March 24, 1964 A. BOUWERS 3,126,480

APPARATUS FOR X-RAY FLUOROSCOPY OR PHOTOFLUOROGRAPHY

Filed April 25, 1960

Fig. 1

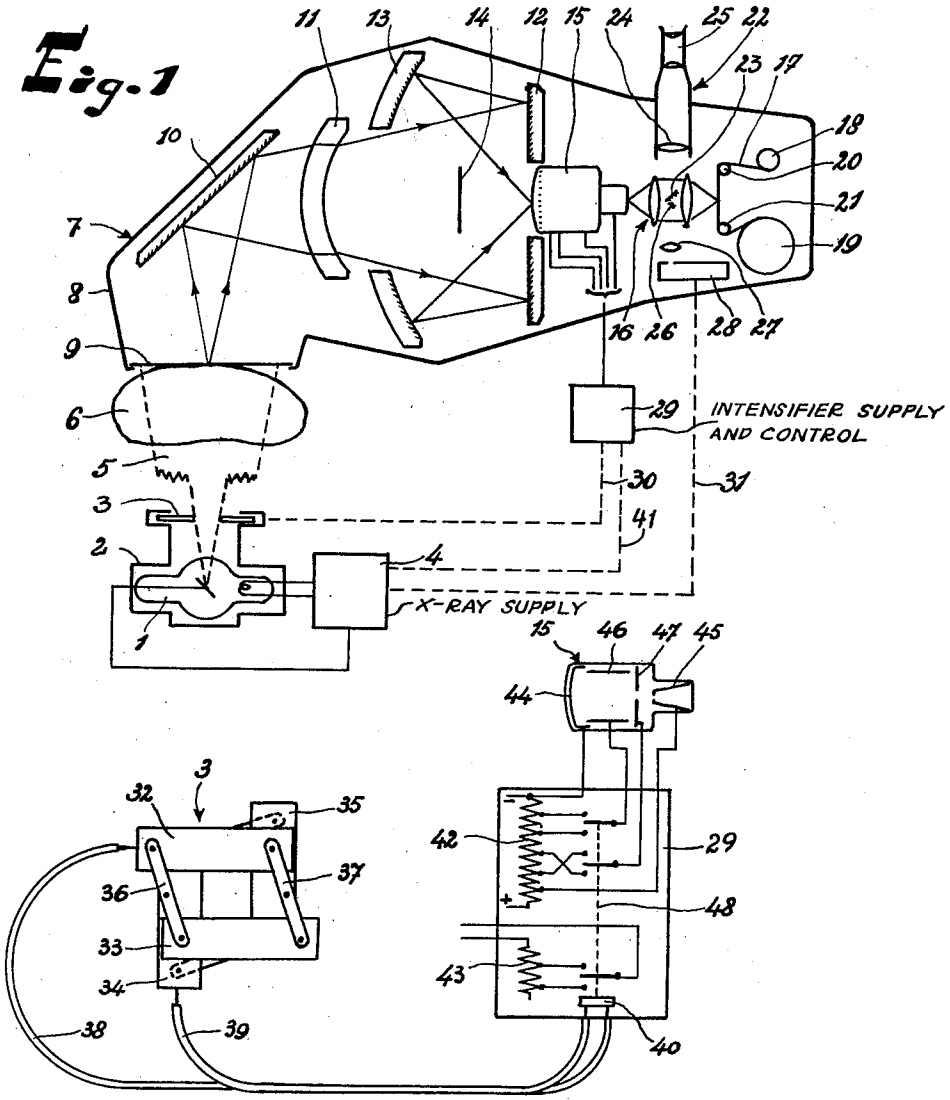

Fig. 2

INVENTOR

ALBERT BOUWERS

BY Wenderoth, Lind & Ponack

ATTORNEYS

United States Patent Office 3,126,480 Patented Mar. 24, 1964

3,126,480

APPARATUS FOR X-RAY FLUOROSCOPY OR PHOTOFLUOROGRAPHY

Albert Bouwers, The Hague, Netherlands, assignor to N.V. Optische Industrie "De Oude Delft," Delft, Netherlands

Filed Apr. 25, 1960, Ser. No. 24,432
Claims priority, application Netherlands Apr. 29, 1959
4 Claims. (Cl. 250—65)

The invention relates to apparatus for X-ray fluoroscopy or photo-fluorography and, more particularly, to a device of that type employing an image intensifier tube.

Image intensifier tubes having a variable magnification, i.e. tubes in which by controlling the electron-focusing field a part of the photo-cathode of selectable or variable dimensions can be pictured on the luminescent screen of the tube, have become known in the art. Tubes of this type are advantageous in X-ray apparatus in that they provide the possibility to produce easily and instantly enlarged images of interesting details selected from a larger field.

One object of the invention is to provide an X-ray fluoroscopic or photo-fluorographic device in which a variable magnification image intensifier tube is used and which permits the X-ray dose for the patient under examination to be kept at a minimum.

Another object of the invention is to provide a means in apparatus of the above type to maintain the brightness of the resultant X-ray picture substantially constant irrespective of the selected magnification of the image intensifier tube.

According to the invention in apparatus for X-ray fluoroscopy of photo-fluoroscopy employing an image intensifier tube, the latter tube has a variable magnification and a variable diaphragm is provided between the X-ray source and the fluorescent screen, the means for controlling the tube magnification and the means for controlling the diaphragm aperture being gang controlled in such a way that the diaphragm intercepts a substantial part of the X-rays taking no part in the imagery.

In this way it is at all times assured when switching to a higher tube magnification that substantially only those parts of the patient's body become irradiated which are actually imaged in the resulting X-ray picture.

As is well known, in image intensifier tubes the magnification has strong influence on the brightness of the resulting fluorescent image. Hence, when the magnification is varied the picture brightness will also show variations which in many causes should preferably be compensated, e.g. when using the device in fluoroscopy.

Accordingly, in a preferred embodiment of the apparatus according to the present invention a means for controlling the X-ray tube current is provided which is gang controlled with the means for controlling the tube magnification, such that when the tube magnification is varied the brightness of the resulting X-ray picture in the image intensifier tube is substantially maintained constant.

In this way the unexpected effect is obtained that the X-ray dose to which the patient's body is exposed is independent of the selected magnification, i.e., if the magnification is increased by a factor of e.g. 2, then the intensification factor or brightness gain of the image intensifier is increased by a factor of 4 necessitating a fourfold increase of X-ray intensity. At the same time, however, the irradiated surface of the patient is decreased likewise by a factor of 4 as the diaphragm aperture is adapted to a magnification which is two times higher linearly.

The term gang control is used herein and in the appended claims to indicate a control by which two or more variable elements are all forwardly controlled to a predetermined extent and at the same time, as will be exemplified by the following detailed description of the invention, reference being had to the drawings in which:

FIG. 1 is a diagrammatic view of an embodiment of the invention shown in section, and

FIG. 2 is a diagrammatic view of one specific form of means for simultaneous gang controlling the intensifier tube, the X-ray source and the X-ray diaphragm.

In FIG. 1 an X-ray tube **1** is forming a point-shaped source of X-rays and is shown as accommodated in a housing **2** having an exit window with a diaphragm **3** whose aperture can be varied. Current for the X-ray tube filament and high tension for the tube electrodes are supplied by an X-ray supply circuit **4** of any suitable construction which of course may comprise conventional means to control the filament current and the tube voltage. The X-ray diaphragm **3** may also be of any available construction provided that such construction permits to vary its effective aperture. It may be particularly noted that in the system according to the invention the X-ray diaphragm may be located at any desired place in the X-ray beam between the focus of the X-ray tube and the patient's body and need not to be made a part of the tube assembly itself.

In the beam of X-rays **5** a patient's body **6** is shown to be positioned in front of and close to the fluorescent screen of a photo- or cine-fluorographic camera generally designated **7**. The screen **9** produces a fluorescent image which by means of a suitable optical system of fixed minification is projected onto the photocathode surface of an image intensifier tube **15**. The optical system illustrated comprises a flat mirror **10** under an angle of 45° with the fluorescent screen **9**, a correcting lens **11**, a flat apertured mirror **12** and an apertured concave spherical mirror **13**. A baffle **14** blocks most of the light that would otherwise strike the photocathode of tube **15** without being reflected by the flat mirror **12** and the spherical mirror **13**. The optical system illustrated is known per se and will not further be described.

It will be evident, though, that the invention is not restricted in its application to apparatus of the type illustrated in which an optical system projects an image of a separate fluorescent screen such as **9** onto the photocathode of the image intensifier tube. If applied to an X-ray intensifier tube having a fluorescent screen in direct contact with the photocathode in the interior of the tube it has substantially the same effect.

The minified and brightened replica image appearing on the fluorescent screen at the end of the image intensifier tube **15** is projected by a symmetrical optical lens system **16** with unity magnification onto a photographic film **17** which, on rollers **20** and **21**, is conveyed from a supply spool **18** towards a take up spool **19**. It will be appreciated that dependent on the way in which the film is fed past the image frame of the camera, the latter may be a still or a cinematographic camera. The image to be recorded can also be visually observed by the aid of a magnifying viewing tube **22**. In the parallel beam of light rays between the halves of the objective **16** a small mirror **23** is provided which reflects part of the beam towards the objective lens **24** of the viewer **22**. The image produced by this objective is viewed through an eye piece **25**. By means of a further small mirror **26** and a lens **27** another image of the anode screen of tube **15** is projected onto the diaphragm of a photo-electric cell e.g. a photomultiplier tube **28**. This diaphragm which is only schematically indicated in the drawing has a number of small apertures through which the light impinges on the cathode electrode of the photomultiplier tube so that an average image brightness is measured.

The image intensifier tube **15** illustrated may comprise, in addition to the photocathode and the anode, a number

of intermediate electrodes, e.g. two in a suitable configuration such that the magnification of the tube can be changed by varying the potentials of such intermediate electrodes in a correlated manner without an appreciable loss of image definition being suffered. Thereby a portion of the photocathode image of variable dimensions is reproduced as a replica image on the fluorescent screen of the tube, this replica image being always of the same size. The technique of varying the magnification of image intensifier tubes is well-known in the art and need not be discussed here in greater detail than is desirable for a good comprehension of the invention. It may still be noted, that image intensifier tubes whose magnification is varied by means of magnetic fields of varying strength are likewise applicable, of course, for the purpose of the present invention.

The image intensifier tube **15** receives its current from a source of high tension in an intensifier supply and control box **29** diagrammatically shown in the drawing. Control box **29** also contains switches or other electrical appliances for controlling the magnification of the tube **15**. It is mechanically or electrically connected to the diaphragm **3** of the X-ray tube such that whenever a higher magnification is selected by the operator and, accordingly, a smaller part of the fluorescent screen **9** is actually pictured on the fluorescent screen of tube **15**, the X-ray beam penetrating the patient's body **6** is limited to its effective part. The nature of the coupling which is diagrammatically indicated in FIG. 1 by the dotted line **30**, is, of course, immaterial for the purpose of the invention.

In control box **29** also a means is provided to perform gang control of the X-ray tube filament current in such a manner that the change in brightness of the screen image of intensifier **15** which would result from a change in magnification is compensated by a change in intensity of the X-ray beam. To indicate the necessary gang control connection between the X-ray supply **4** and the magnification control means, a broken line **41** is shown in FIG. 1 between that supply and the control box **29**. This connection, like the coupling **30**, can be of any nature. In a preferred simple form as shown in FIG. 2, however, a controllable rheostat will be accommodated in the control box **29** which is e.g. series connected to the filament of X-ray tube **1**. It will be understood, of course, that such a rheostat, though it is bodily associated with the control box **29**, does nevertheless constitute a part of the X-ray tube supply circuit **4**.

In FIG. 1 it is further indicated by the dotted line **31** that the output signal of the photo-electric cell **28** is electrically fed back in the control circuit **4** of the X-ray tube **1**. The output signal may be applied to control in a manner known per se the filament current of the X-ray tube whereby the brightness of the picture produced on the fluorescent screen of the image intensifier tube can be maintained substantially constant under varying conditions, such as the patient's thickness. This additional kind of X-ray intensity control, has previously been used in the art and should well be distinguished, of course, from the gang control applied when changing the magnification and which is a feature of the present invention.

FIG. 2 shows some details of a particularly simple embodiment of the magnification control in accordance with the invention. The diaphragm **3** of the X-ray tube is shown to consist of two pairs of parallel strips of lead or any other X-ray absorbing material **32**, **33**, **34** and **35**. The strips of each pair are connected at their ends by pairs of rods such as **36** and **37** which are parallel inter se. The rods are pivotally mounted at their middle point in the housing of the X-ray tube. The lead strips of each pair together with the corresponding rods refine parallelograms and the width of the gap between the strips can be varied by drawing or pushing the core wires of Bowden leads **38** and **39**. The core wires are on one end secured to a common actuation piece **40** in the control box **29** which further houses a potentiometer **42** and a control rheostat **43**.

Potentiometer **42** supplies the electrode-potentials for the tetrode image intensifier tube **15** which, in addition to the cathode **44** and anode **45**, is provided with a cylindrical electrode **46** and a disc shaped electrode **47**. The magnification factor of the tube can be changed by varying in opposite senses the potentials of the electrodes **46** and **47**.

In FIG. 2 it is supposed that two different magnifications can be selected. The electrodes **46** and **47** may each be connected to one of a pair of tappings of the potentiometer **42** by means of a switch **48**. This switch has a third pole which selects from the tappings of the resistance **43** in the circuit of the X-ray tube filament the appropriate one in order to maintain the picture brightness at the optimum value irrespective of the selected magnification. At the same time the switch actuates through the Bowden leads **38** and **39** the X-ray tube diaphragm **3**. In this way a gang control of all relevant factors is assured by very simple and reliable means, the operator having only to actuate a single switch in order to pass on from one magnification to another.

What I claim is:

1. A device for X-ray fluoroscopy or X-ray photofluorography, comprising a substantially point-shaped source of X-rays, a fluorescent screen to receive an X-ray image of an area of an object irradiated by said X-rays, an X-ray diaphragm between said source and said object having an aperture of variable size for controlling said area being irradiated, an image intensifier tube having a photo-emissive cathode, an electron-optical lens system and an anode screen, said tube being positioned to receive a light image from said fluorescent screen on said photo-emissive cathode, said electron-optical lens system producing on said anode-screen sharp electron replica images at variable magnification of said light image on said photo-emissive cathode, means for varying the size of said aperture and so the size of the light image on said photo-emissive cathode, and means for varying the magnification of said electron-optical system to maintain the electron image on said anode screen substantially of the same predetermined size when the size of said aperture is varied, and gang control means controlling said means for varying the size of said aperture and said means for varying the magnification of said electron-optical system.

2. A device as claimed in claim 1, comprising means for controlling the intensity of said source of X-rays to maintain the total X-ray flux passing through said aperture substantially constant when the size of said aperture is varied, said means for controlling the intensity of said source being controlled by said gang control means with said means for varying the size of said aperture and said means for varying the magnification of said electron-optical system.

3. A device for X-ray fluoroscopy or X-ray photofluorography, comprising a substantially point-shaped source of X-rays, a fluorescent screen to receive an X-ray image of an area of an object irradiated by said X-rays, an X-ray diaphragm between said source and said object having an aperture of variable size for controlling said area being irradiated, an image intensifier tube having a photo-emissive cathode, an electron-optical lens system and an anode screen, said tube being positioned to receive a light image from said fluorescent screen on said photo-emissive cathode, said electron-optical lens system producing on said anode-screen sharp electron replica images of said light image on said photo-emissive cathode of at least two different magnifications, gang control means having at least two different selectable positions for simultaneously varying in discrete steps the intensity of said X-ray source, the size of said aperture and the magnification of said electron-optical system to maintain said electron image on said anode-screen of substantially constant size and the total X-ray flux passing through said aperture

substantially constant when said gang control means is operated.

4. A device for X-ray fluoroscopy or X-ray photofluorography, comprising an X-ray tube providing a substantially point-shaped source of X-rays, a fluorescent screen to receive an X-ray image of an area of an object irradiated by said X-rays, an X-ray diaphragm between said source and said object having an aperture of variable size for controlling said area being irradiated, an image intensifier tube having a photo-emissive cathode, a plurality of intermediate electrodes and an anode screen, an optical system for projecting a light image of said fluorescent screen at constant magnification onto said photo-emissive cathode, said image intensifier tube producing on said anode screen a sharp electron replica image of said light image, a source of electric potentials for said cathode, said intermediate electrodes and said anode of said image-intensifier tube of which at least the potentials of said

intermediate electrodes are variable to vary the ratio of the size of said electron replica image to that of said light image on said photo-emissive cathode, a source of variable electric current for said X-ray tube, and gang control means for simultaneously controlling said aperture of said diaphragm, said source of electric potentials and said source of electric current to maintain said electron replica image of substantially constant size and the total X-ray flux passing through said aperture substantially constant when said gang control means is operated.

References Cited in the file of this patent

UNITED STATES PATENTS

2,412,662	Watson	Dec. 17, 1946
2,499,322	Mather et al.	Feb. 28, 1950
2,739,257	Sheldon	Mar. 20, 1956
2,825,816	Rogers	Mar. 4, 1958
2,913,582	Collins et al.	Nov. 17, 1959