

[54] **ROLLING CYLINDER CASSETTE FOR ELECTRON RADIOGRAPHY**

[75] Inventors: Arthur Lee Morsell, Tarzana; Norton L. Moise, Los Angeles, both of Calif.

[73] Assignee: Konics, Inc., Van Nuys, Calif.

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[58] Field of Search 250/66, 68, 65 ZE, 250/61.5

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Primary Examiner—James W. Lawrence

Assistant Examiner—B. C. Anderson

Attorney—Ford W. Harris, Jr. et al.

[57]

ABSTRACT

An X-ray system for producing a fan-shaped beam and scanning the beam over the object to be X-rayed for reducing fogging due to scattering and reducing exposure of the patient. A cassette for holding the record medium in a gas filled gap between electrodes, and a mechanism for rotating the record medium past a slit in synchronism with the X-ray beam scan.

8 Claims, 7 Drawing Figures

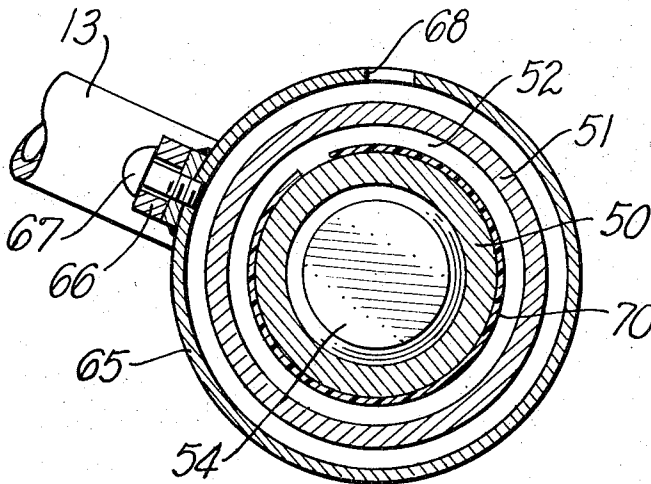


FIG. 2.

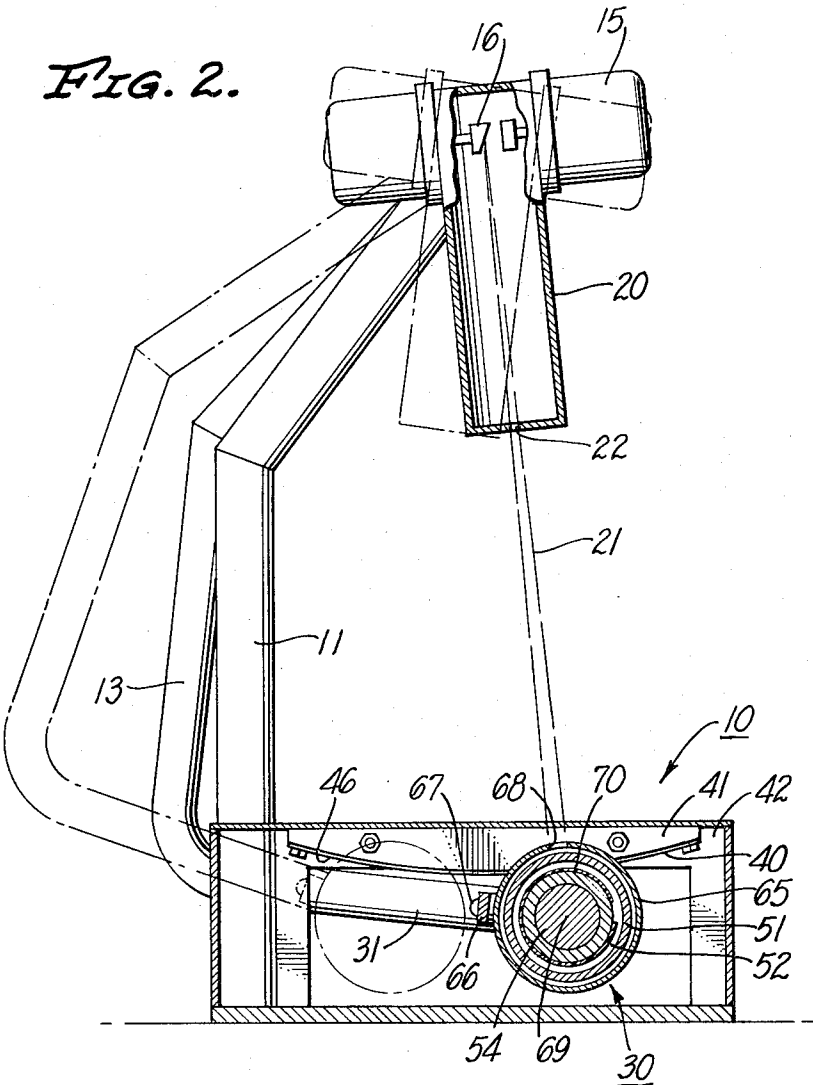
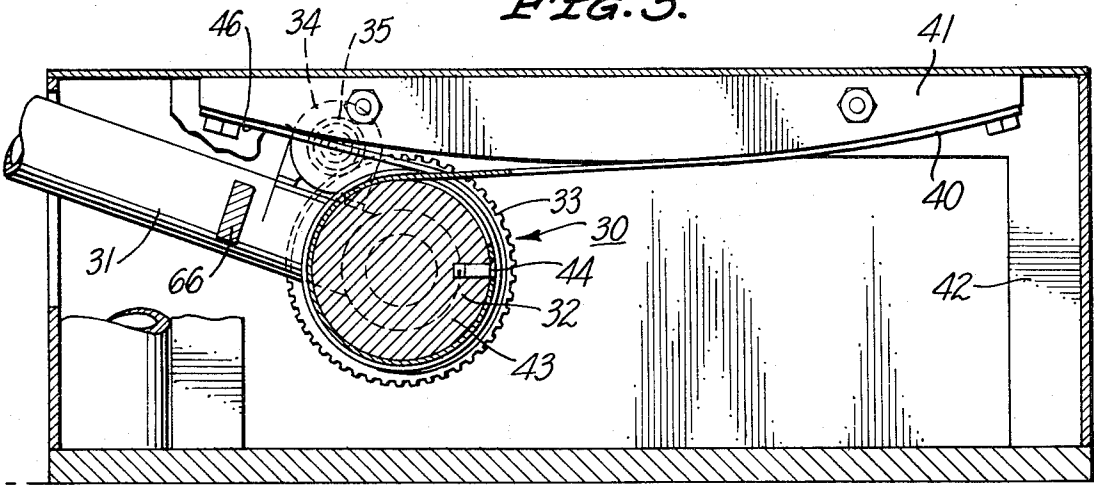


FIG. 3.



ROLLING CYLINDER CASSETTE FOR ELECTRON RADIOGRAPHY

This invention relates to X-ray systems and, in particular to a new and improved X-ray system which provides for scanning a narrow beam across the object being X-rayed and a cassette for holding the record medium. The invention may be used with various known X-ray techniques and is particularly adapted for use with radiographic systems in which an X-ray source produces electrons to form an electrostatic image suitable for printing. This type of radiographic system is sometimes referred to as ionography and utilizes a dielectric sheet as the record medium in place of the more conventional photographic film. The variation in X-ray intensity exiting from the object illuminated by the X-ray source produces a variation in electron density on the dielectric sheet. The electrostatic image on the dielectric sheet is then converted to a visual image using conventional techniques, such as the xerographic process. For further information on the basis ionographic system, reference may be made to copending application entitled **RADIOGRAPHIC SYSTEM WITH XEROGRAPHIC PRINTING**, U.S. Pat. Ser. No. 217,394, filed Jan. 12, 1972, now abandoned, and assigned to the same assignee as the present application. The present application is directed to an improvement on the system of said copending application.

The ionographic system utilizes electrodes with a gas at high pressure in the gap between the electrodes. It is difficult to build a structure strong enough to contain the high pressure gas and maintain the electrode spacing, but still thin enough to permit the passage of X-ray radiation into the gap. This structural problem is especially severe in the case of devices with flat, large area gaps such as is required for present day medical X-ray practice. Curving the X-ray window structure eases the problem of providing the necessary strength and transparency to X rays but introduces a number of other problems. Curving the X-ray window without curving the electrode gap generates the problem of finding a suitable filler material to interpose between the curved window and the flat gas gap; such filler must be transparent to X rays, yet must withstand the high gas pressure. If the gas gap is curved to match the curvature of the window, the bounding surfaces of the gap will not be nearly perpendicular to the propagation direction of the X rays and hence there will be a loss in image quality.

All X-ray imaging systems suffer to some extent from the problem of fogging of the image from radiation scattered from the object being X-rayed. The unusual means of handling this problem is the Potter-Bucky diaphragm, which is a device consisting of a grid of flat lead strips separated by strips of material transparent to X rays. The device is placed between the object being X-rayed and the imaging system carrying the record medium. The strips of the grid are oriented with respect to the X-ray source in such a way that undeflected rays are more likely to pass between the lead strips than are the rays deflected by scattering in the object. A mechanism is provided for moving the grid during the X-ray exposure to eliminate the shadow of the grid in the resulting image. The moving grid is quite effective in removing the image fogging, but there is an appreciable loss of desired, undeflected rays. Therefore when a Potter-Bucky diaphragm is used it is necessary to increase

the dosage to the patient by as much as a factor of three.

The system of the present invention provides a solution to the problems encountered in these prior art systems. The system of the invention provides for scanning the X rays over the object in a narrow beam defined by moving slits. The system of moving slits minimizes the dose or exposure received by the patient while maintaining the X-ray intensity at the record medium. The moving slit system also substantially reduces the undesirable scattered radiation reaching the imaging system with the record medium. A reduction in fogging of the image is obtained without any loss of the desired unscattered rays. The Potter-Bucky diaphragm is not needed and the patient exposure is substantially reduced.

A cassette is provided for the dielectric sheet which serves as the record medium in the ionographic system and includes a pair of electrodes, at least one of which is cylindrical, with the gas gap therebetween. The outer electrode may be a cylindrical sleeve with high structural strength resulting from the small radius of curvature and hence may be quite thin or have a thin window section with low X-ray absorption while maintaining structural integrity and gap dimensional control under high gas pressure. A mechanism is provided for rotating the record medium as the cassette is moved across the image area. A slit limits the exposure to a portion of the gas gap with bounding surfaces nearly perpendicular to the direction of propagation of the X rays.

It is an object of the invention to provide a new and improved X-ray system with these features. Other objects, advantages, features and results will more fully appear in the course of the following description. The drawings merely show and the description merely describes preferred embodiments of the present invention which are given by way of illustration or example. In the drawings:

FIG. 1 is a side view of an X-ray system incorporating the presently preferred embodiment of the invention; FIG. 2 is a sectional view taken along the line 2—2 of FIG. 1;

FIG. 3 is an enlarged sectional view taken along the line 3—3 of FIG. 1;

FIG. 4 is an enlarged sectional view taken along the line 4—4 of FIG. 1; and

FIGS. 5, 6 and 7 are views similar to that of FIG. 4 showing alternative embodiments of the invention.

Referring to FIGS. 1—4, the X-ray system includes a housing 10 with an upright support 11. The object to be X-rayed may rest on the top of the housing 10 or on a table or other support (not shown) positioned above the housing 10. An arm 13 is journaled in the upper end 14 of the support 11. An X-ray tube 15 is carried on the arm 13, preferably with the target 16, at which the X rays are generated, aligned with the pivot axis 17 of the arm 13. A shield 20 is carried on the tube 15 for limiting radiation from the tube to a fan-shaped beam 21 by means of a slit 22 at the lower end of the shield 20.

An electrode unit 30 is carried at the lower end 31 of the arm 13. In the preferred embodiment illustrated, a shaft 32 is journaled in the arm end 31, with a gear 33 carried on one end of the shaft 32. A drive motor 34 is carried on the arm 13 with a gear 35 on the motor output shaft engaging the gear 33 for rotating the shaft 32.

A mechanism is provided for coupling the shaft 32 to the housing 10 so that rotation of the shaft will move the arm 13 as well as rotate the electrode unit 30. One end of a strap 40 is fixed to a rib 41 carried on a frame member 42 in the housing 10. The strap 40 is wrapped on an intermediate section 43 of the shaft 32 with the other end of the strap fixed to the shaft as by a screw 44. Another strap 46 is wrapped on the intermediate section 43 in the opposite direction with one end fixed to the rib 41 and the other end fixed to the shaft 32. With this arrangement, rotation of the shaft 32 drives the lower end 31 of the arm 13 laterally as seen in FIG. 3 in an arcuate path about the pivot axis 17. Preferably but not necessarily, the lower surface of the rib 41 is an arcuate section about the axis 17 providing minimum stress on the arm. Various other drive arrangements will readily be apparent, such as a single strap looped around the shaft 32 and anchored at both ends to the rib 41 or a shaft gear engaging a gear rack on the rib 41.

The electrode unit 30 includes an inner electrode 50 and an outer electrode 51. The electrodes are cylindrical and concentric with a gap 52 therebetween. The outer electrode 51 may be carried on the shaft 32 at the intermediate section 43, with an electrical insulating sleeve 53 between the electrode and shaft. The inner electrode 50 may be a slide fit onto the end 54 of the shaft 32 and threadedly engageable with a threaded portion 55. A gasket 56 provides a pressure seal and electrical insulation between the inner and outer electrodes. A flexible tube 57 connected to the end of the electrode 50 provides for introducing gas under pressure into the gap through a passage 58. A high voltage from a power supply 60 may be connected across the electrodes by connecting one terminal of the power supply to the inner electrode through system ground and connecting the other terminal of the power supply to the outer electrode through a feedthrough terminal 61 and a flexible conductor 62.

A sleeve 65 of a material opaque to X rays is carried on the arm 13 and surrounds the electrode unit 30. The sleeve may be mounted on a boss 66 projecting laterally from the arm 13 by a screw 67. A slit 68 is provided in the sleeve 65, with the slit 68 in alignment with the slit 22, the target 16 and the axis of rotation 69 of the shaft 32. In the embodiment illustrated in FIGS. 1-4, the inner electrode 50 is the anode, and a receptor or record medium in the form of a dielectric sheet 70 is wrapped on the inner electrode 50. Typically the sheet 70 may be dipped in a volatile conducting liquid such as alcohol and then wrapped on the electrode, after which the electrode is threaded onto the shaft. The outer electrode 51 is constructed of a material which is highly transparent to X rays, typically beryllium. The operation of the system in forming the electrostatic image on the sheet 70 is the same as in the aforementioned copending application. The slit 68 is made just large enough to admit all of the radiation beam 21 to illuminate a rectangular segment at the gap 52 and thus confine the radiation to that part of the gas gap bounded by electrode surfaces nearly perpendicular to the direction of incidence of the X rays, since the resolution of the image is degraded as the gas gap tilts with respect to the incident beam. The shield 65 blocks the undesired radiation scattered by the object being X-rayed thereby substantially eliminating fogging without requiring the Potter-Bucky diaphragm. The shield 20

limits radiation from the X-ray tube to the beam path 21 so that the patient is not exposed to any unnecessary radiation.

In operation, a dielectric sheet is mounted on the inner electrode as described and the inner electrode is installed. The gap between the electrode is charged with gas. The mechanism is moved to one extreme position, the object to be X-rayed is placed in position, the power supply to the electrodes is turned on, the drive motor 34 is energized, and the X-ray tube is turned on. The drive motor rotates the shaft 32 which in turn rotates the anode carrying the dielectric sheet and also moves the arm 13. The X-ray beam 21 defined by the slits is scanned over the object and the sheet 70 is "exposed" as the sheet rotates during the scanning. When the mechanism has moved to the opposite extreme, the drive motor, electrode power supply and X-ray tube are shut off and the anode is removed for development of the visual image in the conventional manner.

The scanning with the narrow beam formed by the aligned slits, one above and one below the object being X-rayed, can be utilized with a stationary record medium, such as a flat sheet, as well as with the rotating cassette construction, to obtain the advantages of minimum patient exposure and minimum fogging. This arrangement would be suitable where maintenance of a gap between electrodes is not a problem. Also, a rotating anode moving across the zone being X-rayed with exposure of the record medium limited by a slit can be utilized where total exposure to the object is not a problem, while obtaining the structural advantages of the concentric cylinders with the high pressure gas in the gap.

Various modes of construction for the electrode arrangement may be utilized, such as having two electrodes assembled as a unit externally of the housing with the unit mounted on the shaft 32. Also, the relationship of anode and cathode can be changed as desired. In FIG. 5, the outer electrode is operated as the anode, with the dielectric sheet 70 carried thereon. Further, it should be noted that both electrodes do not have to rotate, it merely being required that the dielectric sheet rotate for scanning the exposure over the entire sheet. One alternative embodiment with the inner electrode serving as the anode and rotating while the outer electrode is fixed, is shown in FIG. 6. The inner electrode 50 is insulated from the shaft 32 at end 54 by an insulating sleeve 72. In this embodiment, the outer electrode 51 also serves as the shield 65. The slit 68 is closed by a window 76 of material highly transparent to X rays, typically beryllium. The inner surface of the outer electrode 51 may be lined with an insulator 77 everywhere but in the region of the slit 68. With this construction, only a small amount of the expensive beryllium is required. The insulator 77 reduces the likelihood of breakdown between the outer electrode and the sheet 70 when the gas pressure is lowered just prior to opening the cassette. Also, the gas gap between the electrodes can be very small everywhere except in the region of the slit 68 with a saving in the amount of gas utilized.

As another alternative configuration, in the arrangement of FIG. 5 with the dielectric sheet on the outer electrode, the outer electrode could rotate with the inner electrode stationary.

While the electrodes are generally cylindrical in configuration, both electrodes do not have to be complete

cylinders. By way of example, in the embodiment of FIG. 7, the sheet 70 is carried on the inner surface of the rotating outer electrode 51. Since the system is operative only in the portion of the gap 52 adjacent the slit 68, the other electrode need only be present at the area of the slit 68 as the sheet 70 is driven thereby. Hence the inner electrode 50' may be a strip carried on a stationary insulating sleeve 80. With this configuration, the gap 52 may be made very small everywhere except in the region 81. The outer surface of the electrode 50' can be convex as in FIG. 5, or flat as shown in FIG. 7, or concave. With the flat and concave shapes, the size of the beam as determined by the size of the slit 68 can be increased and the exposure time reduced while maintaining the same quality of image. This is possible because the field lines between the electrodes are more nearly parallel to the path of the X rays through the gap for the non-parallel electrode configurations. Similarly, the window 76 in the embodiment of FIG. 6 may be flat or convex.

In the preceding discussion, the ionographic system has utilized the electrons produced in the gap by the X rays, with the electrons being attracted toward the anode and collected on the dielectric sheet. In an alternative mode, the positive ions produced in the gap by the X rays and attracted toward the cathode, may be collected on a dielectric sheet at the cathode and converted to a visual image in the same manner. If desired, dielectric sheets may be disposed at cathode and anode for obtaining two images at the same time.

Although exemplary embodiments of the invention have been disclosed and discussed, it will be understood that other applications of the invention are possible and that the embodiments disclosed may be subjected to various changes, modifications and substitutions without necessarily departing from the spirit of the invention. By way of example, while a pivoting arm 13 has been illustrated with arcuate motion for the slits, a translating system with a linear motion for the slits can also be utilized. The only requirement is that the X-ray source, the slits and the axis of rotation of the cassette carrying the record medium be maintained in alignment during the scanning.

We claim:

1. In a cassette for a radiographic system or the like, the combination of:

a pair of electrodes comprising an anode and a cathode, at least one of said electrodes being cylindrical;

means for mounting said electrodes in spaced relation with a gap therebetween to form a unit having an axis of rotation;

means defining a slit on said unit exteriorly of said

gap, with said slit aligned with said axis;
a dielectric sheet carried in said gap on said one electrode;

means for maintaining a gas in said gap;

means for connecting a high voltage electric power supply across said electrodes for attracting charged particles towards said one electrode for deposit on said sheet;

means for moving said unit during an exposure, along a path generally perpendicular to a plane, said plane being defined by said axis and a radius from said axis passing through said slit; and

means for rotating said sheet and one electrode about said axis as said unit is moved.

2. A cassette as defined in claim 1 wherein said electrodes are concentric and said one electrode is the inner electrode.

3. A cassette as defined in claim 1 wherein said electrodes are concentric and said one electrode is the outer electrode.

4. A cassette as defined in claim 1 wherein the inner and outer electrodes are concentric and rotate together.

5. A cassette as defined in claim 1 wherein said electrodes are concentric and said one electrode is the inner electrode and the outer electrode is non-rotating and formed of a material of high X-ray absorption with a slit defining window of low X-ray absorption therein.

6. A cassette as defined in claim 1 wherein the other of said electrodes is carried in a cylindrical insulator and said one electrode rotates about said insulator moving said sheet past said other electrode.

7. A cassette as defined in claim 1 wherein said means for moving and rotating includes:

a fixed support;

a moving arm carried on said support, with said unit mounted on said arm;

a drive motor mounted on said arm; and

means coupling said motor to said one electrode and to said fixed support with said motor when energized rotating said one electrode and moving said arm relative to said fixed support along said path.

8. A cassette as defined in claim 7 wherein said coupling means includes:

a drive shaft for said one electrode and journaled in said arm;

interengaging gear means on said motor and shaft for rotating said shaft; and

tension means fixed to said support and wrapped on said drive shaft for moving said shaft along said path as said shaft rotates.

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