and fairly high electron voltages, and it will be appreciated that the form in Fig. 1 may be varied with respect to the angle of intersection of the axis of the cathode and anode, by the employment of modified supporting structures as will be apparent to one skilled in the art, wherefore the tube may be employed for substantially any desired range of electron voltages with maximum efficiency.

The tube constructions of the present invention admit themselves to complete internal shielding against stray X-rays, as by coating the exterior, or, preferably, as by lining the interior of the housing with a lead sheath or the like, as indicated at **98** in Fig. 5, if desired. Shield members opaque to X-rays may also be provided on the cathode stem, as indicated at **80** in Fig. 6, for example.

The electron beam is emitted from the cathode with a circular cross-section centered about the axis of rotation of the cathode member so that this rotation does not influence the shape or position of the focal spot. The oblique impingement of this beam on the anode surface gives an elongated, approximately elliptical, focal spot whose increased area on the target facilitates cooling. The oblique emergence of the utilized cone of X-rays reduces the projected area of this focal spot so as to minimize geometrical unsharpness of the images formed by the X-rays, as in radiography.

The target surface portions of the anodes employed in the present constructions may be of any desired metallic material, such as tungsten, gold, or the like, while the base portion of the anode is preferably formed of a metal having high heat conductivity, whereby the heat generated by the electron impingement will rapidly be carried away from the target surface. The target material may be formed as a layer on the anode body, as indicated at L in Figs. 1, 5, 6, and 9. The thin target employed in the form shown in Fig. 8 may comprise a base of copper foil, provided with a thin layer of gold, for example, or may be formed as a thin sheet of a relatively hard gold-silver or gold-copper alloy. Owing to the very rapid heat dissipation made possible by the present constructions, low melting-point target layers, such as of lead, may be effectively employed.

The target surface portions of the anode member are in each case removed from the X-ray-permeable window member in a direction towards the opposite end of the evacuated envelope, and in each case the origin of the cathode beam will be located at a point further removed in the same direction. The target surface portions will also in each case comprise a surface of revolution, of substantially conical configuration (it being appreciated that a cylinder, as in Fig. 1, is one limiting form of a cone, while a plane, as in Fig. 8, is the other limiting form of a cone).

The expression "adapted for rotation about a line extending along the length thereof" as employed in the claims in description of the manner in which the elongated evacuated housing is established for rotation, will be understood to include not only a straight line (as in the form shown in Fig. 6), but also a simple curved line (as in the form shown in Fig. 1), or a compound curved line (as in the forms shown in Figs. 5, 8, and 9). In each case this line about which the rotation is effected will be straight at the position of the anode and cathode members, due to the fixed rotative path of these members as defined by the bearing means, and such portions of such line may be used as reference lines to describe the position of the target surface portion, the direction of propagation of the electron beams, or the like. Determination of the optimum rate of rotation of the X-ray envelope for a given power input is primarily a thermal problem, the theoretical considerations and mathematical treatment of which, as applied to X-ray assemblies which provide a mobile focal spot (either by actual movement of the anode or by movement of the cathode) will be found in an article in the July 1935 issue of the "Review of Scientific Instruments", published by the American Institute of Physics, of which I am co-author.

In the form shown in Figs. 6 and 7 the electromagnets 68 constitute the means for directing the electron beam into impingement upon the target surface portion of the anode, while in the remaining forms reliance is placed upon a "focusing" type of cathode to project a directed beam of small cross-sectional area upon the anode. The use of modified types of cathode structures will be apparent to one skilled in the art, having in mind the particular type of focal spot desired for a particular use of the apparatus. The focal spot of the cathode beam, i. e., the area on the target member which is impinged by the cathode beam, will in each case be substantially fixed in space, to realize a low degree of geometrical unsharpness in the X-ray beams. This relative fixity in space depends, however, upon the fixity of the axes of rotation in space, and will be understood to contemplate the use of suitable supporting means adapted to secure the entire X-ray generating unit against movement during an exposure.

The electrical connections to the device, for application of high tension current to the cathode and anode, may be established in any common manner, as will be apparent to those skilled in the art. In the accompanying drawings the anode members of the several forms of device are shown as grounded (as through the bearing 26 and support 27, or through the gear 33) to the housing (such as shown at 1) which encloses the entire X-ray envelope, and the high tension side of a current-supply transformer may be connected to either of the leads communicating with the conductor rings 20, with the low tension side of such transformer being grounded to the housing. The lead connected with the other conductor ring 20 is conveniently connected to one side of a filament transformer which is associated with the main current-supply transformer at the high tension side thereof. Other methods of applying the supply voltage to the cathode and anode will be apparent to those experienced with X-ray apparatus.

Other modifications of the invention than are herein delineated and described will be apparent to skilled workers in the art, wherefore I do not choose to be limited to these specific embodiments but rather to the scope of the subjoined claims.

I claim:

1. An X-ray generating device which comprises: an evacuated envelope; a rotatable anode member defining a portion of said envelope and provided with an internal target surface portion of extended area removed from the axis of rotation of said anode member and movable therewith in a fixed annular path; means for generating and directing an electron beam, from a source located within said envelope and at one side of said fixed path, against said target surface portion at a position on said path substantially fixed in space, to cause generation of X-rays directed away from said target surface portion at the other side of said path; and external housing surrounding said evacuated envelope and adapted to contain a body of cooling fluid in contact with the exterior surface of such portions of said anode member as define a portion of said envelope, and means for rotating said anode member to cause said target surface portion to pass through said position.

2. An X-ray generating device which comprises: an elongated evacuated envelope mounted for rotation about a line extending longitudinally thereof, and provided with an annular target surface portion disposed transversely with respect to said line adjacent one end of said envelope, said envelope including an X-ray-permeable window member longitudinally removed from said target surface portion towards

said one end; means for generating and directing an electron beam towards said one end into impingement upon a restricted area upon said target surface portion at a position substantially fixed in space, from a source located within said envelope and longitudinally removed from said target surface portion towards the other end of said envelope, to cause generation of X-rays directed away from said target surface portion and through said window member; and means for rotating said envelope to cause said target surface portion to rotate through said position.

3. The X-ray generating device set forth in claim 2, and comprising in addition an external housing surrounding said evacuated envelope and adapted to contain a body of cooling fluid in contact therewith.

4. An X-ray generating device which comprises: an elongated evacuated envelope mounted for rotation about a line extending along the length thereof and provided with an anode member having a target portion of extended area adjacent one end of said envelope, said target portion comprising a surface of revolution and having an axis of rotation lying along said line adjacent said one end and being symmetrical with respect to but radially removed from said axis; means for generating and directing an electron beam towards said one end into impingement upon a restricted area on said target portion, at a position substantially fixed in space, from a source located within said envelope and spaced from said target portion in a direction toward the other end of said envelope, to cause generation of X-rays directed away from said target portion toward said one end of said envelope; and means for rotating said envelope and said anode member to cause said target portion to rotate through said position and thus effect relative movement of said restricted area of electron impingement over the extended area of said target surface portion.

5. An X-ray generating device which comprises: an elongated evacuated envelope mounted for rotation about a line extending along the length thereof, and provided with an X-ray-permeable window member at one end; a conical anode member rotatable with and forming a part of said envelope, symmetrically disposed with respect to said line at one end of said envelope and located inwardly of said window member adjacent said one end; means for generating and directing an electron beam towards said one end into impingement upon said conical anode, at a position substantially fixed in space, from a source located within said envelope and spaced from said anode member in a direction toward the other end of said envelope, to cause generation of X-rays directed away from said anode member toward said window member; and means for rotating said envelope to cause said anode member to rotate through said position.

6. An X-ray generating device which comprises: an evacuated envelope; a rotatable anode member defining a portion of said envelope and provided with an internal target surface portion of extended area removed from the axis of rotation of said anode member and movable therewith in a fixed annular path; cathode means disposed within said envelope and positioned to generate and direct a stream of electrons non-axially from a position at one side of said fixed annular path toward and against said target surface portion at a position on said path substantially fixed in space, to cause generation of X-rays directed away from said target surface portion at the other side of said path; and means for rotating said anode member to cause said target surface portion to pass through said position.

7. An X-ray generating device which comprises: an elongated evacuated envelope mounted for rotation about a line extending along the length thereof, and provided with an X-ray-permeable window member at one end; a conical anode member rotatable with and forming a part of said envelope, symmetrically disposed with respect to said line at one end of said envelope and located inwardly of said window member adjacent said one end; cathode means disposed within said envelope and positioned to direct a stream of electrons toward said one end into impingement upon said conical anode, at a position substantially fixed in space, from a point spaced from said anode member in a direction toward the other end of said envelope and non-axial with respect to the axis of rotation of said anode member, to cause generation of X-rays directed away from said anode member toward said window member; and means for rotating said envelope to cause said anode member to rotate through said position.

8. An X-ray generating device which comprises: an elongated evacuated envelope mounted for rotation about a line extending longitudinally thereof, and provided with an annular target surface portion and X-ray-permeable window means adjacent one end thereof, and including means for generating and directing an electron beam toward said one end into impingement upon said target surface portion to cause generation of X-rays directed from said target portion toward said one end and through said window member; an elongated housing member having an open end and adapted to receive said envelope; removable cover member for said housing mounted at the open end thereof; supporting means secured to said cover member and extending inwardly of said housing member, said supporting means being provided with bearing means carrying said elongated envelope, and said housing member and said removable cover member serving to define a container surrounding said envelope and adapted to hold a body of cooling fluid in contact with said envelope; and means for rotating said envelope.

9. An X-ray generating device which comprises: an elongated evacuated envelope mounted for rotation about a line extending along the length thereof, and provided with an X-ray-permeable window member at one end; a conical anode member rotatable with and forming a part of said envelope, symmetrically disposed with respect to said line at one end of said envelope and located inwardly of said window member adjacent said one end; cathode means disposed within said envelope and positioned to direct a stream of electrons toward said one end, along a line substantially parallel to the axis of rotation of said conical anode member and radially spaced from said axis, into impingement upon said conical anode at a position substantially fixed in space, from a point spaced from said anode member in a direction toward the other end of said envelope, to cause generation of X-rays directed away from said anode member toward said window member; and means for rotating said envelope to cause said anode member to rotate through said position.

10. An X-ray generating device which comprises: an evacuated envelope; a rotatable anode member defining a portion of said envelope and

provided with an internal target surface portion of extended area removed from the axis of rotation of said anode member and movable therewith in a fixed annular path; cathode means disposed within said envelope and positioned to direct a stream of electrons, from a point at one side of said fixed annular path, along a line substantially parallel to the axis of rotation of said anode member and radially spaced from said axis into impingement upon said target surface portion at a position on said path substantially fixed in space, to cause generation of X-rays directed away from said target surface portion at the other side of said path; and means for rotating said anode member to cause said target surface portion to pass through said position.

11. An X-ray generating device which comprises: an evacuated envelope; a rotatable anode member defining a portion of said envelope and provided with an internal target surface portion of extended area removed from the axis of rotation of said anode member and movable therewith in a fixed annular path; cathode means disposed within said envelope and rotatable therewith about an axis extending non-axially with respect to said first-named axis, said cathode means being positioned to direct a stream of electrons non-axially with respect to said first-named axis, from one side of said fixed annular path against said target surface portion at a position on said path substantially fixed in space, to cause generation of X-rays directed away from said target surface portion at the other side of said path; and means for rotating said envelope and said anode member to cause said target surface portion to pass through said position, said envelope being provided with a flexible side-wall portion intermediate the ends thereof and adapted to flex during rotation whereby the respective axes of rotation of the anode member and cathode means persist in their respective positions during such rotation.

12. The X-ray generating device set forth in claim 11, and comprising in addition an external housing surrounding said evacuated envelope and adapted to contain a body of cooling fluid in contact therewith.

13. An X-ray generating device which comprises: an evacuated envelope; a rotatable anode member defining a portion of said envelope and provided with an internal target surface portion of extended area removed from the axis of rotation of said anode member and movable therewith in a fixed annular path; a cathode assembly mounted for rotation about an axis inclined to the axis of rotation of said anode member and having electron emitting means positioned to direct a stream of electrons along the axis of rotation of said cathode assembly from one side of said fixed annular path toward and against said target surface portion at a position on said path substantially fixed in space, to cause generation of X-rays directed away from said target surface portion at the other side of said path; a flexible tube member hermetically sealed to said anode member and to said cathode assembly, and cooperating with the latter to define a portion of said envelope; and means for rotating said envelope to cause said target surface portion of said anode member to pass through said position.

14. An X-ray generating device which comprises: an elongated evacuated envelope mounted for rotation about a line extending along the length thereof, and provided with an X-ray-permeable window member at one end; a hollow conical anode member rotatable with and forming a part of said envelope, said anode member being provided with an internal target surface portion symmetrically disposed with respect to said line at one end of said envelope and located inwardly of said window member adjacent said one end; cathode means disposed within said envelope and positioned to direct a stream of electrons along a line substantially parallel to but removed from the axis of rotation of said anode member toward said one end into impingement upon said internal target surface portion, at a position substantially fixed in space, from a point spaced from said anode member in a direction toward the other end of said envelope, to cause generation of X-rays directed away from said target surface portion toward said window member; and means for rotating said envelope to cause the target surface portion of said anode member to rotate through said position of impingement.

15. An X-ray generating device which comprises: an elongated evacuated envelope mounted for rotation about a line extending along the length thereof, and provided with an X-ray-permeable window member at one end; a hollow conical anode member rotatable with and forming a part of said envelope, said anode member being provided with an internal target surface portion symmetrically disposed with respect to said line at one end of said envelope and located inwardly of said window member adjacent said one end; cathode means disposed within said envelope and positioned to direct a stream of electrons toward said one end from a point spaced from said anode member in a direction toward the other end of said envelope; magnet means located exteriorly of said envelope and positioned to establish a magnetic field extending through said stream of electrons to deflect said stream into impingement upon said target surface portion at a position substantially fixed in space, to cause generation of X-rays directed away from said target surface portion toward said window member; and means for rotating said envelope to cause said target surface portion of said anode member to rotate through said position of impingement.

16. An X-ray generating device which comprises: a housing member; an elongated evacuated envelope mounted for rotation within said housing member about a line extending along the length of said envelope, and provided with an X-ray-permeable window member extending transversely across one end thereof, and X-ray producing means disposed interiorly thereof to cause generation of X-rays directed through said window member; bearing means for said envelope, mounted within said housing exteriorly of said envelope; a body of lubricating fluid of high dielectric strength within said housing member and surrounding said envelope and said bearing means; and means for rotating said envelope.

17. An X-ray generating device which comprises: an elongated evacuated envelope; a rotatable anode member defining a portion of said envelope disposed adjacent one end thereof and provided with an internal target surface portion of extended area removed from the axis of rotation of said anode member and movable therewith in a fixed annular path; a cathode assembly located within said envelope and rotatable therewith about an axis which is non-axial with respect to said rotatable anode member and said cathode assembly being provided with electron-

emitting means located at a position spaced from said fixed annular path at the side thereof towards the other end of said envelope, said electron-emitting means being positioned to direct an electron stream of small cross-sectional area from said position toward and against said target surface portion at a position on said fixed annular path removed from the axis of rotation of said anode member; a flexible tube member hermetically sealed to said anode member and to said cathode assembly, and cooperating therewith to define said envelope; and means for rotating said envelope and said anode member and cathode assembly while maintaining the respective axes thereof relatively fixed.

JESSE W. M. DU MOND.