March 10, 1964 C. GRAY 3,124,710

X-RAY TUBES

Filed March 6, 1961

3 Sheets-Sheet 1

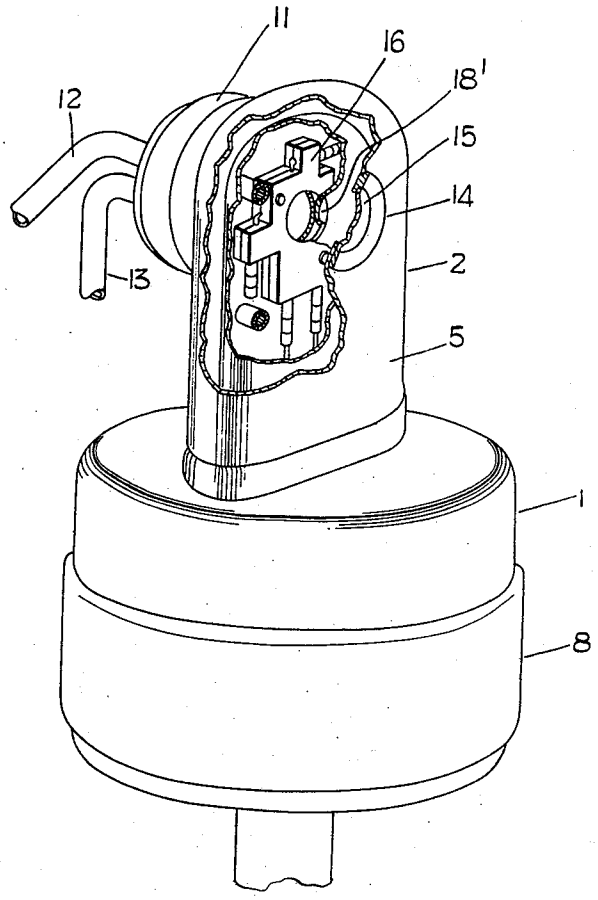

Fig. 1

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Fig. 3

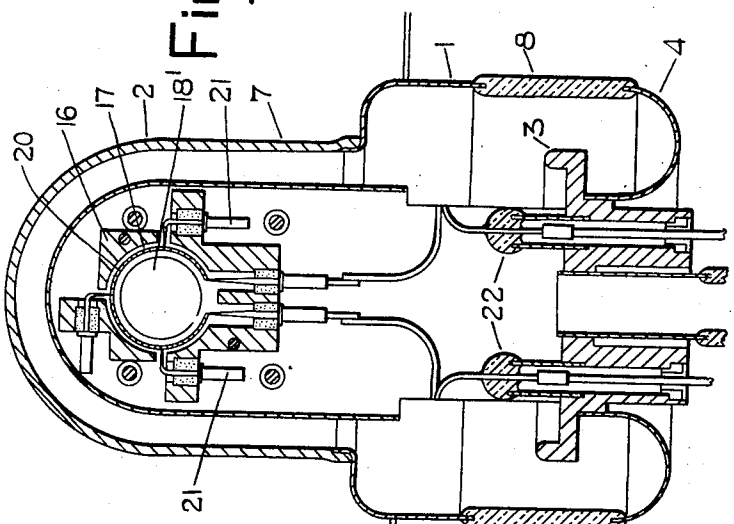
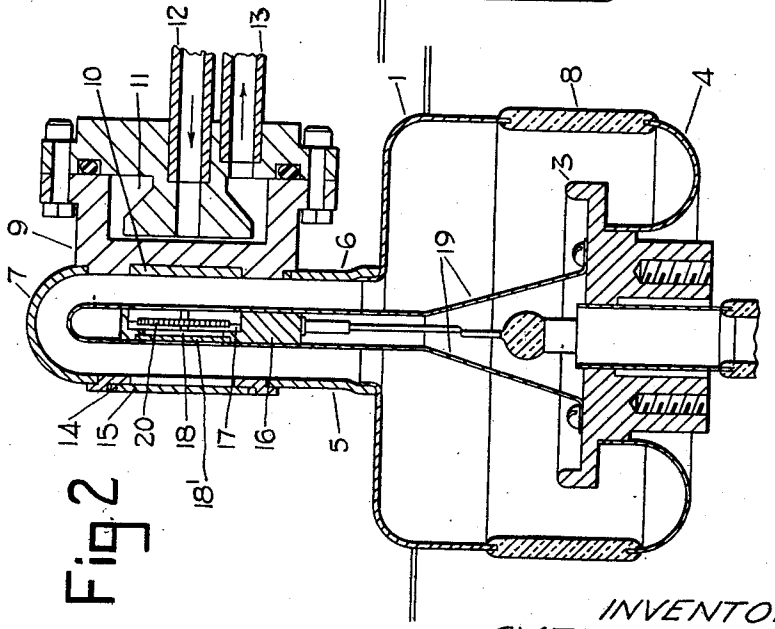


Fig. 2



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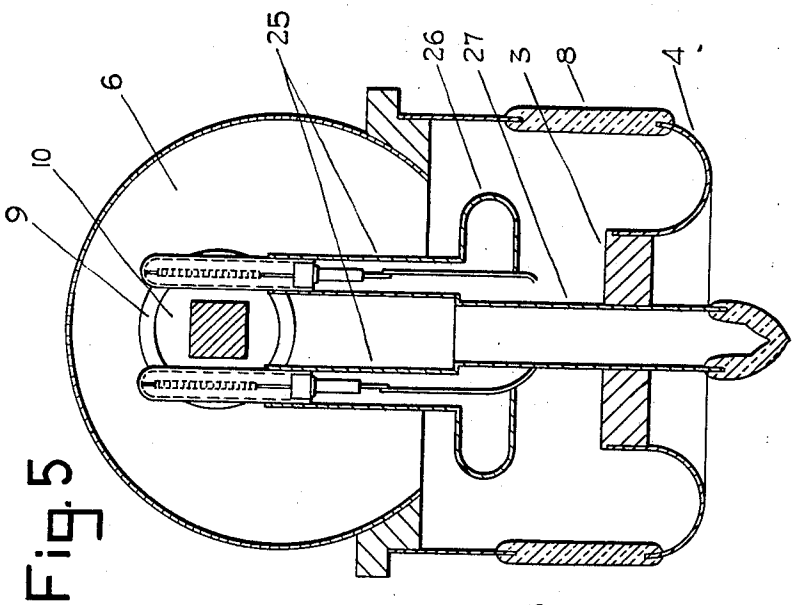

Fig. 5

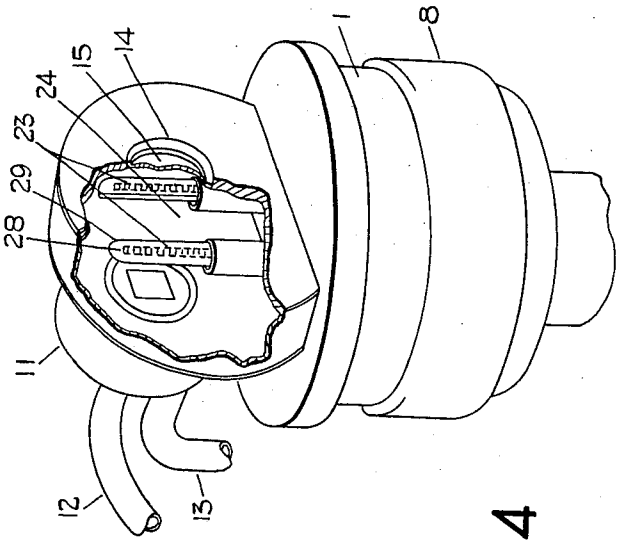

Fig. 4

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X-RAY TUBES

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3 Claims. (Cl. 313—57)

This invention relates to X-ray tubes and in particular to tubes capable of producing large quantities utilisable X-radiation.

It is well known that upon bombardment of the target of an X-ray tube with electrons emitted from a cathode assembly X-rays are issued therefrom in all directions within the area subtended by the plane of the target surface, regardless of the angle at which the electron stream impinges upon the target. Some of this radiation can be usefully employed outside the containing envelope of the tube by allowing it to pass through a window area, of material permeable to X-radiation formed, in the wall of the envelope.

For medical purposes a small quantity of X-radiation is usually required, but there are many applications, particularly in the field of quantitative analysis of materials in which much more intense radiation is needed.

It is the purpose of this invention to satisfy the need for an X-ray tube capable of producing large quantities of utilisable X-radiation.

According to the present invention in an X-ray tube in which electrons from an electron emitting cathode assembly are focused on to a target surface of an anode, said cathode assembly is spaced apart from said target surface in such a direction that the useful X-radiation from the target passes through an effective opening or aperture in said cathode assembly.

The opening or aperture in the cathode assembly may be occupied wholly or in part by an electrostatic shield for the purpose of deflecting secondary electrons emitted from the target thus preventing them from impinging upon and damaging a window formed in the evacuated envelope through which the useful X-rays egress from the envelope. The shield may be a thin sheet of X-ray permeable material for example beryllium or it may be in the form of a grid of conducting wire.

The minimum distances between the cathode, target and the envelope of an X-ray tube are determined mainly by the amount of electrical insulation required between these components taking into account the high electrical-potential which exists between them when the tube is in operation. The arrangement of these components in an X-ray tube constructed in accordance with this invention allows the target to be placed close to the window in the envelope so that a considerable proportion of the radiation produced at the target may be utilised outside of the tube.

A further feature of this invention is that the cathode assembly is given a high negative potential with respect to the anode and the envelope which are kept at earth potential, this arrangement simplifies considerably the cooling arrangements of the anode.

In order that the invention may be more readily understood, the invention will now be described with reference to the accompanying drawings in which:

FIG. 1 is a cut-away projection of an X-ray tube in accordance with one embodiment of the invention.

FIG. 2 is a sectioned side elevation of the X-ray tube shown in FIG. 1.

FIG. 3 is a sectioned front elevation of the X-ray tube shown in FIG. 1.

FIG. 4 is a cut-away projection of an X-ray tube according to a further embodiment of the invention.

FIG. 5 is a sectioned front elevation of the X-ray tube shown in FIG. 4.

Referring now to the drawings in which like parts are given the same reference numeral the evacuated envelope of an X-ray tube consists of a cylindrical member 1 having a flattened end portion 2 which is located symmetrically with respect to the longitudinal axis of the member 1. The end of the cylindrical member 1 remote from the open connection with the portion 2 is closed by means of a cathode assembly support plate 3 supported by a re-entrant wall 4. The flattened end portion which comprises two substantially parallel opposing walls 5 and 6 separated by a further wall 7, is formed from electrically conducting material. An annular sleeve 8 forming part of the wall of the cylindrical member 1 is formed of glass or other electrically insulating material in order to insulate the support plate 3 from the metallic end portion 2. The remaining portions of the wall of member 1 are formed from a metallic alloy having an expansion characteristic similar to that of the glass to which they are sealed in order to minimise any stresses which would otherwise be set up in the glass due to unequal thermal expansion of the glass and the adjoining metal.

The anode of the tube consists of a copper electrode 9 mounted in an aperture in the wall 6 of the portion 2. The inner surface of the electrode has a tungsten disc 10 inlaid therein which provides a target surface, and the outer surface of the electrode is cooled by water flowing in contact therewith. The water enters a jacket 11 which is mounted on the outside of the portion 2 by means of a pipe 12 and leaves by a second pipe 13.

An aperture 14 is formed in the wall 5 of the portion 2, in line with the axis of the tungsten disc 10, and is covered by a sheet of beryllium 15 or other material permeable to X-radiation to form a window area through which the X-radiation formed within the tube is allowed to egress to the exterior of the envelope.

The cathode assembly according to the embodiment of the invention illustrated in FIGS. 1–3 of the accompanying drawings comprises a single electron emitting cathode section consisting of a metallic cathode throat 16 provided with a toroidal recess 17 and a circular opening or aperture 18 centrally located within the recess. The cathode section is secured to the support plate 3 by means of a pair of legs 19 and is located between the anode 9 and the aperture 14 such that the longitudinal axis of the opening 18 extends substantially normal to the plane containing the target surface of the disc 10. A filament 20 of material capable of emitting electrons is located in the recess 17 of the cathode throat and is supported around the periphery of the opening 18 by means of a plurality of pins 21 insulatingly extending from the cathode throat 16. Electrical connections to the filament pass through apertures in the support plate 3 and are sealed into the envelope by means of glass to metal seals 22. The cathode throat 16 acts as a focussing electrode and in particular the curved wall of the recess 17 serves to direct the electrons emitted by the filament on to the target surface.

In a further embodiment of the invention, illustrated in FIGS. 4 and 5, the cathode assembly comprises two similar electron emitting cathode sections 23, spaced apart, one on each side of the line joining the centre of the window to the centre of the target surface, with an opening 24 between them. The sections are mounted on individual sleeves 25 and are located equidistant from the target surface. The sleeves 25 are secured to a metallic radiation shield 26 which is in turn mounted on a further sleeve 27 which passes through and is rigidly secured to the support plate 3.

Each cathode section 23 consists of a filament 28 of

tungsten, or other material capable of emitting electrons when heated, lying substantially perpendicular to the axis of the tungsten target disc 10 and a concave focussing shield in the form of a hemi-cylinder 29 partially surrounding the filament.

In both of the embodiments of the invention the cathode assembly is given a negative electrical potential with respect to the anode and the envelope which are kept at earth potential.

The filament connections are supplied with a suitable electrical potential and the temperature of the filaments is raised sufficiently for them to emit electrons, which are directed onto the tungsten target 10. This bombardment of the anode causes it to issue X-radiation, and a proportion of it passes through the opening or aperture in the cathode assembly and reaches the exterior of the tube through the window in the envelope. The close proximity of the target to the window ensures that a large proportion of the radiation is utilisable.

It has been found that the X-ray permeable material covering the aperture in the envelope may be impinged upon and damaged by secondary electron emission given off by the anode. In both illustrated embodiments of the invention this may be obviated by covering the opening in the cathode assembly either wholly or in part with a suitable material so that the cathode assembly has an equi-potential surface and the electrons are repelled back to the anode. The material may be a sheet of material permeable to X-radiation as shown at 18' in FIGS. 1 and 2 or a thin wire grid through which the X-radiation can pass.

What I claim is:

1. An X-ray tube comprising an evacuated envelope consisting of a cylindrical member having a re-entrant end portion and a flattened end portion providing two substantially parallel walls, an anode providing a target surface which forms part of one of said walls, a window permeable to X-radiation and forming part of the other of said walls and located in alignment with said target surface, a cathode assembly supported within said flattened end portion between said window and said target surface by said re-entrant end portion, said cathode assembly comprising at least one electron emitting filament, the major extension of which lies in a plane substantially parallel with those of said target surface and said window and a focusing electrode positioned between each filament and said window, said assembly being formed with an opening in alignment with said window and said target surface through which X-radiation produced at the target surface, in response to bombardment thereof with electrons from each filament passes to reach said window.

2. An X-ray tube comprising an evacuated envelope consisting of a cylindrical member having a re-entrant end portion and a flattened end portion providing two substantially parallel walls, an anode providing a target surface which forms part of one of said walls, a window permeable to X-radiation and forming part of the other of said walls and located in alignment with said target surface, a cathode assembly supported within said flattened end portion between said window and said target surface by said re-entrant end portion, said cathode assembly comprising a pair of similar electron emitting filaments located equidistant from the target surface and a focusing electrode associated with each filament and positioned between said filament and said window, the major extension of each filament lying in a plane parallel to the longitudinal axis of the cylindrical member and said filaments being spaced apart to provide an opening in alignment with said window and said target surface through which X-radiation produced at the target surface, in response to bombardment thereof with electrons from each filament, passes to reach said window.

3. An X-ray tube comprising an evacuated envelope consisting of a cylindrical member having a re-entrant end portion and a flattened end portion providing two substantially parallel walls, an anode providing a target surface which forms part of one of said walls, a window permeable to X-radiation and forming part of the other of said walls and located in alignment with said target surface, a cathode assembly comprising a metallic body having a recess formed therein, an opening located within said recess and an electron emitting filament insulatingly supported within the recess adjacent the periphery of the opening, the major extension of said filament lying in a plane parallel to the longitudinal axis of the cylindrical member and said assembly being supported within said flattened end portion between said window and said target surface by said re-entrant end portion such that X-radiation produced at the target surface in response to bombardment thereof with electrons from said filament, passes through said opening to reach said window.

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