Aug. 17, 1937. H. F. MESICK 2,090,582

X-RAY TUBE

Filed Feb. 9, 1934 3 Sheets-Sheet 1

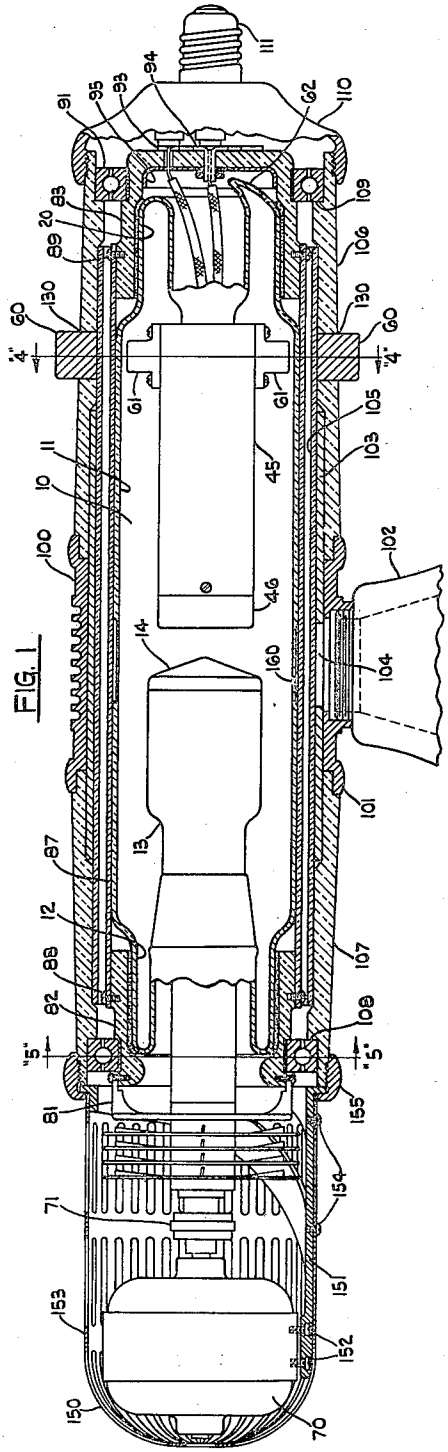

FIG. 1

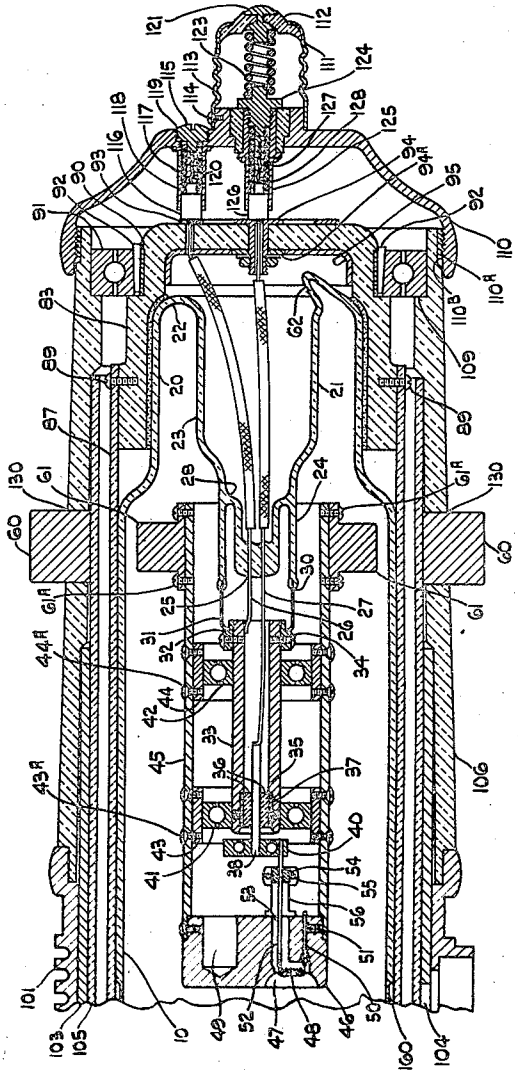

FIG. 2

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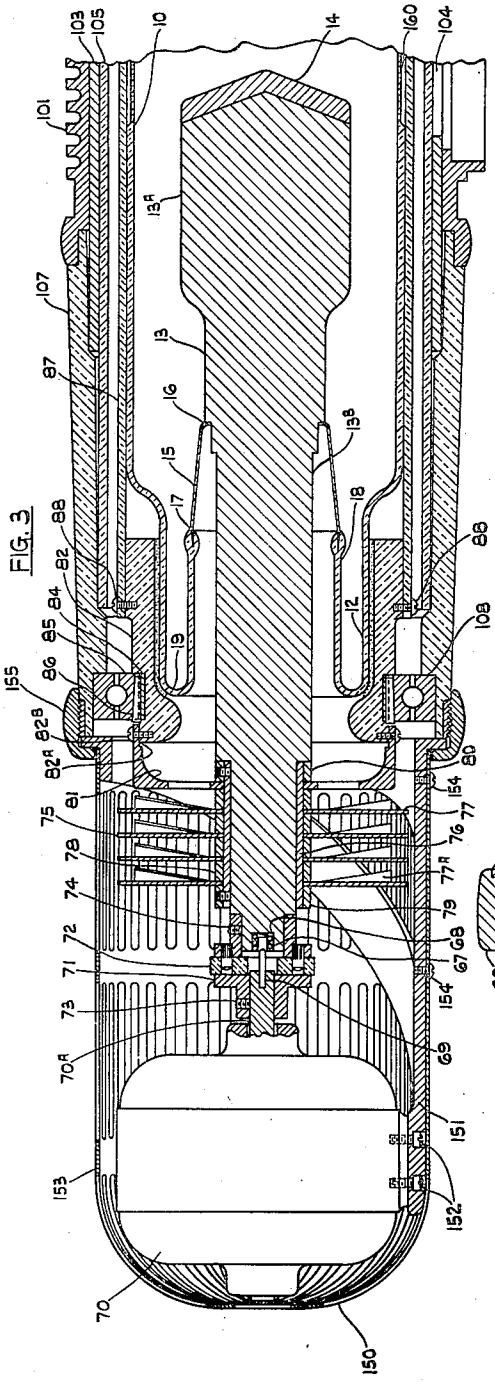

FIG. 3

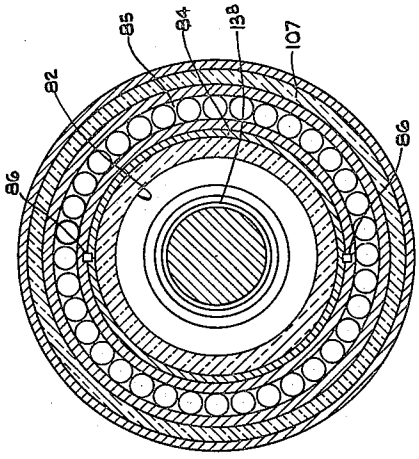

FIG. 5

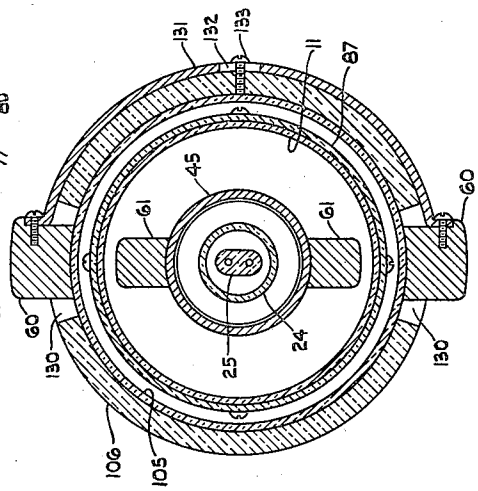

FIG. 4

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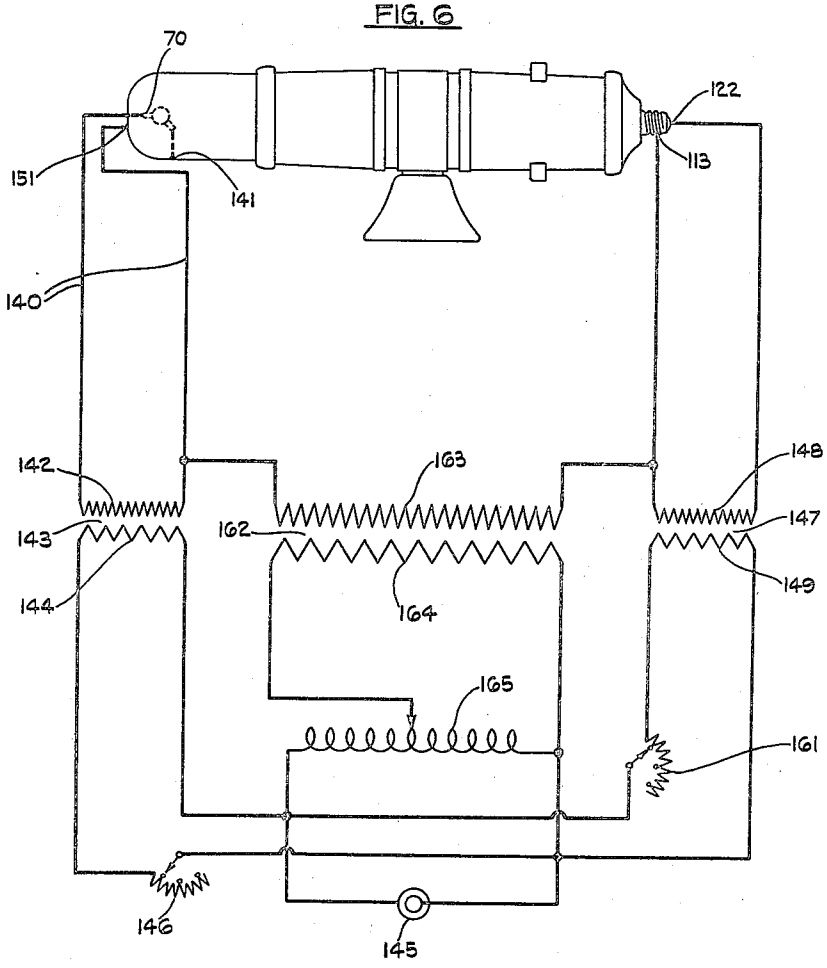
FIG. 6



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2,090,582

UNITED STATES PATENT OFFICE

2,090,582

X-RAY TUBE

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Application February 9, 1934, Serial No. 710,432

9 Claims. (Cl. 250—35)

This invention has to do with an X-ray tube in which the area of bombardment or focal spot on the target is constantly shifted by rotating the tube or anode so as to subject an ever changing surface of target material to bombardment during any given X-ray exposure, thus increasing the area subjected to electronic bombardment without increasing the size of the focal spot.

A tube of the type herein described is capable of handling large amounts of energy with a relatively small focal spot, thus making the tube applicable to heavy or fast work where extremely good definition is essential. Tubes of this type constructed previously to this invention contain definite limitations, either as to load capacity or focal spot shape, which limit their usefulness. These limitations are avoided in the type of tube constructed by applicant.

The present invention relates further to means whereby a line focus cathode may be used in a tube of the type described in connection with an anode which is stationary with respect to the tube envelope, and hence is capable of transmitting heat generated at the focal spot to a radiator exterior to the envelope at a rate to permit energization of the tube for relatively long periods of time.

The invention has to do further with an X-ray tube, the cathode of which is rotatable within the tube envelope and with reference thereto, but in which no brushes are used within the envelope.

The invention concerns also novel means for bringing the focal spot in a rotating X-ray tube with a line focus cathode into proper position for use of the X-rays emanating therefrom, and for directing them so that their greatest intensity will be in a single direction.

Involved in the attaining of these objects are novel means for supporting an X-ray tube, unique means for supporting a cathode in such tube, improved means for causing a tube to rotate, novel electrical connections, unique cooling means, and improved means for holding one element of the tube against rotation.

These objects and such other objects as may hereinafter appear are obtained by the novel construction, unique arrangement and improved combination of elements illustrated in the accompanying drawing of a tube embodying the subject matter of the invention, hereby made a part of this specification, and in which:

Figure 1 is a median longitudinal section of an improved X-ray tube in which the invention is disclosed;

Figure 2 is a median longitudinal section of the cathode end of the same device on the same plane as Figure 1;

Figure 3 is a median longitudinal section of the anode of the same device on the same plane as Figure 1;

Figure 4 is a cross section of the X-ray tube on line 4—4 of Figure 1;

Figure 5 is a cross section of the device on line 5—5 of Figure 1; and

Figure 6 is a diagram of circuit which may be employed with the present tube.

Like reference characters are used to designate similar parts in the drawings and in the following description of such embodiment of the invention.

The X-ray tube 10, shown in the several figures, comprises a glass envelope 11 of reduced diameter at its anode end, indicated 12. An anode 13 in the tube consists of a copper head 13a, and a shank 13b, and has a tungsten face or button 14. The tungsten button 14 is attached to the anode in any manner which produces a good thermal union between such button and the body of the anode. A sleeve 15 is attached, in any desired manner as by means of soldering, to the anode at 16. The sleeve 15 is used to make a tight joint between glass and metal while avoiding the danger of breakage because of the differential expansion and contraction of the materials consequent upon temperature changes. It is made of relatively thin nickel steel or some other suitable metal.

The outer end 17 of the sleeve 15 is sealed to a glass cylinder 18 in a manner well known in the art and the cylinder 18, in turn, is sealed at 19 within the reduced portion 12 of the envelope.

The cathode end of the envelope 11 has a reduced portion 20 into which a cathode stem 21 is sealed as indicated at 22. The cathode stem includes a main cylinder 23 having one end 24 of reduced diameter. A pinch seal 25, through which two wires 26 and 27 pass, closes the reduced section 24, the joint being made secure by means of a ring seal 28.

The inner end of the reduced section 24 of the cathode stem is sealed at 30 to a small sleeve 31 to which there is attached, in any desired manner as by copper brazing, a collar 32. The sleeve 31 is of the same type and similar to the sleeve 15 before mentioned. A center supporting tube 33, made of steel or similar material, is attached to the collar 32 in any desired fashion, as for instance by means of the screws 34. At the inner end of the tube 33 there is a bored out

section 35 serving as a receptacle for a split insulator 36 and a collar 37 about said insulator.

The insulator 36 supports within its center the rod 38. Three set screws penetrate the wall of the tube 33, lock against the collar 37 and urge the split insulators 36 toward one another to lock the inner rod 38 in a selected position. The free end of the rod 38 carries an annular ball bearing 40. The two wires 26 and 27 are attached in any desired fashion, as for instance, by spot welding, respectively to the cylinder 33 and to the inner rod 38.

On the periphery of the cylinder 33 and near the opposed ends thereof are two annular ball bearings 41 and 42. Each of these bearings carries a cylinder 43 and 44, respectively, about its periphery.

Attached to the cylinders 43 and 44, in any desired fashion as by means of the screws 43*a* and 44*a*, is an outer cathode supporting cylinder 45. The inner end of said cylinder 45 carries a focusing cup 46. An opening 47 for the purpose of supporting a filament 48 is eccentrically located with respect to the center of the cup 46. Material is removed at 49 in the back of the cup 46 on the opposite side of its center or axis in a fashion to offset the removal of the material for making the hole 47.

One end of the filament 48 is attached, in any desired fashion as for instance by arc welding, to a support wire 50 which is, in turn, supported in the cathode cup 46 by means of a set screw 51. The other end of the filament is similarly supported on a support lead 52 which is in turn insulated from the cathode cup by passing the lead through an aperture 53 in the cathode cup without touching the walls of the aperture, and supporting it between two insulators 54, which are clamped together by means of screws 55 and supported by means of supports 56. The inner end of the wire 52 is fastened in any desired fashion to the outer ring of the ball bearing 40, as shown.

Due to the fact that the ball bearings 41, 42 and the entire cathode structure must be brought up to a dull red heat during evacuation of the tube, it is necessary to make the bearings out of a self-hardening steel. The term "cathode structure" appearing in the immediately preceding sentence and in the claims refers to the combination of the filament 48, the cathode supporting cylinder 45, and the focusing device 46 in case such a device is employed. Most of the high speed steels are suitable for this work, but applicant has found a high tungsten content steel to be best.

Seal off 62 is what remains of the exhaust constriction after the tube was exhausted and sealed off.

A motor for rotating the tube is designated 70, and is connected to the tube by a shaft 70*a* and a flexible coupling 71 having a heat insulating section 72 of any suitable heat-resisting non-heat conducting material to prevent passage of heat from the shank of the anode directly into the motor by conduction. One end of the flexible coupling 71 is attached to the motor shaft by a set screw 73, and the other is attached to the anode shank by a set screw 74.

A radiator 75 acts both as a means of radiating the heat generated in the anode and as a fan for circulating air about the exterior of the X-ray tube. The radiator 75 consists of an inner sleeve 76 having thereon washers 77 supported by spacers 78. Rings 79 and 80 hold the entire structure in assembly. Several of the washers, as indicated at 77*a*, are notched and portions thereof bent fan-wise to provide blade-like devices for driving air in the manner of a fan. This fanning action causes additional air movements about the tube and the rotating washers and increases the radiation of heat therefrom. The high tension connection to the anode is through a spring 67 set in a cavity 68 in the end of the anode 13 and bearing on the end of a pin 69 set in the shaft 70*a* of the motor 70.

Attached to the inner sleeve 76 next to ring 80 is a driving member 81. The X-ray tube 10 has attached at the reduced portion 12 at the anode end an anode cap 82, which is held in place by cement or in any other suitable manner. In a similar fashion, a cathode cap 83 is attached by cement at the reduced section 20 of the cathode end. The anode cap 82 is made preferably of insulating material such as a phenol condensation product, and carries a steel ring 84 onto which annular ball bearing 85 is attached in any desired fashion, as for example by the keys 86. Connection is also made between the driving member 81 and the cap 82 as indicated at 82*a* by screws 82*b*.

A phenol condensation product insulating tube 87 is fastened at one end to the anode cap 82, as indicated, by screws 88. The insulating tube 87 passes over the entire X-ray tube as shown, and is fastened to the cathode cap by means of screws 89.

From the foregoing it will be seen that the power applied to the shank of the anode 12 is not transmitted through the sleeve 15 but by member 81 to anode cap 82 and the anode end of the tube, also to the insulating tube 87, to cathode cap 83, and to the cathode end of the tube. In this fashion the placing of undue strain on the relatively fragile sleeve 15 and the joint 17 between it and the glass is avoided.

Cathode cap 83 carries a steel sleeve 90 to which an annular ball bearing 91 is secured by means of a key 92. The outer ends of the two wires 26 and 27 are secured respectively to a slip ring 93 and to a stud 94 at the outer end of the cathode cap 83. Wire 26 passes through a hole in a lead lining 95 of the cathode cap, thence through a hole in the cap, and is secured to said slip ring 93 by soldering, as shown. Wire 27 leads through an insulator 94*a*, through lead lining 95 of the cathode cap, and through the cathode cap 83, and is secured to stud 94 by soldering.

It is apparent that if proper supporting means are provided for the annular bearings 85 and 91 and for the motor 70, it is possible to rotate the tube 10. The support for these parts consists of a casing 100. This casing is similar in structure to that described in copending application of Malvern J. Gross, entitled Tube casing, Serial Number 685,867, filed August 19, 1933, assigned to General Electric X-Ray Corporation, a corporation of New York, August 8, 1933, and recorded in Liber H-157, page 235 of the records of titles, and consists essentially of a metallic middle section 101, into which a supporting cone 102 is screwed as shown. The middle section is telescopically assembled into an X-ray protective cylinder 103 preferably made of lead. This cylinder is provided with an opening 104 through which the beam of useful X-rays passes. Inside of the protective cylinder 103 is an insulating cylinder 105 made of insulating tubing. As the two cylinders 103 and 105 are of greater length

than the center section 101, they project along each side of the latter and are surrounded by insulating sleeves 106 and 107 made of insulating material opaque to X-rays.

Sleeves 101, 103, 105, 106 and 107 can be attached to each other in any manner desired. In the preferred embodiment of the invention, a phenol condensation product cement is used, and serves not only as a good mechanical bond between the various units but, because of its high insulating qualities, also to fill effectively all the joints from an electrical standpoint and prevent the passage of electric current longitudinally of the tube along paths lying in the spaces between the various telescoped sections.

The annular ball bearing 85 is positioned in a recess 108 provided for it in sleeve 107. In the same fashion, bearing 91 is held in a recess 109 in sleeve 106.

The cathode end of the cylinder 106 is closed by means of a cap 110, which is formed preferably of conducting material and is adapted to be locked onto the sleeve 106 by means of screw threads 110*a* on the cap and 110*b* on the sleeve. The cathode base carries at its end a so-called "Edison" plug 111, having a center section 112 and a circumferential section 113. This plug can be fastened to the end piece in any desired fashion, as for instance by means of screws 114. Contact is made from the circumferential section 113 to the slip ring 93 through the medium of a brush contact mechanism 115. This mechanism consists of a brush 116 adapted to ride within a guide tube 117. A spring 118 forces the brush into engagement with the ring 93. This spring engages the brush at one end and at the other end engages the inner surface of the adjusting screw 119 which closes tube 117. A pigtail 120 short circuits the spring 118 to prevent loss of tension therein by heat due to the passage of the current through it.

Center section 112 of plug 111 has attached to it a stud 121, a projection of which passes through the center section 112 and is soldered on the outside thereof. A spring 123 engages the stud 121 at one end and at the other end engages a screw plug 124 which acts as a cap for a tube 125 within which rides a brush 126. A spring 127 engages the plug 124 at one end and at the other end engages brush 126 to urge the latter into contact with the center stud 94. A pigtail 128 short circuits the spring 127 to prevent loss of temper thereof by heating, due to the passing of current through it.

Thus, if the terminals of the heating circuit are placed at the terminals of the Edison plug, connections are made to the cathode of the tube while the latter rotates, through the medium of the contact rings and brush mechanism just described.

At the outer end of cathode supporting cylinder 45 and opposite each other are two lugs 61 of magnetic metal such as iron one hundred eighty degrees apart and fastened to cylinder 45 by screws 61*a*. The insulating sleeve 106 is provided with two oppositely disposed apertures 130 one hundred eighty degrees apart and on a line concentric with the lugs 61. Through these apertures the retaining magnets 60 pass in as close proximity as possible to the insulating sleeve 105. The sizes of the apertures 130 and the magnets 60 are such that the magnets can be shifted in the apertures about the long axis of the tube. The two magnets 60 are made preferably of some high permeable material, such as cobalt steel or other alloy, and are connected together by means of a yoke 131 made preferably of magnetic material. Slot 132 in the yoke 131 cooperates with a screw 133, making it possible to move the two retaining magnets about the longitudinal axis of the tube as a unit.

Movement of the magnets causes corresponding movement of the independently movable cathode structure through the interaction of the lugs 61 with the magnets. By this means it is possible to position accurately the opening 47 in the cathode focusing cap 46 to cause the focal spot of the tube to move about the longitudinal axis of the tube as a center, so as to bring the latter into the desired relation with the opening 104 in the X-ray protective cylinder 103. This is necessary due to variations in the various parts of the bearings, and because the cathode will assume various angles of lag with respect to the magnets 60 incidental to changes in the speed of rotation of the tube from time to time.

At the open end of the sleeve 107 at the anode end of the tube is a motor supporting casing 150. This consists of an open supporting casting 151, partially cylindrical in shape, and on which the motor 70 is fastened by means of screws 152. A perforated metallic casing 153 is secured to the casting 151 by means of screws 154. The entire unit so formed is attached to the tube casing and held in engagement therewith by means of a ring 155.

To avoid excessive absorption of radiation by the glass walls of envelope 11, the portion of the glass wall which comes between the focal spot and the opening 104 is reduced in thickness as indicated at 160.

The operation of the device which has been described is clear from the foregoing. The tube is adapted to be rotated within its casing by the motor at the anode end of the tube. The driving power of the motor is transmitted to the tube through the external caps and sleeves. While the tube is rotated contacts for the high and low tension electric currents are maintained at the outer cathode end of the tube through brushes outside of that tube and thence through the ball bearings within the tube to the cathode and the cathode filament.

The filament current passes from the outside 113 of the Edison plug through brush 116 to the ring contact 93 and wire 26, from there through the tube 33 and the bearings 41 and 42, to the cathode cap to which is grounded one end of the filament. The current then goes through the filament to the rod 52 and through it and the ball bearing 40 to the rod 38. This rod is connected to wire 27 which carries the current to the brush 126 whence it reaches the center contact 112 of the Edison plug.

The anode high voltage connection is through the electric motor. While the tube and anode are rotated by the motor, the cathode within the tube is kept stationary by the drag of the magnets 60 on the lugs 61. The position of the magnets can be altered to adjust the cathode, making it possible to keep the focal point on the anode always in the proper place with respect to the opening 104 for X-rays. The cathode remaining stationary and the anode rotating with the rest of the tube, the focal point remains only an instant on any one spot on the anode. Thus a small and line focal point with consequent excellence of definition can be employed for long periods with minimum damage to the anode.

Connections are made to the anode of the tube

by means of the two wire cables 140. (See Figure 6.) One of these wires is grounded to the support casting 151, and the other connects to one terminal of the motor 70, the other motor terminal 70 being also grounded as shown at 141. The two free ends of the wire 140 connect to the terminals of a secondary 142 of the insulation transformer 143. Primary winding 144 is energized from any suitable source of power, as, for instance, that indicated at 145.

A rheostat 146 is interposed in this primary circuit for the purpose of bringing the motor up to speed slowly and thus avoiding stresses on the various rotating parts of the tube. The filament is energized from a secondary 148 of filament transformer 147 connected to the center contact 122 and the shell 113 of the cathode terminal of the tube.

The primary 149 of this transformer is energized from any suitable source of power, such as indicated at 145 as shown, a control 161 being interposed in the primary circuit for the purpose of regulating the amount of energy to the filament of the tube. A high tension transformer 162 has at the ends of its secondary 163 connected, one to the secondary 142 of the motor insulation transformer, and the other to the secondary 148 of the filament insulation transformer. The primary 164 is energized from auto transformer 165, which is in turn connected to any suitable source of power, as, for instance, that indicated at 145.

Claims covering broadly the feature of a cathode and an anode, respectively, movably and immovably mounted within the envelope of an X-ray tube together with means for moving the envelope and anode with respect to the cathode are contained in the Ungelenk application, Serial No. 408,587, filed November 20, 1929 and assigned to the same assignee as the present application. Consequently, the claims in the present application are limited to details of the broad invention disclosed and claimed in the said Ungelenk application.

What is claimed as new and is desired to be secured by Letters Patent of the United States is:

1. In combination, a casing and an X-ray tube containing a filamentary cathode and anode, said cathode and anode being respectively movably and immovably mounted with respect to said tube, rotary bearing members between said tube and casing, means for rotating said tube and anode within said casing while maintaining the cathode stationary, whereby the anode and cathode are moved with respect to one another.

2. In combination, a casing and an X-ray tube containing a filamentary cathode and anode, said cathode and anode being respectively movably and immovably mounted with respect to said tube, rotary bearing members between said tube and casing, means including an electric motor for rotating said tube within said casing while maintaining the cathode stationary, whereby the anode and cathode are moved with respect to one another.

3. An X-ray tube having a support, bearing means between said tube and said support allowing rotation of said tube, an anode and a cathode structure immovably and movably mounted respectively with respect to said tube, means for rotating said tube and anode with respect to said cathode structure, a filament constituting part of said cathode structure, power supply means for said filament, annular ball bearing means supporting said cathode structure within said tube, other annular ball bearing means electrically insulated from said first mentioned ball bearing means, one race of said first ball bearing means being electrically connected to one side of said filament and the other race thereof being electrically connected to one side of said filament power supply means, and one race of said other ball bearing means being electrically connected to the other side of said filament, and the other race thereof being connected to the other side of said filament power supply means.

4. An X-ray tube having an envelope containing an anode and a cathode structure immovably and movably mounted respectively with respect to said envelope, said anode having a projecting stem and being sealed to said envelope by a sleeve, bearing means allowing rotation of said tube and anode, rotative power means therefor, coupling means between said power means and said anode stem, rotative impulse transmission means between said anode stem and said envelope and removed from said sleeve, and means for holding said cathode structure stationary when the anode and envelope are rotated.

5. In combination, an X-ray tube having an envelope containing an anode and a cathode structure immovably and movably mounted respectively with respect to said envelope, said anode having a projecting stem, bearing means allowing rotation of the envelope and anode and permitting the cathode structure to remain stationary, power means for rotating said tube, means for holding said cathode structure stationary when the anode and envelope are rotated, and heat radiating means attached to said anode stem and comprising vanes thereabout, parts of said vanes being shaped to cause circulation of air when said anode stem, vanes and envelope are rotated.

6. In combination, an X-ray tube having an envelope containing an anode and a cathode structure immovably and movably mounted respectively with respect to said envelope, said anode having a projecting stem, bearing means allowing rotation of said tube and anode and permitting the cathode structure to remain stationary, rotative power means to rotate said tube, means for holding said cathode structure stationary when the anode and envelope are rotated, and coupling means comprising heat insulating and resistant material between said rotative power means and said anode stem.

7. In combination, an X-ray tube having an anode and a cathode structure including a filament, said anode and cathode structure being immovably and movably mounted respectively with respect to said tube, bearing means allowing rotation of said tube and anode and permitting the cathode structure to remain stationary, means for causing rotation of said tube, means for holding said cathode structure stationary when the anode and envelope are rotated, a source of electrical energy for said filament, a cap over the cathode end of said tube, contact means on said cap, other contact means on said cap and electrically insulated from said first mentioned contact means, said contact means being electrically connected to the ends of said filament, a second cap separate from said first cap, brush means in said second cap and in electrical connection with said contact means, and electrical connectons between said brush means and said source of energy.

8. In combination, a casing and an X-ray tube containing a filamentary cathode and an anode, said cathode and anode being respectively mova-

bly and immovably mounted with respect to said tube, rotary bearing means between said tube and casing, means contained within the casing for rotating the tube with respect to the casing, and means for maintaining the cathode stationary whereby the anode and cathode are moved with respect to one another.

9. In combination, an X-ray tube and a support for said tube, said tube containing an anode and a cathode structure including a filament, said anode being fixedly secured to said tube, rotatable means for supporting the cathode structure within said tube, and for permitting rotation between the tube and said cathode structure, means for producing relative motion between the tube and the cathode structure, an electrical connection including a rotatable device between one end of said filament and the exterior of said tube, the other end of said filament being connected to said cathode structure, and an electrical connection between said rotatable means and the exterior of said tube whereby current may be supplied to said filament while the tube and the cathode are being rotated with respect to one another.

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