May 27, 1958 Z. J. ATLEE 2,836,749

360° X-RAY GENERATOR

Filed Feb. 28, 1955

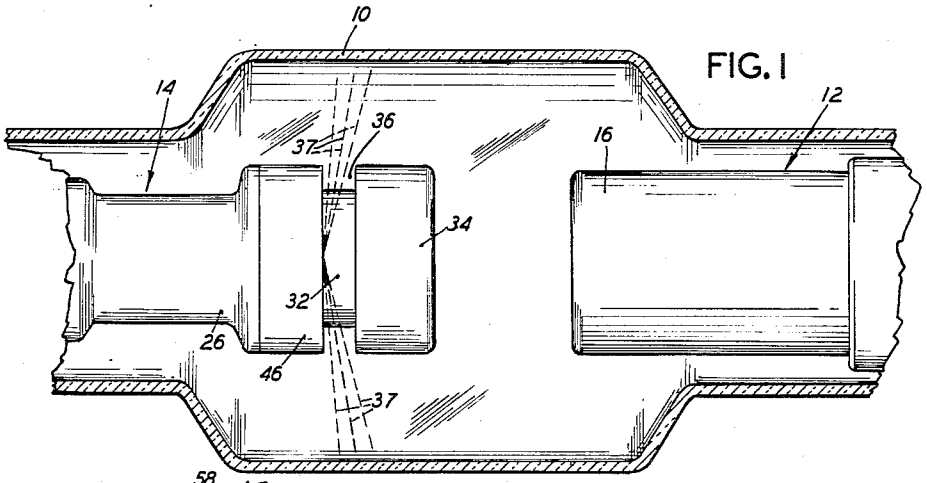


FIG. 1

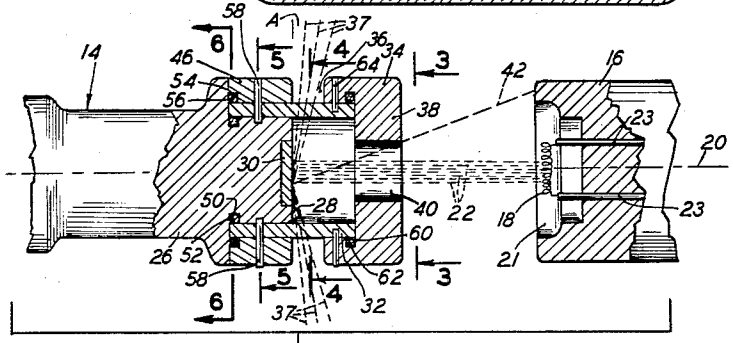


FIG. 2

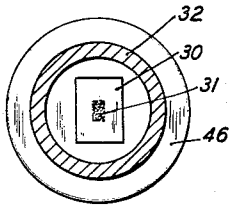


FIG. 4

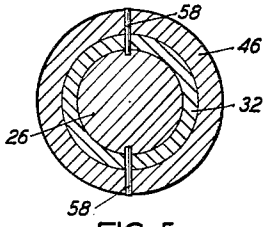


FIG. 5

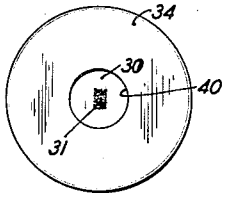


FIG. 3

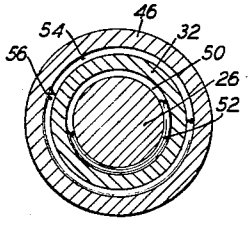


FIG. 6

INVENTOR.
ZED J. ATLEE
BY
Buckhorn and Cheatham
ATTORNEYS

United States Patent Office

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360° X-RAY GENERATOR

Zed J. Atlee, Chicago, Ill., assignor to Dunlee Corp., Chicago, Ill., a corporation of Illinois

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9 Claims. (Cl. 313—59)

The present invention relates to X-ray generators, and particularly to a new and improved neutral grounded type X-ray generator or tube having a 360° useful beam of radiation.

Prior neutral grounded 360° radiation X-ray tubes, that is, tubes having an X-ray generating target positioned in a central location of a tubular envelope through which the X-rays are projected, have been suitable for only intermediate voltages, for example, up to about 180 kilovolts. The upper range of operating voltage has been limited heretofore because of the lack of protection for the tube envelope against electron impingement. At high potentials, the electrons in an X-ray tube are highly excited and if permitted to impinge upon the envelope cause deteoriation of the envelope material, and, additionally, collect to form areas of high charge subjecting the envelope to electrical strain under which it may fail. Accordingly, it is a principal object of the invention to provide a neutral grounded X-ray tube capable of generating a 360° radiation beam and having means for protecting the tube envelope from electron impingement whereby the tube may be operated at significantly higher voltages than has been permissible heretofore.

It is presently the practice to inspect by X-ray the soundness of annular welds between sections of pipe lines, penstocks and like structures formed of pipes of large diameter. Such inspection is most conveniently done by placing a source of X-rays within the structure to be welded and positioning a film strip circumferentially about the weld on the exterior of the pipe, and apparatus has been designed to provide a 360° beam of radiation so a complete picture of the weld may be made with one exposure. However, with the X-ray generators or tubes provided heretofore for such apparatus, it was necessary to provide shielding within the apparatus moved through the pipe line so as to confine the radiation to a narrow beam sufficient to obtain the necessary exposure but to eliminate extraneous radiation as protection to personnel. This shielding added materially to the weight of the apparatus, thus increasing the difficulty in maneuvering and handling the same and, furthermore, created design problems because of the space requirements. Thus, it is another principal object of the present invention to provide an X-ray tube which will emit a circular useful beam of radiation of relatively narrow depth, thus requiring a minimum of exterior shielding to protect personnel.

More particularly, it is an object to provide an X-ray tube constructed and arranged with shielding members therein to prevent extraneous X-radiation from the tube and to prevent impingement of electrons upon the tube envelope.

Another object of the invention is to provide a new and novel arrangement for mounting shielding hood members within an X-ray tube.

A further object is to provide an X-ray tube having a 360° beam of useful radiation which may be manufactured at relatively low cost.

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

In accordance with the illustrated embodiment of the present invention, an X-ray generator is provided having spaced apart anode and cathode units with shielding members so arranged within the generator that all X-rays generated at the target are intercepted except for a circular beam of relatively narrow depth and the envelope of the generator is protected from electron impingement.

For a more complete description of the invention, reference is made to the accompanying drawing wherein:

Fig. 1 is a fragmentary side elevation of an X-ray tube constructed in accordance with the invention;

Fig. 2 is a view of the anode and cathode units of the generator of the invention shown partially in medial section;

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

Fig. 4 is a sectional view taken substantially along line 4—4 of Fig. 2;

Fig. 5 is a sectional view taken substantially along line 5—5 of Fig. 2; and

Fig. 6 is a sectional view taken substantially along line 6—6 of Fig. 2.

The illustrated embodiment of the invention includes an evacuated envelope 10 which is shown as being of glass but which may be of any other suitable material. Mounted within the envelope 10 in any suitable manner is a cathode unit indicated at 12 and an anode unit at 14 which are shown as mounted in coaxial facing relation. The cathode unit 12 includes a cylindrical head portion 16 of iron or similar metal having electron generating means therein including an elongate filament 18 extending at right angles to the axis 20 of the anode and cathode units and substantially equidistantly on opposite sides of the axis 20. The filament 18 is mounted within a cathode cup 21 which is focused to project a beam of electrons, indicated at 22, toward the anode unit. Energy for the filament 18 is supplied to leads 23 which extend outwardly of the envelope 10 in any suitable fashion.

The anode unit 14 includes a generally cylindrical body 26 which is preferably a casting of copper or other metal having good heat conductivity properties. The body 26 is formed with a planar end 28 facing the cathode unit 12, in which end is embedded an X-ray generating target 30 and upon which the electron beam 22 is focused on a focal spot indicated at 31 in Fig. 4. As is well known, the electrons impinging upon the target element 30 cause the generation of X-rays which will be emitted from the face of the target in a generally hemispherical pattern of substantially uniform intensity with the exception of the zone next adjacent the target face wherein a zone of weak field intensity exists. Beyond a small angle such as 5 or 6 degrees, as indicated at A in Fig. 2, the field intensity of the radiations from the target 30 will be substantially uniform in all directions.

In accordance with the preferred embodiment of the present invention, the tube is constructed and arranged so that all of the X-rays will be intercepted within the tube except for a field or beam 27 extending in annular fashion about the axis of the tube and having a relatively narrow width or depth longitudinally of the tube. Mounted on the anode body 26, and projecting outwardly from the face 28 in coxial relation to the anode unit, is a tube or sleeve 32 formed of a material having high permeability to X-rays but impermeable to electrons and having sufficient mechanical strength for its purpose as a shield or hood supporting means, to be further described. A suitable material for the sleeve is beryllium. Mounted on the distal end of the sleeve 32 is an annular hood member 34 composed of a material relatively opaque to X-rays such as, for example, copper, wolfram or other

metal of high atomic number. As shown, the hood member 34 is spaced from the plane of the body face 28 so as to define a relatively narrow, annular window or portal space 36 immediately in front of the anode body face through which X-rays may pass as indicated by the dotted lines 37. The hood member 34 is formed with an inwardly directed flange 38 on the end thereof adjacent the cathode unit 12 defining a coaxial, circular, electron admitting opening 40 for the passage of the beam 22 to the target 30. The opening 40 is preferably of a diameter substantially equal to the length of the filament 18, which provides an opening of just sufficient width to admit the electron beam 22. An opening of larger diamter than necessary is not desired, for it provides a greater opening for the escape of X-rays from the target 30 whereas, if it is too small, the electron beam 22 will impinge upon the hood member 34, which may cause excessive heating and melting thereof in the case of metals having relatively low melting points, or may even cause a generation of X-rays if the hood member is composed of materials of relatively high atomic weight such as, for example, wolfram.

In a preferred embodiment of the invention, the cathode head portion 16 is of relatively large diameter and is spaced from the anode unit at a distance whereby all X-rays generated at the focal spot 31 of the target element escaping through the hood opening 40 will impinge upon the head portion as indicated by the dotted line 42 which represents the escaping X-ray of greatest divergence through the opening 40.

In X-ray generators operating at high potentials, some of the X-rays generated at the target face will pass backwardly through the target and the body 26 of the anode unit. Thus, to provide additional protection, in some instances it is desirable to provide a collar 46 of X-ray impermeable material about the sleeve 32 and body 26 immediately rearwardly of the body face to intercept any X-rays which may escape through this relatively thin portion of the body 26. It will ordinarily not be necessary to extend the collar or shield 46 for a greater distance rearwardly than substantially as shown since the body length through which the X-rays pass in other directions will be sufficiently great to attenuate and stop substantially all the X-rays.

While the shield 32 and hood members 34, 46 may be secured in any suitable fashion, they may be mounted conveniently in the manner now to be described. As shown in Figs. 2 and 6, the body member 26 is formed with a groove 50 over which the sleeve 32 is positioned and in which groove a ring of solder 52 is placed prior to the positioning of the sleeve. Similarly, the hood member 46 is provided with a groove or recess 54 in the surface which abuts the sleeve 32, and in which groove a ring of solder 56 is positioned prior to the assembly of the hood member upon the sleeve. In assembling the tube, after placing the sleeve 32 and hood member 46 upon the body 26, pins 58 are driven through cooperative openings formed in the hood member 46, sleeve 32 and the body member 26 so as temporarily to secure the various parts together. The hood member 34 is also provided with a groove, indicated at 60, in which a ring of solder 62 is positioned prior to its assembly on the sleeve 32, and fastening pins 64 are driven through the hood member 34 into suitable openings in the sleeve 32 similarly to the pins 58. After the anode and cathode units are mounted in the envelope 10, the tube is exhausted and the anode unit heated by any suitable means, such as by induction heating, so as to cause the solder rings 52, 56, 62 to melt, thereby effecting soldering of the hood members 34, 46, sleeve 32 and body 26 together and into an integral unit.

It will be observed that with the X-ray tube of the present invention, an X-ray beam 37 will be emitted in complete 360° fashion from the tube but that the beam will be of relatively narrow width or depth longitudinally of the tube and that a minimum weight of shielding is utilized to obtain this result. If shielding were placed outside of the X-ray tube to confine the radiation to the narrow band which is produced in the operation of the tube of the invention, a vastly greater amount of shielding material would be necessary, which would, of course, increase the overall weight of the apparatus with which the X-ray tube is used and which shielding may furthermore present difficulties in that it interferes with the arrangement of the other parts of an apparatus with which the X-ray tube is used.

While X-rays may pass through the portal 36, the sleeve 32 and hood member 34 will attenuate any electrons which may diverge from the beam 22 or attenuate secondary electrons scattering laterally from the target 30, thus preventing such electrons from striking the envelope 10. As a result of this protection, a tube made in accordance with the invention can be operated at voltages in the neighborhood of 250 kilovolts or higher as compared to a limit of 180 kilovolts in similar tubes having no electron protection for the envelope. Moreover, the tube of the invention can be made at relatively low cost as compared with end grounded tubes which heretofore were the only type of tube capable of operating at voltages comparable to those under which the tube of the invention can be operated.

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. An X-ray generator comprising an anode unit and a cathode unit mounted in coaxial spaced apart facing relation, said anode unit comprising a cuprous body having a planar face extending perpendicularly to the axis of said anode unit and a target element embedded in said face, a tubular X-ray impervious hood member spaced between said anode and cathode units defining a passage for the electron beam from said cathode unit to said target element, said hood member being spaced wholly from the plane of said body face in the direction of said cathode unit, and means composed of X-ray pervious material extending between said anode body and hood member and supporting said hood member from said body, whereby an annularly extending opening is provided between said anode body and said hood member for the passage of X-rays generated at said target in a beam extending radially from the axis of said anode unit in an arc of 360 degrees.

2. An X-ray generator comprising spaced apart anode and cathode units facing one another, said anode unit comprising an elongate cast body having a front end facing said cathode unit and an electron target embedded in said end, means on said cathode unit for focusing a beam of electrons upon said target, a layer of X-ray shielding material surrounding said body immediately adjacent said end, a hood member of X-ray shielding material positioned between said cathode and anode units and having an aperture therethrough for passage of said electron beam, said hood member being spaced from said body in the direction of said cathode unit so as to provide an annular opening between said body and hood member for X-rays generated at said target, and support means permeable to X-rays supporting said hood member from said body.

3. An X-ray generator comprising coaxial, spaced apart anode and cathode units, said anode unit comprising a generally cylindrical body having a planar end facing said cathode unit and extending at right angles to the axis of said units, a target element embedded in said body end, a beryllium tube secured at one end to said body in coaxial relation therewith and extending outwardly from said end toward said cathode unit, and an

annular hood member composed of material opaque to X-rays secured to the distal end of said tube, said hood member being spaced from said anode body end whereby to define an annular portal space immediately in front of said end through which X-rays from said target may pass, said cathode unit including a head portion facing said anode unit comprising means for generating and focusing upon said target element a beam of electrons.

4. An X-ray generator comprising coaxial, spaced apart anode and cathode units, said anode unit comprising a generally cylindrical copper body having a planar end facing said cathode unit and extending at right angles to the axis of said anode unit, a planar target element embedded in said body end, a sleeve of X-ray transparent metal mounted on said body in coaxial relation therewith and projecting toward said cathode unit, an annular hood member composed of material relatively opaque to X-rays secured to the distal end of said sleeve, said hood member being spaced a predetermined distance from said anode body end whereby to define an annular portal space immediately in front of said end through which X-rays from said target may pass, and a collar member composed of material relatively opaque to X-rays surrounding said sleeve and body adjacent said body end so as to intercept any X-rays passing through said body in the portion adjacent the said end thereof whereby X-ray radiation from said tube is confined substantially to the radiation passing through said portal space.

5. An X-ray generator comprising coaxial, spaced apart anode and cathode units, said anode unit comprising a generally cylindrical body having a planar end facing said cathode unit and extending at right angles to said axis, a target element embedded in said body end, a beryllium sleeve secured to said body in coaxial relation therewith and extending outwardly from said end toward said cathode unit, and an annular hood member composed of material relatively opaque to X-rays secured about the distal end of said sleeve, said hood member being spaced a relatively short distance from said anode body end whereby to define a narrow, annular portal space immediately in front of said end through which X-rays from said target may pass, said cathode unit including a cylindrical head portion comprising an elongate electron generating filament extending at right angles to said axis and substantially equal distances on opposite sides thereof, said filament having a length substantially less than the inner diameter of said sleeve, said hood member having an inwardly directed flange on the end thereof defining a coaxial, circular electron admitting opening of a diameter substantially equal to the length of said filament, said cathode head portion being of a relatively large diameter, and said cathode unit being spaced from said anode unit at such distance whereby all X-rays generated at the focal spot of said target element and escaping through haid hood electron admitting opening impinge upon said head portion whereby X-ray radiation from said tube is confined to the radiation passing through said portal space.

6. An X-ray generator comprising an elongate cylindrical envelope and an anode unit and cathode unit mounted in said envelope in facing, spaced apart relation, a planar target element on the end of said anode unit facing said cathode unit, said cathode unit comprising means for generating a beam of electrons and focusing the same upon said target element, and tubular hood means extending from said anode unit coaxially of the path of said electron beam including a first annular portion immediately forward of said target permeable to X-rays but impermeable to electrons and a further annular portion spaced from said target element impermeable to X-rays whereby electrons in the interior of said hood means cannot escape through the wall of such hood means, but X-ray radiation from said target element may pass unimpeded through said first annular portion to provide a beam throughout an arc of 360 degrees.

7. An X-ray generator comprising an anode unit and a cathode unit mounted in coaxial spaced apart facing relation, said anode unit comprising a cuprous body having a planar face extending perpendicularly to the axis of said anode unit and a target element embedded in said face, a tubular X-ray imprevious hood member spaced between said anode and cathode units defining a passage for the electron beam from said cathode unit to said target element, said hood member being spaced from the plane of said body face in the direction of said cathode unit, and tubular means composed of X-ray pervious, electron imprevious material extending between said anode body and hood member and supporting said hood member from said body.

8. An X-ray generator comprising a sealed, elongate, cylindrical, X-ray permeable envelope having mounted therein longitudinally spaced apart coaxial cathode and anode units facing one another, an X-ray generating target element on the end of said anode unit facing said cathode unit, electron generating means in said cathode unit for focusing a beam of electrons upon said target element, and hood means in said envelope including a portion defining a window for X-rays generated at said target element, said window portion completely encircling said axis and being of relatively narrow width with respect to the longitudinal direction of said envelope whereby the field of X-rays emitting from said envelope extends radially thereof in a 360 degree arc but is of relatively narrow depth longitudinally of the envelope, said window portion being impermeable to electrons.

9. An X-ray generator comprising spaced apart anode and cathode units facing one another, said anode unit comprising an elongate cast body having a front end facing said cathode unit and an electron target embedded in said end, means on said cathode unit for focusing a beam of electrons upon said target, a hood member of X-ray shielding material positioned between said cathode and anode units and having an aperture therethrough for passage of said electron beam, said hood member being spaced from said body in the direction of said cathode unit so as to provide an annular opening between said body and hood member for X-rays generated at said target, and support means permeable to X-rays supporting said hood member from said body.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,836,749 May 27, 1958

Zed J. Atlee

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 60, for "beam 27" read --beam 37--; column 5, line 55, for "haid" read --said--; column 6, line 16 and line 22, for "imprevious", each occurrence, read --impervious--; same column 6, list of references cited, under "UNITED STATES PATENTS" insert the following:

2,340,361	Atlee et al.	Feb. 1, 1944
2,490,246	Zunick	Dec. 6, 1949

Signed and sealed this 29th day of July 1958.

(SEAL)
Attest:
KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents