

[54] **X-RAY TUBE HAVING A RAY TRANSMISSION ROTARY ANODE**

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[56] **References Cited**

UNITED STATES PATENTS

2,863,083 12/1958 Schram.....313/60 X
3,473,028 10/1969 Curry.....250/90 X

FOREIGN PATENTS OR APPLICATIONS

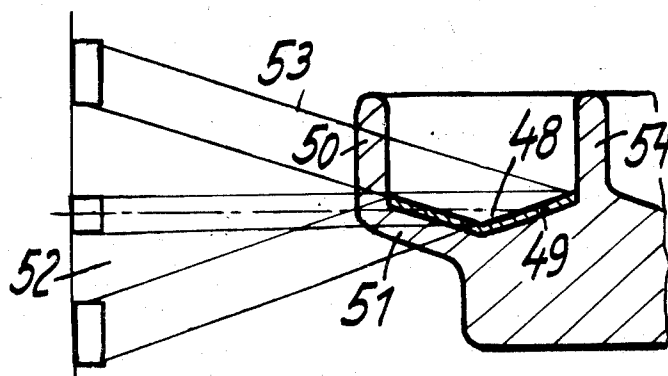
1,200,962 9/1965 Germany.....313/60
1,470,382 2/1967 France.....313/60

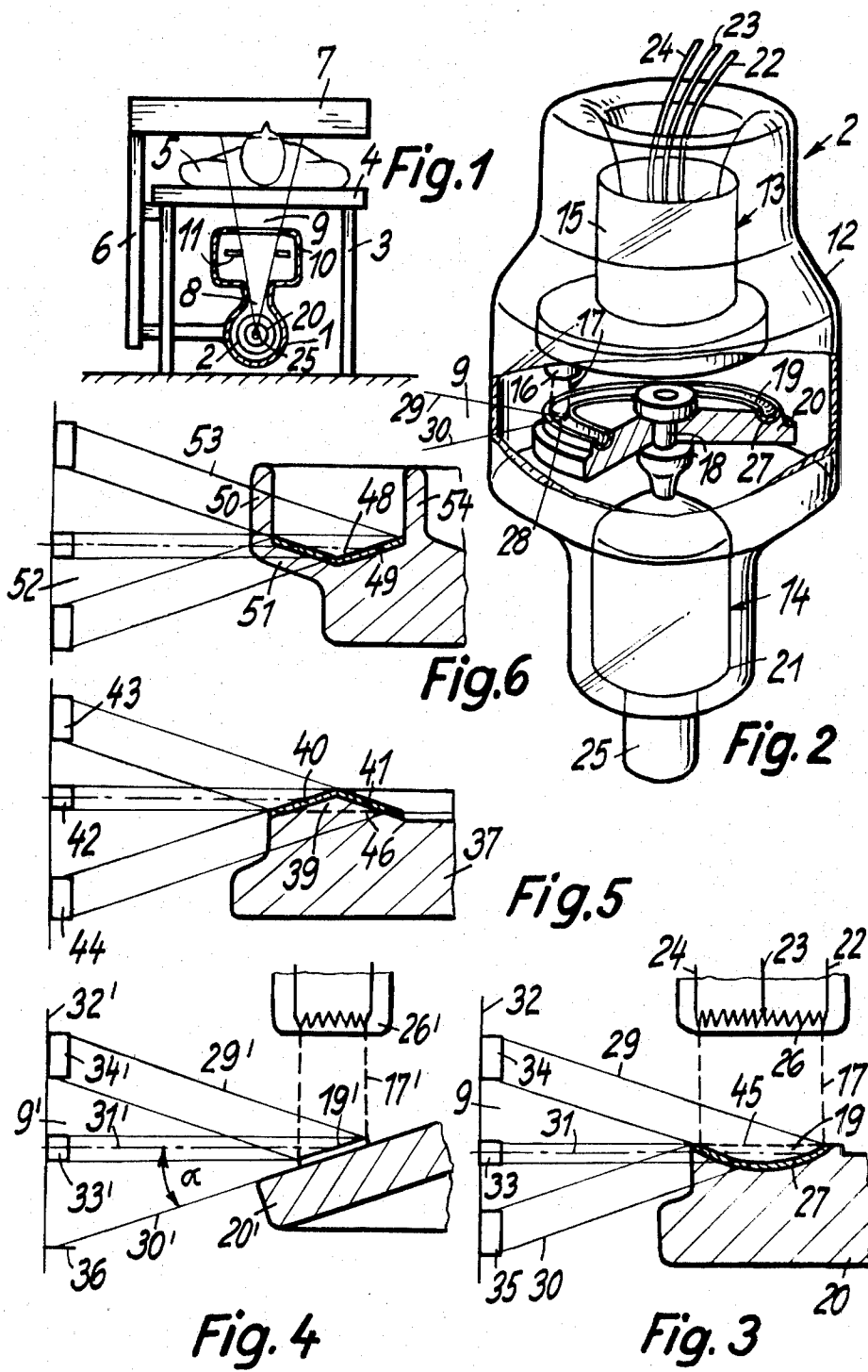
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[57] **ABSTRACT**

An X-ray apparatus has an X-ray tube situated in a cover screening the rays. The effective focal point of the X-ray tube is located behind a ray transmitting opening in the cover,—the ray outlet window,—upon a thin layer of difficultly fusible material which itself is carried by an anode body made of ray transmitting material. The present invention is particularly characterized in that this layer is constructed as the ray transmitting anode in that at least parts of its upper surface and of its lower surface lying upon the transmitting supporting material of the anode, are directed toward the ray outlet window and in that the thickness of the layer at least approximately corresponds to the depth of penetration of electrons into the material of the layer at the expected highest acceleration voltage.

7 Claims, 6 Drawing Figures





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X-RAY TUBE HAVING A RAY TRANSMISSION ROTARY ANODE

This invention relates to an X-ray apparatus and refers more particularly to an X-ray apparatus the X-ray tube of which is enclosed by a cover screening the rays, the effective focal point of the tube being located behind a ray transmitting opening in the cover upon a thin layer of material which fuses with difficulty and which is carried by an anode body of ray transmitting material.

X-ray devices now in general use employ X-ray tubes with rotary anodes as sources of energy. The focal point of the anodes which is produced by the electrodes, extends at an angle to the central ray, which is the X-ray aligned with the center of the image and usually perpendicular to the direction of the electrons, this direction being parallel to the axis of rotation. The anode angle α , which is the angle of inclination of the anode surface containing the focal point path to a horizontal plane extending through the axis of rotation, lies in the majority of presently used tubes between 10° and 20° depending upon the size of the field to be illuminated. For a predetermined optical focal point value F_z effective in the central ray, a focal point value F_α actually produced by the electrons appears upon the anode, its amount varying depending upon the anode angle α and being represented by the formula:

$$F_\alpha = F_z / \sin \alpha.$$

When the ray cone is completely open, namely, is equal 2, an optically effective focal point value F_K appears on the side of the cathode represented by the formula

$$F_K = 2 \times F_z$$

In existing X-ray diagnosis devices only those X-rays are used for illumination, exposure, etc., which emerge above the free surface of the anode. As is known, the base usually consists of a material which fuses with difficulty, for example, wolfram, which strongly absorbs the X-rays. Therefore, no X-rays can be used upon the side on which the anode body lies. Thus a large part of the X-ray illumination, which emits rays with practically equal intensity to all sides, is lost.

This is also true as far as existing tubes with rotary anodes are concerned, wherein the anodes have a body consisting of graphite and covered with a layer of difficultly meltable metal; they use only the ray field located above the surface of the anode.

An object of the present invention is to improve existing X-ray apparatus.

Other objects of the present invention will become apparent in the course of the following specification.

In the accomplishment of the objectives of the present invention that part of the rays which in existing rotary anodes is not used and is absorbed in the anode body, is incorporated into the bundle of useful rays. This is accomplished when using an X-ray tube with an anode body made of ray transmitting material and wherein at least the focal point path is coated with a thin layer of a material which is fusible with difficulty and contains a substance of high atomic weight, by constructing the layer as a ray transmitting anode. This is accomplished by directing at least parts of the upper surface of the layer and of the lower surface lying upon the transmitting supporting material of the anode,

toward the ray outlet window and by making the layer of a thickness which at least approximately corresponds to the depth of penetration of electrons into the material of the layer at the expected highest acceleration voltage.

In this construction the focal point path can lie in the plane of the central ray, so that the anode angle will be equal to zero. Since the supporting material is ray transmitting the rays above as well as below the focal point become useable. The geometrical requirements which are then changed produce for the same F_z a larger focal point F_o which is considerably greater than F . Since the load increases proportionally to the ratio $F_o : F$, the increase in load is represented by the formula

$$G = 2 \frac{\sin \alpha}{\tan \alpha} - 1$$

In the case of a flat path, namely, a path which is inclined to the central ray, to the extent of 0° , as compared to a focal point path inclined relatively to the central ray by 17.5° , so that $2\alpha = 35^\circ$, there is a gain amounting to $G = 90\%$. In comparison with an α of 10° there is a G of 97%.

As ray transmitting materials can be used, by way of example, such substances as carbon (graphite), beryllium or suitable low atomic compounds of beryllium and bors etc., which absorb little radiation, such as, for example, beryllium oxide, etc. Suitable materials with which the anode body is coated primarily for the braking of electrons, consist, as is known, of substances with higher order number and melting points, such as wolfram, tantalum, rhenium, uranium, etc., and their alloys. When carbon is used as the base, carbides of high atomic metals are also suitable, such as, for example, hafnium carbide, tantalum carbide, wolfram carbide, thorium carbide, uranium carbide. The thickness of the coating applied to the anode body should at least in the range of the focal point path be about that of the penetration depth of the electrons and, by way of example, in the case of tube voltages generally employed in X-ray diagnosis and when wolfram is used, should be less than 100μ . Thinner layers will allow a part of the electrons to pass through without using them, while thicker layers impede the passage of X-rays.

An X-ray apparatus at the present invention containing an X ray tube mounted in a ray screening casing, will produce X-ray exposures having a better clarity of image. In existing anodes the ray cone which is being used, is cut out of the semispherical ray formation over the focal point path, so that the angle of the ray bundle extends only to one side of the focal point path. On the other hand, in the construction of the present invention the section extends outwardly on both sides of the focal point. Thus in addition to a projection transverse to the rotation axis, a true central projection is attained which is parallel thereto.

According to an embodiment of the present invention the anode body can be made of graphite and the surface can be provided with a coating of wolfram having a thickness up to 100μ , specifically $5 - 10\mu$.

In order to avoid the appearance of strips of lesser intensity in a ray field with a flat focal point path, which are produced by the coating, it is advantageous to work the focal point path into the carrier material, so that a groove is formed extending annularly around the axis

of rotation located in the center. The depth of the groove must be greater than or equal to the focal point. Then the passages through the layer material which is a strong absorbent, become shorter and there is no direction in which the rays are particularly weakened.

Instead of arranging the focal point path in a groove, it may be located upon a rib. This construction will also attain the desired effect.

The invention will appear more clearly from the following description when taken in connection with the accompanying drawing showing by way of example only, preferred embodiments of the inventive idea.

In the drawing:

FIG. 1 is a side view of an X-ray apparatus in accordance with the present invention, the protective casing being shown in section adjacent the tube.

FIG. 2 is a perspective side view on an enlarged scale of the X-ray tube located in the casing of FIG. 1.

FIG. 3 is a sectional diagram illustrating the operation of the tube of the present invention.

FIG. 4 is similar to FIG. 3 but illustrates a prior art tube.

FIGS. 5 and 6 are similar to FIG. 3 and shows somewhat differently constructed tubes of the present invention.

The X-ray apparatus shown in FIG. 1 has a protective covering consisting of a ray screening casing 1 for the X-ray tube 2. The tube and its casing are located under a table 3, the top 4 of which can carry the patient 5. The casing 1 is attached to the table 3 in a known manner by means of a holding arm 6 which is movable longitudinally and transversely. The sight 7 is located over the patient 5 upon an end of the arm 6 located above the table top 4. As is known, the sight 7 contains the light screen necessary for direct visibility of the X-ray pictures, as well as slides with X-ray films for photographing the transmitted rays. The casing 1 has a ray transmitting opening provided in its wall directed toward the table top; this opening constitutes the ray outlet window 8. Above the window there is the primary screen box 10 with plates 11 constituting the screen elements which limit the ray bundle 9 to the desired cross-section.

As shown in FIG. 2, the tube 2 has a glass bulb 12 carrying upon its upper end the cathode device 13 and upon its lower end the anode device 14; the cathode device 13 includes a holder 15 and a cover 16 enclosing a glow cathode (not shown). Electrons emerging therefrom extend in a ray 17 parallel to the rotation axle 18 and strike the focal point path 19 upon the anode 20. The anode plate 20 consists of a graphite disc about 15 mm. thick which is centrally mounted upon the rotation axle 18. The anode 20 is rotated by the rotor 21 and a stator (not shown) located in the casing 1. The operating voltage and the heating voltage of the glow cathode are supplied by the conduits 22, 23 and 24 and the connection of the anode at the joint 25.

The operation of the tube 2 is started in the usual manner by rotating the anode plate 20 and supplying the heating current through the conduits 22 and 24 to the glow winder 26 (FIG. 3) for glow emission. This produces the electron ray 17 which is acceleratedly guided by voltage provided between the cathode and the anode to the focal point path 19. The striking electrons produce X-rays in the focal point path 19 coated

with a wolfram layer 27 which is 5μ thick. The wolfram layer 27 of the focal point path 19 is provided upon an annular groove which is eight times as wide as it is deep and is located upon the outer surface of the anode 20. An X-ray bundle 9 limited by edge rays 29 and 30 is the useful part of the rays produced in the focal point 28. The outer upper edge of the plate 20 is cut off to avoid unnecessary absorptions, so that a part of the ray bundle 9 passing through the plate 20 can emerge out of the plate 20 as soon as possible. The lower part of the cut off step which is thus produced is used for receiving electrons which strayed off the ray 17 and which otherwise would move past the anode and would strike the bulb of the tube.

FIG. 4 shows a prior art anode 20' made of heavy metal. An electron ray 17' from the glow cathode 26' strikes the focal point path 19'. The bundle of rays 9' which corresponds in shape and extension to the bundle 9 (FIG. 3) is limited by the two edge rays 29' and 30'. The central ray is indicated by the line 31 in FIG. 3 and the line 31' in FIG. 4. As already stated, the anode angle α between the central ray 31' and the edge ray 30' ranges between 10° and 20° . The focal point value F_z in the central ray is indicated by the square 33' in FIG. 4, while at the side of the cathode there is an optically effective focal point value F_k indicated by the square 34', so that the equation

$$F_k = 2 \times F_z$$

is effective.

As illustrated in FIG. 3, in the tube of the present invention the projection of the optical point upon a projection plane 32 extending perpendicularly to the central ray 31 produces a square 33 having, for example, a side which is 1 mm. long. The length of the side corresponds to the depth of the groove in which the focal point path 19 is located and to the width of the focal point 28. Close to the edge rays 29 and 30 there are projections upon the plane of rectangles 34 and 35 which are located symmetrically to each other and which are similar to a great extent as far as the size and shape are concerned, as well as the strength of illumination.

As far as the prior art anode plate 20' is concerned, which is shown in FIG. 4, the projection of the focal point in the central ray 31' also produces a square 33'. Adjacent the edge ray 29' there is a square 34' which corresponds in shape and location to the square 34 of FIG. 3. Its ray density is smaller, however, since the width of the focal point path and thus the amount of produced rays are smaller. The projection of the edge ray 30' produces a line 36 the extension of which is very small but which has a high ray density. Consequently, there is a non-symmetrical distribution of the ray density in the plate 32' as far as the central ray 31' is concerned. Furthermore, the sharpness of image diminishes beginning with the edge ray 30' toward the edge ray 29' due to the change in the size of projection of the focal point.

On the other hand in the tube of the present invention, as indicated in FIG. 3, the sharpness of image is the same on both sides of the centrally located square 33, and the two squares 34 and 35 are equal to each other. By widening the focal point path 19 in comparison to the prior art path 19', the tube of the present

invention produces more rays due to the increase in the surface of the focal point which is thus attained. Practical experience has shown that this increase in rays in the tube of the present invention having a graphite base and the same speed of rotation as prior art anode 20' 5 the focal point path of which is inclined to the extent of 10° to the vertical plane passing through the axis of the rotation, amounts to about 50%.

FIG. 5 shows a similarly operating tube having an anode 37 with a rib 39 carrying the focal point path 10 covered by a layer of wolfram which is 10μ thick. The rib 39 extends annularly around the central axle, just as the groove upon the anode 20 extends around the axle 18 (FIG. 1). It is apparent that the rib 39 of FIG. 5 wherein the focal point path lies upon two surfaces 15 which are inclined relatively to each other, will have the same improved results as those produced by the groove of FIG. 3. The construction of FIG. 5 also produces a projected central square 42 and two side rectangles 43 and 44 of equal size.

The focal point path may also lie upon a flat surface and yet produce comparable projections. While this focal point construction is not illustrated, it may be assumed that it will replace the broken line 45 shown in FIG. 3 or the known line 46 shown in FIG. 5. In that case only the square 33 of FIG. 3 or the square 42 of FIG. 5 would be replaced by a dark line constituting the shade of the layer of heavy metal applied upon the focal point path. This can be avoided by shifting the focal point path during the rotation to the extent of the focal point in a direction parallel to the axis of rotation. Then the shades of the layer will be wiped out by the movement. The focal point which is then produced will then have in the central ray projection the shape which corresponds to the square 33 of FIG. 3 or the square 42 35 of FIG. 5.

FIG. 6 shows a construction which also produces a uniformly influenced ray emission by means of a wall 50 made of graphite and having a thickness of 3 mm. The wall is located at least upon the outer edge of the focal point path 48 situated in a groove coated by a wolfram layer 49. At the same time the anode body is provided with a portion 51 having the same thickness as the wall 50 and located below the outer half of the focal point path 48. X-rays produced upon the wolfram layer 49 of the focal point path 48 have to pass through an equally thin layer of anode material in the wall 50 and the part 51 within the range of the useful ray cone, provided the wall 50 is sufficiently high to include at least the edge ray 53 of the ray cone 52 located above 50 the focal point path 48. The ray cone 52 is then

homogeneous to a great extent. On the other hand the wall 50 screens the stray electrons produced within the range of the focal point from the tube bulb. Another wall 54 at the inner edge of the focal point path 48 can be used to catch stray electrons moving in the opposite direction.

I claim:

1. In combination with an X-ray shielding member having a window, an X-ray tube for projecting an X-ray beam through said window and having a vacuum bulb, a cathode upon one end of said bulb, an anode upon the opposite end of said bulb and having a rotary anode body having a rotary axle and a surface carrying a layer of refractory material, means actuating said cathode to produce an electron beam having electrons striking said layer, said layer having a region forming the focal spot path, the thickness of said region being substantially equal to the depth to which electrons penetrate into the layer at the highest acceleration voltage to be 20 operatively utilized between the cathode and the anode, said layer having a surface portion facing away from the anode body and emitting X-rays constituting a part of the X-ray beam and a surface portion contacting the anode body and also emitting X-rays constituting a part of the X-ray beam, said anode body having an X-ray permeable region through which the last-mentioned X-rays are emitted.

2. An X-ray apparatus in accordance with claim 1, wherein said anode consists of a graphite plate and wherein said layer consists of wolfram and has a thickness less than 100 μ and ranging between 3 and 10 μ.

3. An X-ray apparatus in accordance with claim 1, wherein said anode has a ridge extending as a ring around said rotary axle, the layer forming the focal point path being carried upon said ridge.

4. An X-ray apparatus in accordance with claim 1, wherein said focal point path is located in a groove extending as a ring around said rotary axle.

5. The X-ray apparatus in accordance with claim 1, comprising a wall consisting of ray transmitting anode material and located at least upon the outer edge of the focal point path.

6. An X-ray apparatus in accordance with claim 5, wherein said anode has a portion extending at least under the outer half of the focal point path and having a thickness equal to that of said wall.

7. An X-ray apparatus in accordance with claim 5, comprising another wall located upon the inner edge of the focal point path.

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