Jan. 26, 1954 S. GRADSTEIN 2,667,585

DEVICE FOR PRODUCING SCREENING IMAGES OF BODY SECTIONS

Filed Jan. 14, 1952

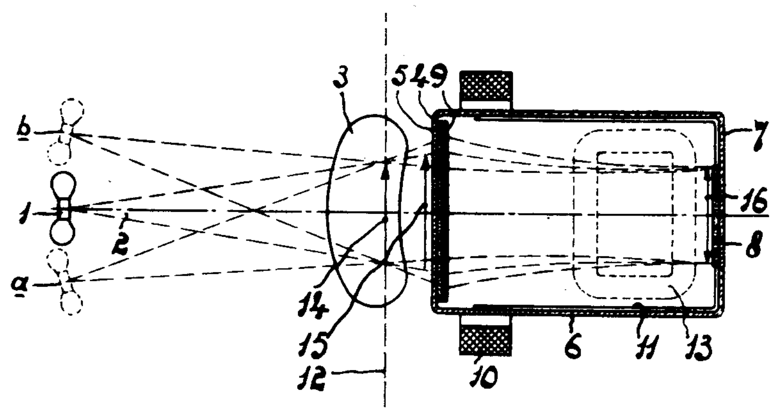

Fig. 1

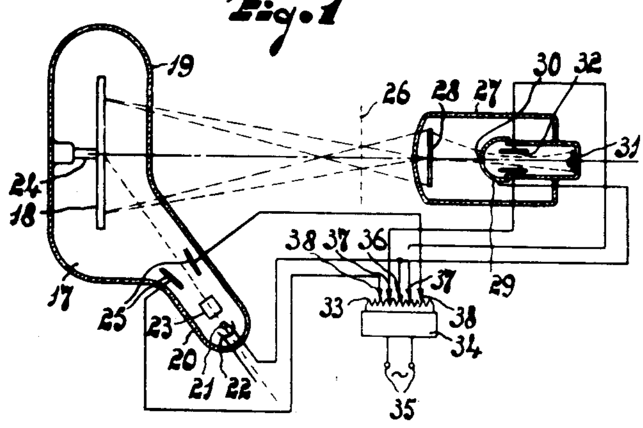

Fig. 2

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Patented Jan. 26, 1954

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UNITED STATES PATENT OFFICE

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DEVICE FOR PRODUCING SCREENING IMAGES OF BODY SECTIONS

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Application January 14, 1952, Serial No. 266,373

Claims priority, application Netherlands February 15, 1951

7 Claims. (Cl. 250—61.5)

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X-ray images having an extremely small depth of sharpness may be obtained by particular technical measures. X-ray apparatus suitable for this purpose is distinguished from apparatus for producing the conventional X-ray images in that the source of rays is displaced during the production of the radiograph, for example, in a path lying in a flat plane at right angles to the section to be reproduced. At the same time the image carrier, which is parallel to the section to be reproduced, is moved in an opposite sense in a manner such that an X-ray passing through a particular point of the section to be reproduced during the operation invariably strikes the same point of the image carrier.

A device of this kind is furthermore used for screening. In this case the image carrier is constituted by a fluorescent screen and with the use of an optical system comprising a mirror or one or more lenses and moved in a suitable manner, the optical image may be caused to move in a sense opposite to the image of the moving image carrier, so that this image seems to be stationary.

A device according to the invention also serves to produce X-ray images of thin sectional portions with the use of a moving X-ray source. It may be used both for medical examination and for the examination of materials.

According to the invention, the image carrier collecting the X-rays is not moved, but it cooperates with an electron-optical reproducing device comprising means to convert the moving image into a directly visible image which is stationary to the operator's eye.

For using an electron-optical reproducing device to amplify X-ray screening images it is known to activate the photo-electric cathode to emit electrons by utilising the luminescent light produced by X-rays in a suitable image layer, the photo-cathode being arranged in optical contact with this image layer.

The means used in accordance with the invention to convert the moving image projected onto the image carrier into a stationary image are constituted by electro-static or magnetic fields, which are arranged transversely to the direction of the electron rays from the photo-cathode. They serve to deflect the electron paths extending between the photo-electric cathode and the collecting screen. The electro-static deflection fields may be produced with the use of one or more pairs of parallel plates, between which a voltage is maintained. The plates of each pair are arranged each on one side of the electron paths. For the magnetic fields, use may be made of magnet coils, of which two coils producing the field in common are each time arranged for the deflection in one direction each on one side of the electron paths. The deflection of the bunch of electron paths may be varied in accordance with the displacement of the X-ray image by varying the voltage between the plates or the energising current of the coils.

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A very suitable embodiment of the invention is obtained with the use of an X-ray tube having a moving focal spot. An X-ray tube is known, in which the focal spot is moved across the anode surface by deflecting the electron beam producing the X-rays with the use of electrostatic or magnetic fields. By coupling the control-members with the use of which the strength of these deflection fields is varied with the members for controlling the strength of the deflection fields in the X-ray image amplifier, an accurate agreement between the displacement of the focal spot in the X-ray tube and that of the amplified X-ray image may be obtained. Moreover, the displacement may be performed at high speed, since mass forces need not be overcome as is the case with apparatus comprising mechanically actuated parts.

In order that the invention may be readily carried into effect, two examples will now be described in detail with reference to the accompanying drawings of which:

Fig. 1 shows diagrammatically an arrangement of the principal parts of a device according to the invention, comprising a moving X-ray tube and

Fig. 2 shows a similar device comprising an X-ray tube having a movable focal spot.

With the use of the X-ray beam **2** produced by the X-ray tube **1** a shadow image of part of the object **3** is produced on the image layer **4**, which is arranged on the flat bottom **5**, which closes one end of the cylindrical glass tube **6**. The other end of the glass tube is closed by a flat wall **7**. This wall is provided with a fluorescent screen **8**.

The image layer **4** is made of a material which radiates luminescent light, when it is struck by X-rays. On the image layer **4** a photo-electric cathode **9** is arranged. It is made of a material which emits electrons under the action of the light produced in the image layer **4**. It is known that an image corresponding with that of the photo-cathode can be reproduced on the fluorescent screen **8**. Use may be made in this case of an electric acceleration field and of an electron-optical lens. The magnet coil **10** serves to produce the lens field. The acceleration field is obtained by providing a conductive coating **11** on the inner wall of the tube 6, extending as far as the proximity of the photo-electric cathode and by applying an electric voltage to the photo-cathode. The fluorescent screen 8 is preferably arranged on a thin, transparent conductive layer, which is electrically connected to the conductive coating 11.

An image of the section 12 of the object 3 is obtained during the operation by moving the X-ray tube 1 between the two extreme positions *a* and *b*, indicated in Fig. 1 by broken lines. The focal spot of the tube 1 need not perform a rectilinear movement; it may, for example, describe a circular or a helical path in a plane parallel to the plane 12 of the section.

Upon displacement of the X-ray tube 1, the shadow images of parts of the body 3 located within the cone of rays are displaced on the image layer 4 in opposite sense, since the latter is not displaced. At the same time also the electron images produced on the photo-cathode 9 are displaced. Consequently moving images will also be produced on the fluorescent screen 8. In order to neutralise the movement of the image of those parts which are located in the body section under observation, use is made of deflection fields for the electron rays. In the case of a rectilinear displacement of the tube an electrostatic or a magnetic transverse field may suffice. In the device shown in Fig. 1 use is made of magnetic deflection. On the coil pairs required one of the coils 13 is shown in broken lines.

With the use of the X-ray beam, the X-ray tube 1 taking up the neutral position, an image 15 of the arrow 14 is projected onto the image layer 4, this image 15 being transmitted with the use of the photo-cathode 9 by electron-optical projection to the fluorescent screen 8 and being indicated by the arrow 16. The electrons from the photocathode travel along paths which strike the screen at points, whose distance from the tube axis is proportional to that of the initial points.

If the X-ray tube 1 takes up the position *a* the image of the arrow 14 has shifted upwards. In order to ensure a continuous observation of this image on the fluorescent screen, even in the case of rapid movements, this image must be caused to coincide with the image 16. This may be effected by energising the deflection coils 13 in a manner such that under the action of the magnetic field produced the electron paths are deflected through the correct angle. The strength of the deflection field must now be continuously varied during the displacement of the X-ray tube. For this purpose a control-device for the coil current may be coupled with the movement of the X-ray tube and thus the current variation across the coils 13 may be derived from the movement of the X-ray tube. Upon movement of the X-ray tube 1 into the position *b*, the deflection coils 13 must be energised in opposite sense. Parts of the object located in front of the section indicated by the arrow 14 or behind it are not reproduced sharply, but, if the X-ray tube is displaced with sufficient speed, they form a vague background, against which the image of the section to be reproduced is sharply outlined.

If it is desired to reproduce sharply a section nearer to the X-ray tube or farther removed therefrom, only the strength of the field produced by the magnet coils 13 need by varied between other limits. The control of the strength of the deflection field thus permits of sharply adjusting the wanted section of the object 3 on the fluorescent screen 8, without the need for displacing the object relative to the X-ray tube.

The X-day tube is moved very rapidly in order to make the background of the image sufficiently indistinct and therefore it will be preferable to move the X-ray tube along a circular closed path. For this purpose a second set of deflection coils is arranged in the image amplifier the axis of the field of these coils being at an angle of 90° with respect to the axis of the field, which is produced by the first coils. By combining the deflection fields and energising the coils by means of alternating currents being 90° out of phase relatively to one another, a combined deflection field is produced the field vector of which moves with the X-ray tube at a suitable choice of the polarity of the energising currents. It produces the desired deflection of the electron rays, which ensures that the fluorescent image of the section of the object remains stationary.

In a further embodiment of the device according to the invention, which is shown in Fig. 2, greater profit is derived from the advantage that the image layer does not move and that no mass forces occur when the fluorescent screen image obtained by electron-optical means is immobilised. Use is made of an X-ray tube 17 having a focal spot moving across the anode. The movement of the focal spot is produced by deflecting the electron beam which produces the X-rays. In this case the X-ray tube need not be displaced.

Referring to Fig. 2, the X-ray tube 17 comprises a glass tube 19, which is provided with a limb 20. Herein is arranged the electrode system for producing a directional electron beam, comprising a cathode 21, a concentrating electrode 22 and an accelerating electrode 23. A great potential difference is applied between the accelerating electrode 23 and the anode 18 arranged in the wide portion of the tube. A stay member 24, which is secured to the tube wall, serves to secure the anode 18. With the use of an electric field between the plates of the pair of deflection plates 25 the electron beam can be deflected and the point of impact of the electron beam can be displaced across the anode surface.

The X-ray tube is arranged in a manner such that the surface struck by the electrons is parallel to the section 26 to be reproduced, indicated by a broken line. On the side remote from the X-ray tube the image amplifier 27 is arranged, which may be constructed in accordance with the device described above. Fig. 2 shows a device having electrostatic focusing of the electron rays. The electrons from the photocathode 28, which is combined with the image layer for collecting X-rays, travel through a small aperture 30 in the anode 29 to the fluorescent screen 31. The anode tube comprises the pair of deflection plates 32.

By applying an alternating potential difference between the plates 25 of the X-ray tube 17 the focal spot moves in a straight line up and down the surface of the anode 18. From the confusion of images produced in this case on the fluorescent screen 31 via the combined image layer and the photo-cathode 28 by electron-optical projection an image of the wanted section 26 may be selected by applying a suitable alternating potential difference to the plates 32.

The required deflection voltages are derived from a potentiometer 33, which is connected to a voltage source 34. The latter is provided with terminals 35 for the connection to the supply mains. In the most simple case the voltage source 34 is constituted by a transformer for converting the mains voltage into a value required for the deflection. However, as an alternative, it may be constituted by a frequency converter or a pulse generator. In order to obtain symmetrical deflection voltages, the centre 36 of the potentiometer 33 is electrically connected to the cathode 22 of the X-ray tube 17 and to the anode 29 of the image amplifier 27. The plates 32 are electrically connected to the adjusting members 37 and the deflection plates 25 are connected to the adjusting members 38 of the potentiometer, so that the deflection fields in the X-ray tube and the image amplifier are coupled and at the same time an accurate adjustment of the two field strengths is permitted.

What I claim is:

1. A device for producing images of a thin section of a stationary object, comprising a source of X-radiation disposed on one side of said object, means for moving said source along a path lying in a flat plane, a stationary image carrier disposed on the other side of said object for receiving the X-radiation after it has passed through said object, said image carrier comprising a photo-cathode for converting the X-ray image produced when the X-radiation traverses said object into an electron image, a fluorescent screen for converting the electron image into a visible image, and electron-optical means for deflecting the electrons produced by the photo-cathode in accordance with the position of said source to produce on the fluorescent screen a fixed corresponding image of the thin section as the source of X-radiation moves relative thereto.

2. A device as claimed in claim 1 in which the electron-optical means includes means for producing at least one field which is transverse to the electron paths.

3. A device for producing images of a thin section of a stationary object, comprising a source of X-radiation disposed on one side of said object, means for moving said source along a path lying in a flat plane, a stationary image carrier disposed on the other side of said object for receiving the X-radiation after it has passed through said object, said image carrier comprising a photo-cathode for converting the X-ray image produced when the X-radiation traverses said object into an electron image, a fluorescent screen for converting the electron image into a visible image, electron-optical means for deflecting the electrons produced by the photo-cathode, and means coupled to the means for moving the source and the electron-optical means for varying the deflection of the electrons in accordance with the position of said source to produce on the fluorescent screen a fixed corresponding image of the thin section as the X-radiation source moves relative thereto.

4. A device for producing images of a thin section of a stationary object, comprising a source of X-radiation disposed on one side of said object, means for moving said source along a linear path lying in a flat plane, a stationary image carrier disposed on the other side of said object for receiving the X-radiation after it has passed through said object, said image carrier comprising a photo-cathode for converting the X-ray image produced when the X-radiation traverses said object into an electron image, a fluorescent screen for converting the electron image into a visible image, electron-optical means for deflecting the electrons produced by the photo-cathode, said electron-optical means including a pair of coils disposed on opposite sides of the path of the electrons and producing a magnetic deflection field transverse thereto, and means coupled to the means for moving the source for varying the extent of the transverse deflection field in accordance with the position of said source to produce on the fluorescent screen a fixed corresponding image of the thin section as the X-radiation source moves relative thereto.

5. A device for producing images of a thin section of a stationary object, comprising a source of X-radiation disposed on one side of said object, means for moving said source along a circular path lying in a flat plane, a stationary image carrier disposed on the other side of said object for receiving the X-radiation after it has passed through said object, said image carrier comprising a photo-cathode for converting the X-ray image produced when the X-radiation traverses said object into an electron image, a fluorescent screen for converting the electron image into a visible image, electron-optical means for deflecting the electrons produced by the photo-cathode, said electron optical means including a pair of coils disposed on opposite sides of the path of the electrons and producing a magnetic deflection field transverse thereto and a second pair of coils at right angles to the first pair for producing a second transverse deflection field, and means coupled to the means for moving the source for varying the extent of the transverse deflection fields in accordance with the position of said source to produce on the fluorescent screen a fixed corresponding image of the thin section as the X-radiation source moves relative thereto.

6. A device for producing images of a thin section of a stationary object comprising in combination; an X-ray tube including an anode having a large surface disposed on one side of said object, means for producing an electron beam within said tube, and deflection means within said tube for deflecting the electron beam onto different areas of the anode to produce a variably-positioned source of X-radiation therefrom, said areas lying along a path in a flat plane; a stationary image carrier disposed on the other side of said object for receiving the X-radiation after it has passed through said object, said image carrier comprising a photo-cathode for converting the X-ray image produced when the X-radiation traverses said object into an electron image, a fluorescent screen for converting the electron image into a visible image, electron-optical means for deflecting the electrons produced by the photo-cathode; a source of variable potential; means for connecting said source of variable potential to said deflection means within said X-ray tube whereby the source of X-radiation is caused to move along the path lying in the flat plane; and means for connecting said source of potential to said electron-optical means for varying the deflection of the electrons in accordance with the position of the moving source of X-radiation to produce on the fluorescent screen a fixed corresponding image of the thin section as the X-radiation source moves relative thereto.

7. A device for producing images of a thin section of a stationary object comprising in combination; an X-ray tube including an anode having a large surface disposed on one side of said object, means for producing an electron beam within said tube, and deflection means within said tube for deflecting the electron beam onto

different areas of the anode to produce a variably-positioned source of X-radiation therefrom, said areas lying along a path in a flat plane; a stationary image carrier disposed on the other side of said object for receiving the X-radiation after it has passed through said object, said image carrier comprising a photo-cathode for converting the X-ray image produced when the X-radiation traverses said object into an electron image, a fluorescent screen for converting the electron image into a visible image, electron-optical means for deflecting the electrons produced by the photo-cathode; said electron-optical means including a pair of deflection plates disposed on opposite sides of the path of the electrons for producing a transverse electric field relative thereto; a source of variable potential; means for connecting said source of variable potential to said deflection means within said X-ray tube whereby the source of X-radiation is caused to move along the path lying in the flat plane; and

means for connecting said source of potential to said deflection plates of the electron-optical means for varying the deflection of the electrons in accordance with the position of the moving source of X-radiation to produce on said fluorescent screen a fixed corresponding image of the thin section as the X-radiation source moves relative thereto.

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