

Sept. 25, 1956

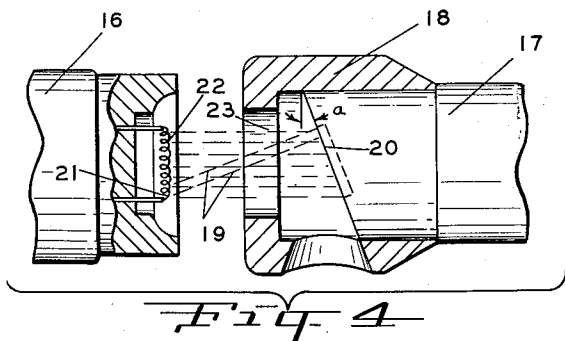
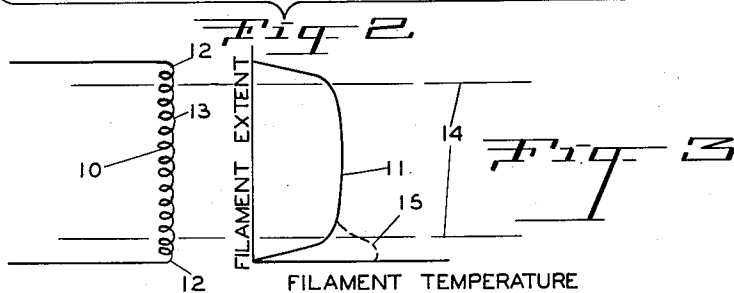
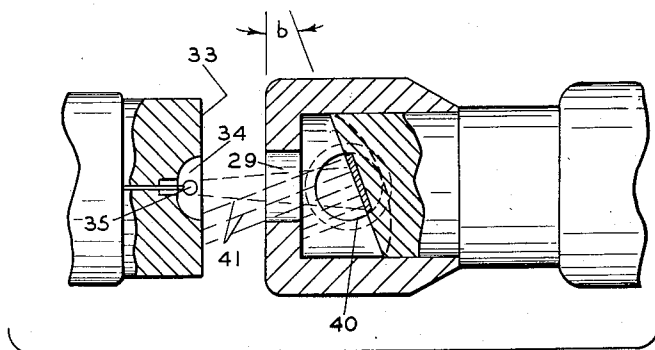
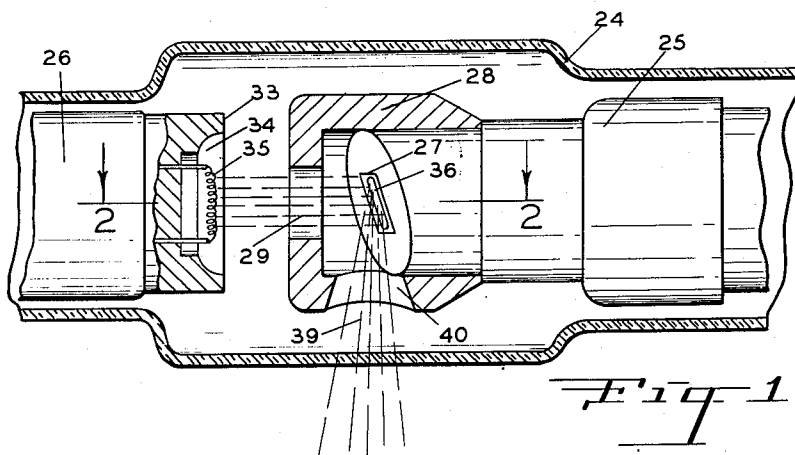
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2,764,706

HOODED ANODE X-RAY TUBE WITH TILTED TARGET

Filed Dec. 26, 1952

2 Sheets-Sheet 1



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HOODED ANODE X-RAY TUBE WITH TILTED TARGET

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2 Sheets-Sheet 2

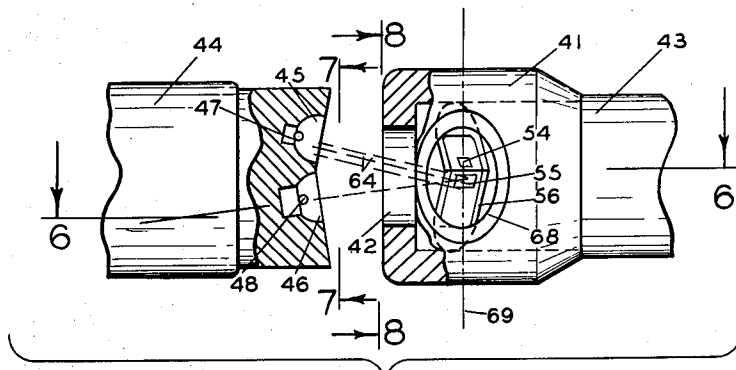


Fig. 5

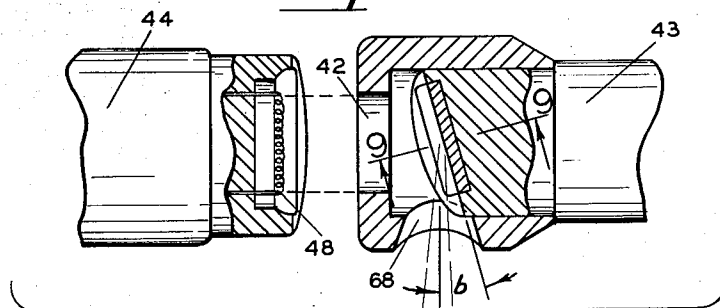


Fig. 6

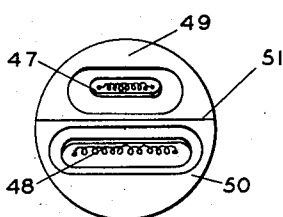


Fig. 7

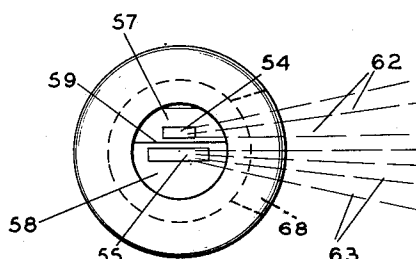


Fig. 8

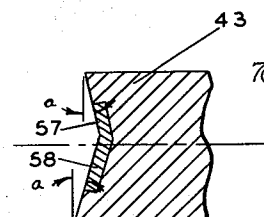


Fig. 9

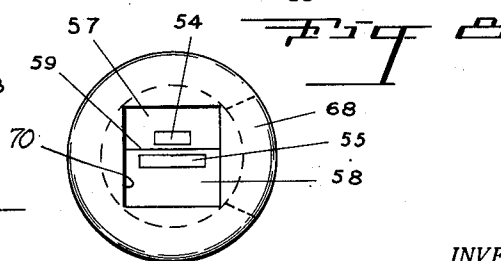


Fig. 10

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## HOODED ANODE X-RAY TUBE WITH TILTED TARGET

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Application December 26, 1952, Serial No. 327,969

7 Claims. (Cl. 313-56)

The present invention relates to X-ray generators and more particularly to improvements in X-ray generators of the hooded anode type.

Anode hoods, that is, tubular shields, surrounding the target element of an anode and projecting toward a cathode, are desirable in X-ray generators to intercept all but the useful portion of the generated X-rays, thus making it possible to reduce the amount of external protection required around the generator. An anode hood also shields the envelope from bombardment by electrons originating from the anode or other stray electrons which will weaken the envelope and may even puncture the same. The hood also constricts the paths of the lines of potential between the cathode and anode making it possible to increase the potential capacity of the generator.

In the normal operation of an X-ray generator having an elongate electron emitting filament, only the central portion of the filament is heated to electron emissive temperature by the heating current. However, in X-ray generators as provided heretofore, the arrangement of the target on the anode is such that inverse electrons from the target may impinge upon one of the filament end portions heating that portion above the emission threshold temperature. It has been necessary, therefore, to provide an opening in the anode hood sufficiently large to admit the electrons generated in this end portion of the filament. A large opening lessens the possible shielding efficiency of the hood, of course, and also permits some divergence of the lines of potential between the anode and cathode so that the generator does not operate at peak efficiency.

It is an object of the present invention, therefore, to provide an X-ray generator having a construction whereby improved hood-shielding characteristics may be obtained.

More particularly, it is an object of the present invention to provide an X-ray generator of the hooded anode type having a hood electron opening of relatively small cross-sectional area.

Other objects and advantages of the present invention will become more apparent hereinafter.

In accordance with the illustrated embodiment of the present invention, the target face of the anode is provided with the conventional angle of inclination in a direction longitudinally of the cathode filament and in addition with a second angle of inclination in the direction at right angles with respect to the plane of the first angle whereby the inverse electron emission from the focal spot on the target of the anode will impinge harmlessly against the inner surface of the anode hood, or against the cathode in a laterally displaced relation with respect to the filament. Since only the central portion of the filament will be heated to an electron emissive temperature, the axial opening of the anode hood need be only of a diameter substantially equal to the emissive length of the filament, which opening may therefore be

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made substantially smaller than in the X-ray generators prior hereto.

For a more detailed description of the invention, reference is made to the following specification taken in connection with the accompanying drawing, wherein:

Fig. 1 is a fragmentary side elevation, partly in cross section, of an X-ray generator made in accordance with the present invention;

Fig. 2 is a cross-sectional view along line 2-2 of Fig. 1;

Fig. 3 is a view showing the emission characteristics of an electron generating filament under various conditions;

Fig. 4 is a fragmentary side elevation, partly in cross section, of a hooded X-ray generator made in accordance with the prior art;

Fig. 5 is a fragmentary view, partly in cross section, of a modified form of X-ray generator embodying the present invention;

Fig. 6 is a cross-sectional view taken substantially along line 6-6 of Fig. 5;

Fig. 7 is an end view of the cathode taken along line 7-7 of Fig. 5;

Fig. 8 is an end view of the anode taken along line 8-8 of Fig. 5;

Fig. 9 is a cross-sectional view of the anode taken substantially along line 9-9 of Fig. 6; and

Fig. 10 is an end view showing a modified hood construction.

Referring first to Fig. 3, a cathode filament is illustrated diagrammatically at 10, the normal temperature characteristic of the heated filament being illustrated by the curve 11 in the adjacent graph, in which graph the ordinate represents the longitudinal extent of the filament and the abscissa represents the relative temperature. As indicated by the curve 11, the opposite end portions 12 of the filament 10 are normally relatively cool in respect to the medial portion 13 lying between the dotted lines 14. Normally an X-ray generator will be operated so that only the medial portion 13 of the filament will be at an electron emitting temperature. In X-ray tubes as heretofore provided, however, and as illustrated in Fig. 4, inverse electrons emitted from the anode target in the direction at right angles to the planar surface thereof, may impinge upon the lower portion of the filament to heat the same above its electron emissive temperature as indicated by the dotted line 15 in Fig. 3. Referring to Fig. 4 which illustrates the heretofore conventional arrangement of a cathode 16 and anode 17 having a hood 18 and in which arrangement the planar anode face is inclined with respect to the cathode face only at the angle  $\alpha$ , it will be observed that the beam 19 of inverse electrons emitted from the focal spot on the anode target 20 may impinge upon the lower end 21 of the cathode filament. Such impingement causes localized heating of the filament end 21 to increase the emission of electrons from that portion of the filament as mentioned above. Because of the emission of the electrons from the lower end portion 21 of the filament 22, the opening 23 in the anode hood 18 must of necessity have a diameter considerably greater than the length of the filament so as to eliminate any possibility for the electrons emitted from the filament end portion 21 to impinge upon the anode hood. Impingement of electrons upon the anode hood would cause it to heat, generating copper vapor which would deposit upon the anode target as well as upon the interior surface of the X-ray generator envelope to effectively reduce the useful life thereof.

Referring now to Fig. 1, there is shown an X-ray gen-

erator in accordance with the present invention and including an envelope 24 and an anode unit 25 and a cathode unit 26 mounted coaxially within the envelope in any suitable manner. The cathode unit 26 includes a head having a planar surface 33 facing the anode and extending perpendicularly to the axis of the units. The cathode head is formed with an elongated electron focusing cup recess 34 therein in which is mounted an elongated filament 35 which extends in a plane perpendicular to the axis of the unit, the filament 35 having a conventional characteristic temperature curve such as the curve 11 in the graph of Fig. 3, whereby electrons will be emitted only from the medial portion of the filament and will be focused upon the target element 27 over an elongated focal area 36.

The anode unit 25 comprises a planar faced target element 27 and a tubular shield or hood 28 mounted on the anode coaxial with the anode axis and extending toward the cathode unit 26, the hood 28 having a coaxial opening 29 in the end facing the cathode unit for the admission of electrons. The target element 27 is inclined at the normal angle of about 20 degrees in respect to the longitudinal direction of the filament 35 so that X-rays generated at the target may be transmitted therefrom as an X-ray beam 39 through an opening 40 provided therefor in the anode hood 28. The target element 27 is further inclined at an angle  $b$ , for example, of about 20 degrees, in respect to the plane of the cathode face in the direction at right angles to the plane of the usual angle of inclination  $a$  mentioned above as may be clearly seen in Fig. 2. As is more fully explained in my copending application Serial No. 197,444, filed November 24, 1950, now Patent No. 2,671,867, and as will be seen from Fig. 2, as a result of the second angle  $b$  of inclination, the inverse electrons generated at the target and leaving the surface thereof at right angles and indicated by the dotted lines 41, will normally impinge against the inner surface of the hood 28, or should any pass through opening 29, they would fall harmlessly upon the cathode surface 33 at a point displaced laterally from the cathode filament 35. Localized heating of the filament end will not occur as in prior types of X-ray generators and the temperature of the filament during operation of the generator will adhere to the normal characteristic curve 11 as illustrated in Fig. 3. This makes it possible to restrict the axial opening 29 in the anode hood 28 to a diameter substantially equal to or only slightly greater than the normal effective electron emitting length of the filament 35 such as, for example, the length corresponding to the portion intercepted by the dotted lines 14 of Fig. 3. The emission from either of the opposite end portions of the filament striking the end of the hood 28 will not be of such magnitude as will cause the copper anode hood to heat to a temperature at which deleterious vaporization will take place. The diameter of the axial hood opening 29 need be no greater than the length of the filament which has not been feasible heretofore and, as explained above, may even be somewhat less than the filament length. It is preferred, however, that the hood opening be of a diameter substantially equal to the length of the filament 35 whereby alignment of the anode and cathode during assembly of the generator is facilitated. The smaller opening makes the hood more effective as a shield, of course, and moreover constricts the lines of potential even more than with hoods of larger openings, making it possible to increase the operating potential and thus improve the efficiency of the generator.

The views of Figs. 5 to 9, inclusive, illustrate the present invention as embodied in a double focus, tilted anode type of generator such as shown and claimed in my copending application Serial No. 303,945, filed August 12, 1952. Referring now more particularly to Figs. 5 and 6, there is shown a generator comprising spaced apart coaxial anode and cathode units 43, 44, respectively. The end of the cathode 44 facing the anode is provided with

a pair of cathode means comprising a pair of elongated, longitudinally parallel electron focusing cup recesses 45 and 46 and in which recesses are disposed the electron emitting filaments 47, 48, respectively. The filaments 47, 48 are connected by suitable means (not shown) to a source of electrical current whereby they may be individually energized. The head end of the cathode 44 is formed with two plane surfaces 49, 50 disposed at a large, obtuse angle with respect to one another and intersecting along a line 51 perpendicular to the longitudinal axis of the cathode head but offset slightly to one side thereof. The cathode faces 49, 50 and the recesses therein are arranged so that the electrons emitted by the cathode filaments are focused on the anode target in elongated, longitudinally parallel focal spots 54, 55 which are laterally spaced from each other substantially diametrically on opposite sides of the anode axis but are relatively closely adjacent.

The anode unit 43 is provided with a coaxial tubular hood 41 which extends toward the cathode unit 44. A coaxial, circular electron admitting opening 42 is provided in the end of the hood 41 facing the cathode unit 44. Embedded in the target face of the anode is a unitary V-shaped target means or element 56, which element is preferably made of tungsten or other X-ray emissive heavy metal having a relatively high melting point. The target element 56 comprises a pair of planar X-ray emitting surface defining portions 57, 58 defining a separate target area for each of the electron beams generated by the filaments 47, 48.

As explained in my copending application Serial No. 303,945, the faces of the target portions 57, 58 are inclined at a small, acute angle  $a$  toward each other which angle may be, for example, about 20 degrees, and intersect along a line 59 which extends in the same direction as the filaments but is inclined at an angle  $b$  with respect to a plane normal to the axis of the tube. The angle  $b$  may also be of the order of 20 degrees. While the angle of inclination  $a$  of the anode faces 57, 58 may be varied, it is important that each face be inclined at such an angle in respect to the electron beam focused thereon that any perpendicular from the focal spot on the anode target will intersect the cathode unit at a point displaced laterally from the filament focused upon the particular target portion. For example, in Fig. 5, the cathode filament 48 is shown focused upon the target face portion 58 but all the perpendiculars from the focal spot 55, representing the paths of flow for the inverse electrons emitted from the focal spot and indicated by the dotted lines 64, strike the inner surface of the hood or should they pass through fall harmlessly upon the cathode head at a point laterally displaced from the filament 48.

As may be seen in Fig. 7, the filament 48 is of greater length than the filament 47. Since localized heating of either end of the filament 48 will not occur as in prior types of X-ray generators and the temperature of the filament 48 during operation of the generator will adhere to the normal characteristic curve 11 as illustrated in Fig. 3, it is possible to restrict the axial electron admitting opening 42 in the anode hood 41 to a diameter substantially equal to or only slightly greater than the normal electron emitting length of the filament 48. To facilitate alignment of the anode and cathode in the assembly of the generator, the opening 42 may be of a diameter substantially equal to the length of the longer filament 48 as shown in Fig. 6, but which diameter is substantially lesser than the diameter of the openings provided heretofore. As in the case of the previous modification, the small opening makes the hood more effective as a shield and constricts the lines of potential to an even greater degree than is experienced with hoods of larger openings, making it possible to increase the operating potential and efficiency of the generator.

The hood member 41 is also provided with an ellip-

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tical opening 68 in the side thereof to provide a path for the X-ray beams 62, 63. The elliptical opening 68 is positioned with the major axis thereof, indicated in Fig. 5 by dotted line 69 extending transversely of the anode and lying in a plane normal to the anode axis and substantially bisecting the focal spots 54, 55. Thus an opening is provided with its greater width in the direction necessary to permit passage of a useful portion of the X-rays generated on the target element but with its width restricted in the opposite direction to effect maximum shielding of the external X-ray generator structure from stray electrons and other portions of the generated X-rays.

In Fig. 10 is shown a modified hood construction in which the electron admitting opening 70 is rectangular. This construction may in some instances be preferred to more positively preclude the possibility of intercepting electrons from the cathode filaments. The rectangular opening 70 provides greater area laterally of the center portion of a beam, and especially at the opposite ends of the beam.

Having illustrated and described a preferred embodiment of the invention, it should be apparent to those skilled in the art that the invention permits of modification in arrangement and detail. I claim as my invention all such modifications as come within the true spirit and scope of the appended claims.

I claim:

1. In an X-ray generator an anode unit having a target, a cathode, and a tubular shield surrounding said target and extending in the direction of said cathode, said cathode comprising an elongated electron emitting filament focused to project electrons upon a planar faced focal spot area on said target in a beam substantially coaxial with said shield, said focal spot area being angularly inclined with respect to the direction of said beam whereby the perpendicular from any point on said focal spot area intersects said cathode at a point displaced laterally from said filament, said shield having an electron admission opening through the end thereof of a diameter no greater than the length of said filament.

2. An X-ray tube comprising coaxially mounted anode and cathode units, said anode unit comprising a planar faced target element and a tubular hood member coaxial with the anode axis and extending toward said cathode unit, said cathode unit including an electron generating means focused upon said target element and comprising an elongate filament extending at right angles to the axis of said cathode unit, said target element being inclined in the direction at right angles with respect to the longitudinal direction of said filament whereby the perpendicular projection of the focal spot on said target element is wholly displaced laterally of said electron generating means, said hood member having an electron admission opening in the end thereof of a diameter less than the length of said filament.

3. An X-ray generator comprising coaxially mounted anode and cathode units facing each other in spaced apart relation, said cathode unit including a head having an elongated electron generating filament mounted thereon, the longitudinal axis of said filament being at right angles to the axis of said cathode unit, said cathode unit axis intersecting said filament axis substantially medially of the filament, said anode unit having a substantially planar faced target element mounted thereon, the plane of said target element being inclined at an acute angle in a plane at right angles with respect to the longitudinal direction of said filament whereby the perpendicular from the focal spot of the target element intersects said cathode element at a point displaced laterally from said filament, said anode unit including a tubular hood surrounding said target element, and projecting toward said cathode, said hood having a circular, axial opening in the end thereof adjacent said cathode unit having a diameter only slightly greater than the normal effective electron emitting length of said filament.

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4. An X-ray tube comprising coaxially mounted anode and cathode units, said anode unit comprising a planar faced target element and a tubular hood coaxial with the anode axis and extending toward said cathode unit, said cathode unit comprising a head having a planar surface facing said anode and extending perpendicularly to the axis of said units, said head having an elongated electron focusing cup recess formed therein, an elongated filament mounted in said recess and extending in a plane perpendicular to said axis whereby electrons emitted from said filament will be focused upon said target element over an elongated focal area, the plane of said target element being inclined at a first angle of approximately 20 degrees in respect to said cathode surface and to the longitudinal direction of said filament, and at a second angle of 20 degrees in respect to said cathode surface in a direction at right angles in respect to the plane of said first angle, said hood having a circular, axial opening in the end thereof not substantially greater than the normal effective electron emitting length of said filament.

5. An X-ray generator comprising spaced apart coaxial anode and cathode units, said cathode unit including a head having a pair of laterally spaced apart electron generating means therein each comprising an elongated electron focusing cup recess formed in said head and an elongate filament mounted in the recess, said electron generating means being focused to project their respective electron beams upon elongate, laterally spaced apart anode focal spots, said anode unit including target means defining a separate planar target area for each of said focal spots, the face plane of each of said target areas being inclined at such angle to the respective beam that all perpendiculars from the focal spot of a target area are displaced laterally from the electron generating means focused thereon, and an anode hood member projecting toward said cathode unit, said hood member having an electron admitting opening having a greatest dimension in the direction parallel to said filaments no greater than the length of the longer of said filaments.

6. An X-ray generator comprising spaced apart coaxial anode and cathode units, said cathode unit including a head having a pair of laterally spaced apart electron generating means therein each comprising an elongate electron focusing cup recess formed in said head and an elongate filament mounted in the recess, said electron generating means being focused to project their respective electron beams upon elongate, laterally spaced apart anode focal spots, said filaments being of different lengths, said anode unit including target means defining a separate planar target area for each of said focal spots, the face plane of each of said target areas being inclined at such angle to the respective beam that all perpendiculars from the focal spot of a target area are displaced laterally from the electron generating means focused thereon, said anode unit including an anode hood member coaxial with the anode axis and projecting toward said cathode unit, said hood member having a coaxial, circular electron admitting opening having a diameter not substantially greater than the normal effective length of the longer of said filaments.

7. In an X-ray generator comprising spaced apart coaxial anode and cathode units, said cathode units including a pair of elongate substantially parallel cathode filaments of unequal lengths focused on spaced apart anode focal spots spaced substantially diametrically on opposite sides of the anode axis, said anode unit having a pair of planar X-ray emitting surface defining portions obliquely inclined in respect to each other and to the direction of said filaments whereby the axes of the paths of the X-ray beams from said planar portions are substantially parallel to one another and substantially at right angles to the anode axis, said anode unit including a tubular hood member projecting toward said cathode unit, said hood member having a circular electron emitting opening having a diameter not substantially greater than

the length of the longer of said filaments, said hood member having an elliptical opening in the side thereof in the path of said X-ray beams, said elliptical opening being positioned with its major axis lying in a plane normal to the anode axis and substantially bisecting said focal spots. 5

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