

Dec. 29, 1959

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2,919,362

STABILIZED X-RAY GENERATOR

Filed April 21, 1958

2 Sheets-Sheet 1

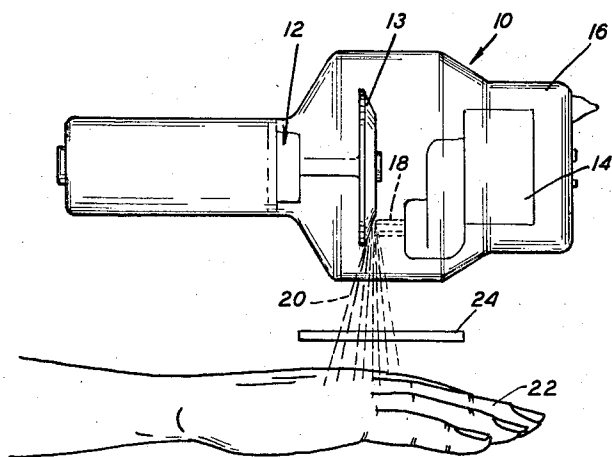


FIG. 1

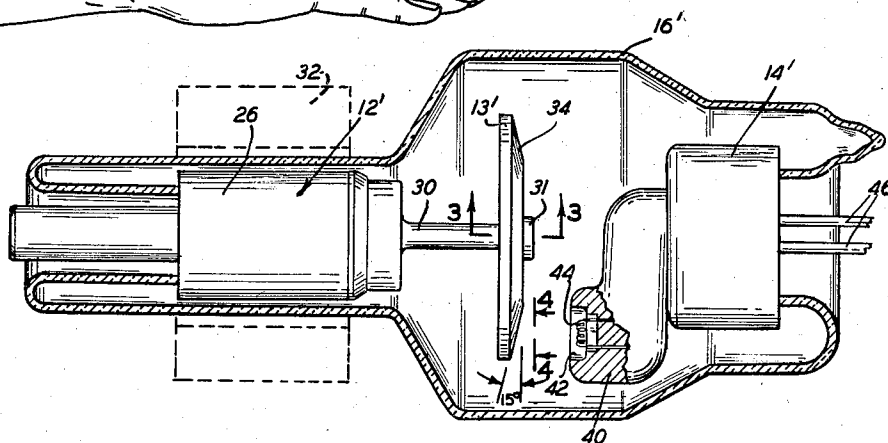


FIG. 2

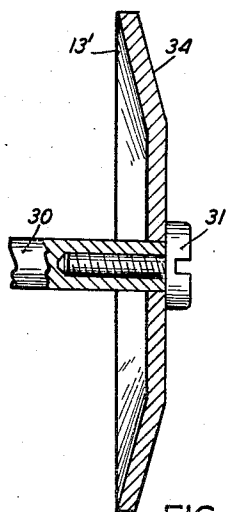


FIG. 3

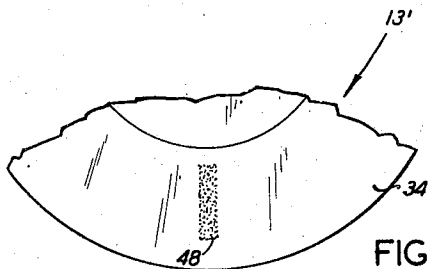


FIG. 4

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2 Sheets-Sheet 2

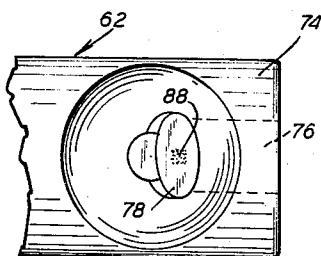
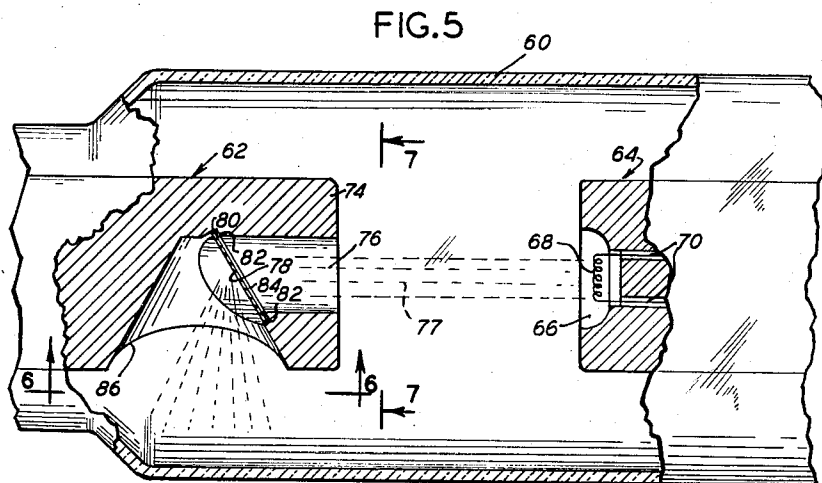


FIG. 6

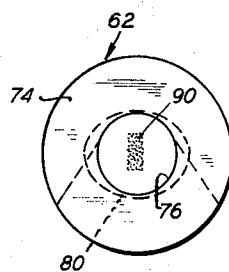


FIG. 7

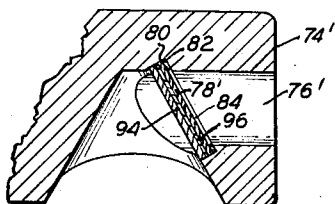


FIG. 8

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## STABILIZED X-RAY GENERATOR

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Application April 21, 1958, Serial No. 729,789

5 Claims. (Cl. 313-55)

The present invention relates to X-ray generators and more particularly to X-ray generators having stable emission and capable of providing monochromatic X-rays.

As is well known, the production of X-ray pictures of an object is dependent upon the variations in the amount of X-rays absorbed in different portions of such object. The amount of radiation absorbed is dependent upon the amount of contrast medium traversed by the radiation and on the absorption coefficient of the medium for the radiation. Mathematically, the relationship between the intensities of the transmitted beam and primary beam of radiation is  $I = I_0 e^{-ux}$  where

$I_0$ : Intensity of incident beam

$I$ : Intensity of transmitted beam

$e$ : Base of natural logarithms

$u$ : Absorption coefficient

$x$ : Amount of absorber traversed.

It has been found that the X-ray absorption coefficient for a material is a function of the atomic number of the absorber in that in general, the amount of absorption increases as the atomic number of the absorber increases. However, the absorption coefficient is also a function of the energy of the radiation, that is to say, with a given absorber material, X-rays of certain energy levels are absorbed to a greater extent than are X-rays of different energy levels. A more extensive discussion of this phenomena may be found in Acta Radiologica, vol. 45, April 1956, "Monochromatic Roentgen Rays in Contrast Media Roentgenography" by Michel Ter-Pogossian. These phenomena have a very practical value in diagnostic radiation studies. Since body tissues have on the average a low atomic number, it is frequently desirable to introduce a material of higher atomic number into a body organ to increase the absorption of X-rays in the organ and secure better contrast in the picture obtained. Iodine, for example, is frequently used for such purpose, but must be used with caution because of its toxicity in high concentration and similar difficulty is encountered with other contrast agents. It has been found, however, that certain contrast agents exhibit an unusually high absorption for X-rays of certain energy levels. For example, iodine exhibits an unusually high absorption coefficient for X-rays having energies of about 33 kev. and iodine can be used in body organs in suitably low non-toxic concentrations but giving good contrast if the energy of the incident radiation is approximately of such level.

It has been found that by electron bombardment of certain metals and by using appropriate filtering arrangements, essentially monochromatic X-ray beams of certain levels can be produced. However, difficulty has been encountered in attempting to provide stable emission from X-ray generators of this type.

Accordingly, it is an object of the invention to provide a new and improved construction of an X-ray generator for providing a monochromatic beam of X-rays.

More particularly, it is an object of the invention to provide an X-ray generator having stabilized emission.

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A particular object of the invention is to provide an X-ray generator capable of providing a stabilized beam of X-rays having an energy level of about 33 kev.

In accordance with the invention, X-ray generators are provided with a cathode comprising a filament of tungsten wire coated with a dissimilar metal having a thermionic work function less than that of tungsten. The target is also constructed of the same dissimilar metal. In the illustrated embodiment of the invention, the target and filament coating comprise cerium metal. The necessity and reasons for this construction will become apparent in the following specification taken in conjunction with the accompanying drawings wherein:

Fig. 1 is a schematic view of apparatus arranged in accordance with the invention;

Fig. 2 is an enlarged side elevation partly in section of an X-ray generator construction in accordance with the invention;

Fig. 3 is a sectional view taken along line 3-3 of Fig. 2;

Fig. 4 is a fragmentary view of the anode of the generator looking in the direction of the arrows 4-4 of Fig. 2;

Fig. 5 is a fragmentary side elevation of a stationary anode type X-ray generator made in accordance with the invention, parts of the generator being shown in longitudinal section to illustrate the same;

Fig. 6 is a fragmentary view of the anode of the generator taken in the direction of the arrows 6-6 of Fig. 5;

Fig. 7 is an end view of the anode of the generator taken in a direction of the arrows 7-7 of Fig. 5; and

Fig. 8 is a longitudinal section through an anode showing a modified target construction;

Reference is first made to Fig. 1, indicated at 10 is an X-ray generator or tube which may be of the rotating anode type having an anode 12, including a target 13, and a cathode 14 mounted within an envelope 16. As is well known, electrons are generated at the cathode 14 and directed in a beam 18 upon the anode target whereat X-rays are generated and emitted outwardly of the tube 10, a beam of generated X-rays being indicated at 20. In accordance with the presently described embodiment of the invention, the anode target 13 is formed of cerium metal and a filter 24 of cerium metal is positioned between the tube 10 and the portion of a body, indicated at 22, being X-rayed so that all X-rays falling upon the object 22 will pass through the filter. The X-rays transmitted through the filter 24 will be essentially monochromatic and will have a wavelength or energy value of about 33 kev.

The positioning of the filter 24 with regard to its proximity to the X-ray tube or the body 22 being X-rayed is immaterial and any suitable means can be provided for supporting the filter so that all of the X-rays falling upon the body 22 to be X-rayed do pass through the filter.

Referring to Fig. 2, there is therein shown in greater detail a rotating anode type X-ray tube such as may be utilized in connection with the present invention. The tube therein shown includes an envelope 16' having a cathode 14' and an anode 12' including a rotor body 26 and a target 13' secured to a stem 30 of the rotor 26 by a stud 31 (see Fig. 3). The rotor 26 is suitably supported in the envelope 16' by means well known to those skilled in the art and the tube is provided with a stator indicated at 32 for providing the field to drive the rotor.

In accordance with the invention, the target 13' is formed of cerium metal and is formed with a target defining annular portion 34 which extends at an angle of 15° with respect to a plane perpendicular to the axis of the rotor 26.

The cathode 14' is provided with a head portion 40

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having an electron focussing cup 42 formed therein and in which is mounted a helical filament 44 comprising a tungsten wire having a coating of cerium formed thereon in any suitable manner. The filament 44 is adapted to be connected to a suitable source of energy through means of leads 46 extending outwardly of the envelope. Electrons generated at the filament 44 are focussed so as to fall upon the target area 34 of the target 13' in a rectangular focal spot 48. As is well known, X-rays will be emitted from this area of the target.

It is quite important that the filament 44 be provided with a coating of cerium. Cerium is a relatively volatile metal when heated and as the anode target 13' becomes heated under the bombardment of electrons, the cerium tends to vaporize and to condense upon other portions of the tube. Some of the vaporized cerium will condense upon the filament 44. If a pure tungsten filament, such as is generally used in X-ray generators, is utilized, this condensation of cerium will give rise to serious difficulties. This is occasioned by reason of the fact that a pure tungsten filament must be operated at a rather elevated temperature in order to obtain the desired electron emission. Cerium has a much lower thermionic work function than tungsten and as a result, if cerium condenses upon a pure tungsten filament operating at the necessary high temperature, the amount of emission from the filament is greatly increased, causing an increase in the X-ray generation at the target. Since the filament is hot, the cerium will tend to revaporize therefrom whereupon the emission will decrease and the X-ray generation correspondingly decrease. This condition will, of course, result in unstable emission from the generator and make difficult, if not impossible, the taking of X-ray pictures. Also, the great increase in emission resulting by the deposition of cerium on the filament will in turn cause greater heating of the target and greater vaporization of the same with the result that a runaway condition can easily occur. However, if the filament is initially coated with cerium, the filament can be operated at a much lower temperature and still obtain the necessary amount of electron emission from the filament without effecting substantial vaporization of the cerium coating. With the filament entirely coated with cerium, additional deposition by reason of vaporization from the target will not affect the overall emission rate from the filament with the result that the emission may be maintained constant and the tube kept under control.

I have found that this same principle is applicable to the construction of X-ray generators in general utilizing X-ray targets of metals having a lower work function than tungsten, that is, the filament of the generator should be provided with a coating of the same metal as forms the target. Metals with which the construction of the invention may be used include thorium, zirconium, germanium, scandium, strontium, calcium, hafnium and rare earths such as lanthanum, yttrium and praseodymium as well as cerium.

Referring now to Figs. 5 to 7, inclusive, the illustrated X-ray generator includes an envelope 60 of glass or other suitable material within which is mounted an anode 62 and a coaxial cathode 64. It will be understood the envelope 60 may be provided with suitable conventional sealed end portions and with suitable means for supporting the anode 62 and cathode 64 therein.

The cathode 64 is provided with a focussing cup recess 66 and a filament 68 which may be connected to a source of electrical energy through leads 70 extending outwardly of the envelope 60 through suitable seals (not shown). For the reasons set forth with regard to the embodiment described above, the filament 68 should be provided with a coating of cerium metal.

The anode 62 comprises a massive body 74 of copper or other suitable material of cylindrical configuration formed with a coaxial electron passageway 76 extending

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inwardly from the anode end facing the cathode 64. Mounted within the anode 62 inwardly of the end of the passageway 76 is a target member 78 comprising a disc of cerium metal having a thickness of about 0.030 inch. The target member 78 is disposed obliquely with respect to the axis of the passageway 76 and also is disposed obliquely with respect to the axis of the filament 68 for purposes to be explained. The cup 66 and filament 68 are designed to project coaxially of the passageway 76 an electron beam 77 of rectangular configuration having its longer cross-sectional axis parallel to the axis of the filament 68.

The target 78 may be secured within the anode 62 by any suitable means, but may be secured in the manner illustrated. As shown, a recess 80 is formed in the walls of the passageway 76 for receiving the target member 78. The recess 80 defines a shoulder 82 to which the target 78 is soldered by means of a thin film 84 of indium or other suitable solder. Such soldering may be accomplished by positioning a ring of the solder between the shoulder 82 and the target 78 during the assembly of the generator. Subsequently, the envelope 60 is evacuated and the anode heated to degas the same. Such heating will cause the solder 84 to melt and effect soldering of the target 78 in position. In Fig. 5 the film 84 is of exaggerated thickness for purposes of illustration. In actual practice the film 84 is of the order 0.001 inch in thickness.

To provide an aperture for X-rays generated in the target member 78 by impingement of the electrons thereon, the hood 74 is cut away immediately rearwardly of the target member 78, that is to say, the anode member is cut away on the side of the target member 78 opposite the side facing the cathode 64. This aperture, indicated at 86, extends generally at right angles to the passageway 76 and parallel to the axis of the filament. Thus, if the target is viewed as shown in Fig. 6, the focal spot area thereon will be a small rectangle as indicated at 88 whereas the focal spot area as viewed from the end of the anode and as shown in Fig. 7 is a long rectangle as indicated at 90. This is, of course, a result of the employment of the line focus principle in the tilting of the target. As will be apparent, the target member 78 in this instance acts as its own filter and the X-rays emitted therefrom the aperture 76 will have a wavelength of about 33 kev.

A cerium plate of 0.030 inch thickness is relatively thin and is subject to injury from overheating and subsequent buckling during operation of the generator. Such buckling and injury may be minimized in the embodiment of Fig. 8 wherein a reinforcing plate 94 is positioned behind a cerium target member 78' mounted within the passageway 76' of the anode body 74'. This reinforcing plate is preferably of a metal of low atomic number, such as, for example, beryllium or aluminum which have low absorption coefficients for X-rays and, therefore, do not materially decrease the number of X-rays transmitted therethrough from the target 78'. The reinforcing member is preferably soldered to the target 78' by means of a thin foil of indium or other suitable material indicated at 96 and may be soldered into position within the anode 62 by means of a ring of indium or other suitable soldering material indicated at 82' as described in connection with the previous embodiment.

Though the invention has been described with particular reference to X-ray generators utilizing targets of cerium, it is obvious that the invention is not limited thereto and I claim as my invention such modifications and alternatives as come within the scope of the appended claims.

I claim:

1. An X-ray generator comprising a cathode having a filament of tungsten metal wire coated with a dissimilar

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metal having a thermionic work function less than that of tungsten, and an anode having an X-ray generating target formed of such dissimilar metal.

2. An X-ray generator as in claim 1 wherein said dissimilar metal is a rare earth metal.

3. An X-ray generator comprising a cathode and an anode, said anode comprising an X-ray generating target member of cerium metal, said cathode comprising a filamentary element of tungsten having a coating of cerium metal thereon.

4. An X-ray generator comprising a cathode and an anode, said anode comprising an X-ray generating target member of cerium metal, said cathode comprising a filamentary element having a coating of cerium metal thereon.

5. An X-ray generator comprising an envelope and co-  
operating anode and cathode units mounted in said en-  
velope in spaced apart relation, said anode comprising  
an X-ray generating target member comprising contact-  
ing, parallel plates of cerium and beryllium, said cathode  
unit having elongate filament means for generating a  
beam of electrons focussed through said passageway upon

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a focal spot area of said anode, said target member be-  
ing disposed in oblique relation with respect to the axis  
of said passageway and to the axis of said filament, said  
anode member being cut away adjacent to and on the  
5 side of said target member opposite said end so as to  
form an aperture through said body for X-rays generated  
at said target, said aperture extending generally at right  
angles to said passageway and parallel to the axis of said  
filament so that the projection of said focal spot area at  
10 right angles to said anode axis extends through said aper-  
ture, said filament comprising tungsten wire coated with  
cerium.

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