April 21, 1964 B. B. TILLING 3,130,313

DIAPHRAGMS FOR USE WITH X-RAY APPARATUS

Filed Nov. 1, 1961 4 Sheets-Sheet 1

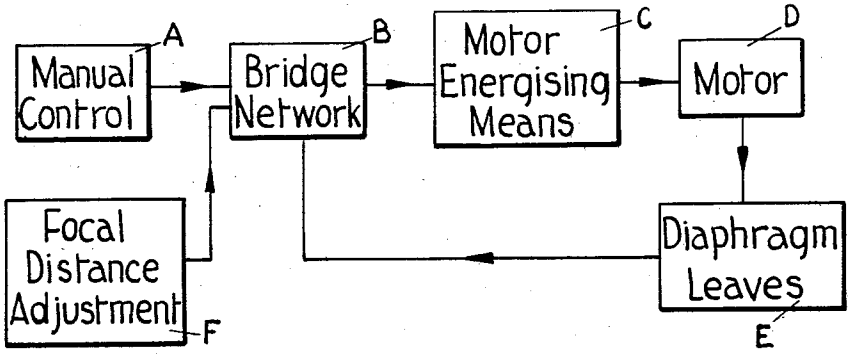


Fig. 1

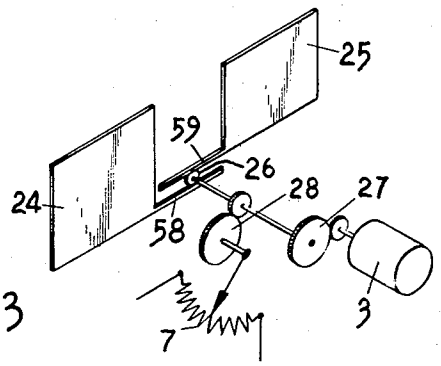


Fig. 3

INVENTOR
BASIL BOYLAND TILLING
BY

ATTORNEYS

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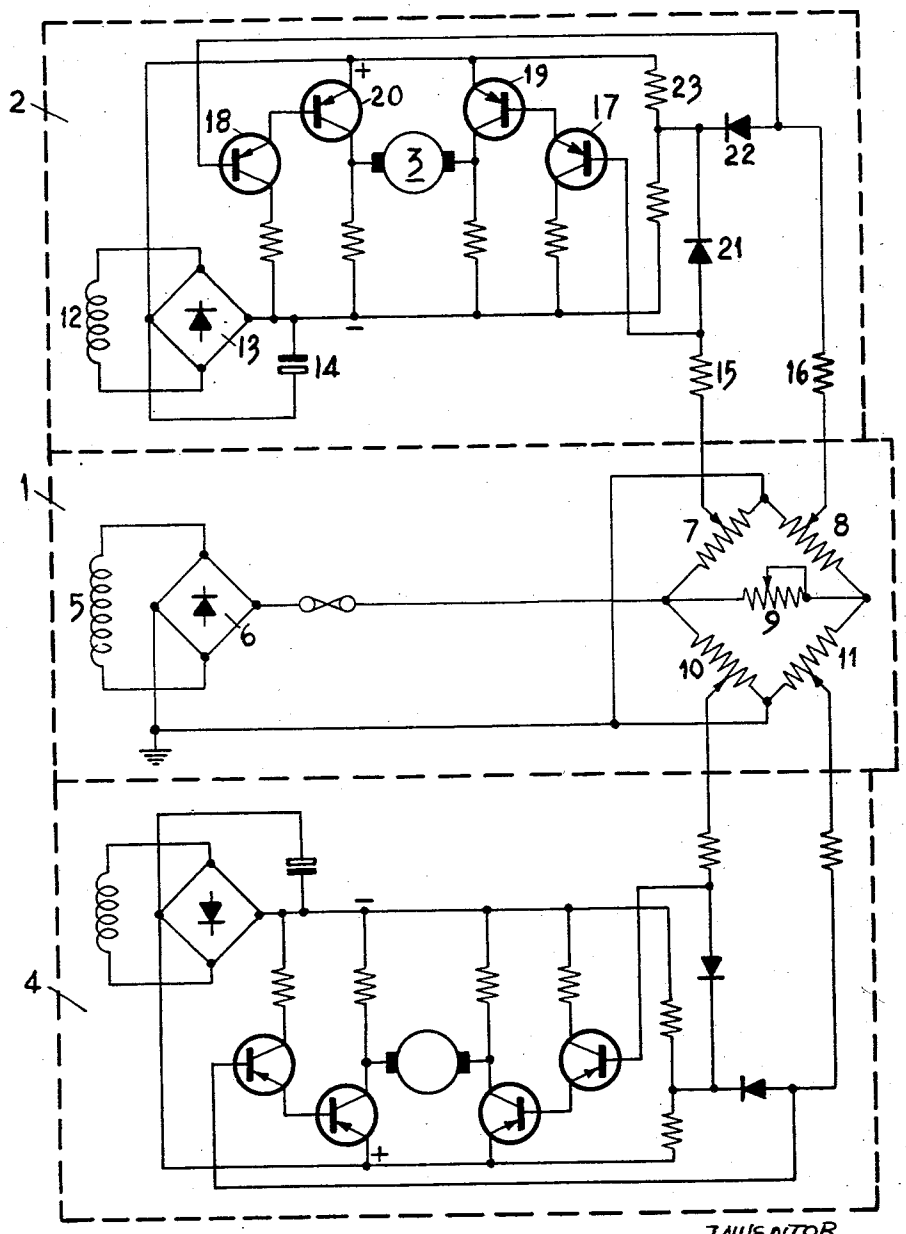


Fig. 2

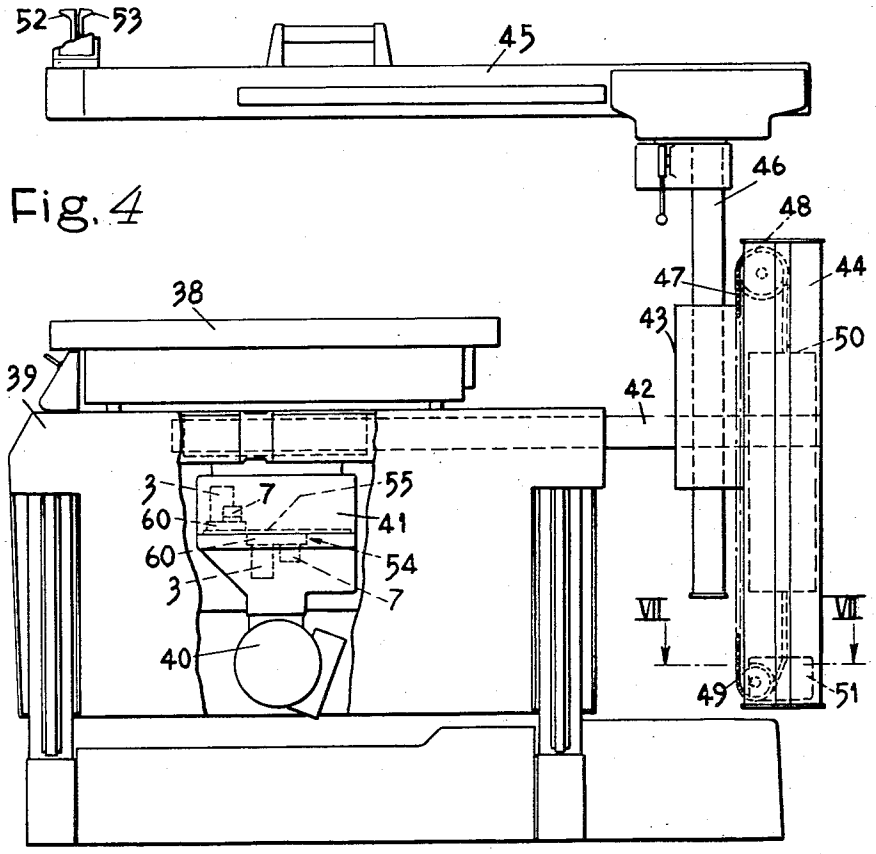
INUENTOR
BASIL BOYLAND TILLING
BY
ATTORNEYS

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DIAPHRAGMS FOR USE WITH X-RAY APPARATUS

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Fig. 4



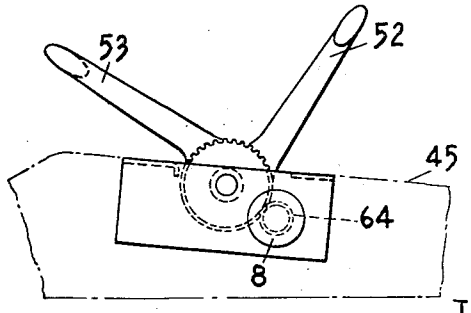


Fig. 6

INVENTOR
BASIL BOYLAND TILLING
BY
ATTORNEYS

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DIAPHRAGMS FOR USE WITH X-RAY APPARATUS

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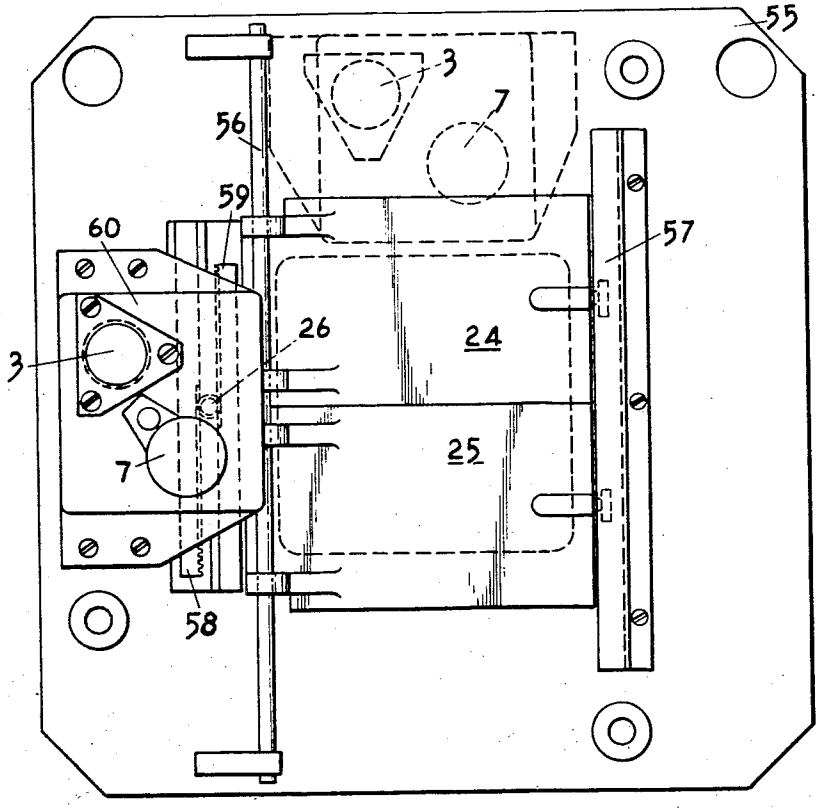


Fig. 5

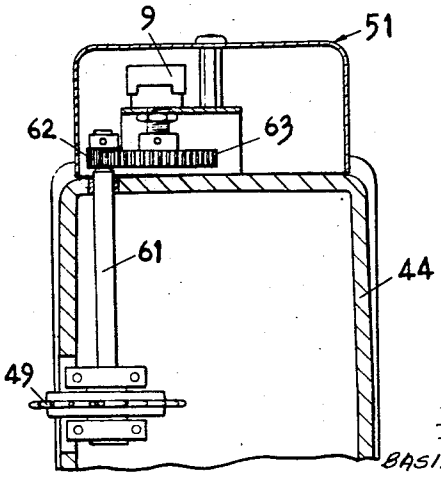


Fig. 7

INVENTOR
BASIL BOYLAND TILLING
BY
ATTORNEYS

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3,130,313
DIAPHRAGMS FOR USE WITH X-RAY APPARATUS

Basil Boyland Tilling, Weybridge, Surrey, England, assignor to The General Electric Company Limited, London, England

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2 Claims. (Cl. 250—105)

The invention relates to diaphragms for limiting the extent of the X-ray beam in X-ray apparatus.

It is usual in X-ray apparatus to provide an adjustable diaphragm to limit the extent of the X-ray beam and thereby to avoid unnecessary exposure of the patient to X-rays. Such a diaphragm usually consists of two pairs of leaves of a radio-opaque material, generally sheet lead, each pair of leaves being independently operable to open or close them, and having parallel beam-defining edges, the two pairs working at right angles to each other and thereby restricting the cross-section of the beam to a rectangular shape.

Manual control means for the two pairs of leaves are generally provided close to the position of the viewing screen when the apparatus is arranged for fluoroscopy, and hitherto connection between the manual operating means and the diaphragm leaves has usually been by means of a mechanical linkage such as a flexible steel wire cable. This arrangement has the disadvantage that if the setting levers are conveniently positioned the course to be taken by the mechanical linkage is a complicated one involving a number of bends and movements, and the mechanical linkage is liable to become stiff or fail after a relatively short operating life. An object of the present invention is to provide an electrical means for operating the diaphragm leaves of X-ray apparatus which avoids the need for mechanical linkages.

According to the present invention the means for selectively positioning at least one pair of diaphragm leaves in X-ray apparatus, comprises a manual control, a first impedance which is continuously variable over a predetermined range and is coupled to the manual control for enabling the first impedance to be set to any selected value within said range, a second impedance which is continuously variable over a predetermined range and is coupled to the diaphragm leaves so as to be varied with the extent of the opening of the leaves, an electric impedance bridge network including both said impedances, a reversible direct current electric motor coupled to the diaphragm leaves for opening and closing the leaves, and motor energizing means including a transistor amplifier having input and output terminals, circuit means connecting said input terminals to the output of the electric impedance bridge network and circuit means connecting the output terminals to said motor for driving the motor in response to an out-of-balance signal obtained from the bridge network to alter the extent of opening of the diaphragm leaves in such a sense as to reduce the out-of-balance signal.

Such an arrangement enables the position of the diaphragm leaves to be set remotely in any desired position within their range of movement to a high degree of accuracy, without the need for mechanical linkages between the manual operating means and the diaphragms.

In a modification of the above arrangement the bridge network may include a further variable impedance linked with the mechanical adjustment of the distance between the focus of the X-ray tube and the viewing screen or film cassette, so that increasing or diminishing this focal distance varies the impedance in the bridge network and so causes the aperture of the diaphragm to diminish or increase in proportion, so as to ensure that the area of the

X-ray beam remains within the limits of the viewing screen or film cassette.

The invention will be further described with reference to the accompanying drawings in which:

FIGURE 1 is a block diagram illustrating the manner in which an arrangement according to the invention functions,

FIGURE 2 is a circuit diagram showing the electric circuit arrangements for the operation of the two pairs of leaves of an X-ray diaphragm,

FIGURE 3 is a schematic diagram illustrating the manner in which the diaphragm leaves are coupled to their operating motor and to an impedance in the bridge network,

FIGURE 4 is an end view of an X-ray table partly broken away to indicate the position of the diaphragm assembly and the other components of an arrangement according to the invention,

FIGURE 5 is a plan view of the diaphragm assembly.

FIGURE 6 is an elevation of the manual control means for operating the two pairs of leaves of the diaphragm, and

FIGURE 7 is a plan section along the line VII—VII of FIGURE 4, showing a resistor adjustable in response to the focus-to-screen distance of the X-ray apparatus.

The general principle of the arrangement will first be explained with reference to the block diagram of FIGURE 1 by following the sequence of operations set in motion when the manual control is altered to alter the setting of one pair of diaphragm leaves.

The sequence of operations when the setting of one pair of diaphragm leaves is altered will first be explained with reference to the block diagram of FIGURE 1. A setting lever which provides the manual control A for the diaphragm leaves and is positioned next to the fluoroscopic screen operates a potentiometer-type variable resistor forming part of an impedance bridge network B. The out-of-balance signal from this bridge network is fed to a motor energising means C which, in the example to be described with reference to FIGURE 2, consists of a two-stage symmetrical transistor amplifier, and the output from this in turn drives a reversible motor D coupled to the diaphragm leaves E. The drive from the motor to the diaphragm leaves is through a gear box which carries a pinion whose shaft in turn is coupled to a second potentiometer-type resistor also included in the impedance bridge network, as represented by the connection back from the block E to the block B.

It will be assumed that initially the bridge network is balanced, and that the setting lever is operated so as to open the diaphragm leaves from a partly closed position. The operation of the setting lever changes the impedances in the bridge network and throws it out of balance. The out-of-balance current is amplified by the transistor amplifier which constitutes the motor energising means, and is applied to the reversible motor in such a sense as to cause the motor to rotate to open the leaves further, at the same time altering the impedance coupled with them in such a way as to tend to restore the bridge network to its balanced condition. When the bridge becomes balanced the input to the motor falls to zero and the leaves remain stationary.

In an optional refinement there is also included a linkage between the focal distance adjustment means F of the apparatus and the bridge network B; thus there is included in the bridge network an additional resistor coupled to the part of the X-ray equipment carrying the fluoroscopic screen in such a way that its resistance varies with movement of the screen relative to the X-ray tube. Such movement therefore throws the bridge network out of balance and causes the motor to be energised to open or close the diaphragm leaves. By a suitable choice for

this resistor it is arranged that the opening of the diaphragm leaves is at least approximately proportional to the focus-to-screen distance, so that on relative movement of the tube and screen the area of the screen irradiated by X-rays remains unaltered, and it is impossible to enlarge the X-ray beam so as to extend beyond the edges of the screen with risk of harmful radiation reaching the operator.

The circuit diagram of FIGURE 2 shows the components represented by the boxes of FIGURE 1, with the exception of the diaphragm leaves themselves. The central dotted portion **1** contains two bridge networks sharing a common adjustable resistor the adjustment control of which is linked with the focal distance adjustment F of FIGURE 1. Each of the bridge networks serves for the operation of one pair of diaphragm leaves, and also their power supply. The dotted outline **2** contains a two-stage balanced transistor amplifier together with its power supply, which amplifier constitutes a motor energising means, and which drives a reversible permanent-magnet D.C. motor **3**. The dotted outline **4** contains a set of components exactly similar to those within the outline **2**, and which therefore need not be separately described.

The power supplies for the bridge networks **1** are obtained from a secondary winding **5** on a mains transformer and converted to D.C. by a bridge-connected rectifier **6**. The unidirectional voltage so obtianed is applied to a bridge network constituted by a potentiometer-type adjustable resistor **7**, a second potentiometer-type adjustable resistor **8**, and an adjustable resistor **9**. The resistor **7** is coupled by gearing to the drive for the diaphragm leaves as will further be described with reference to FIGURE 3, while the resistor **8** is mounted near the fluoroscopic screen of the X-ray apparatus and is controlled by a setting lever to form the manual control for the arrangement. The variable tapping on the resistor **9** is coupled to the arrangement supporting the fluoroscopic screen or photographic cassette so that its value varies with changes in the distance between the tube and screen or cassette. An exactly similar bridge for operating the other pair of diaphragm leaves is constituted by a pair of potentiometer-type resistors **10** and **11** corresponding to **7** and **8** of the bridge just described, and the resistor **9** which is common to both of the bridge networks. The output from the bridge containing the resistors **10** and **11** is fed to the amplifier and motor **4** for the other pair of leaves.

The output of the first bridge network is taken from the two movable contacts of the resistors **7** and **8** and the arms of the bridge are formed, two of them by the two portions into which the movable contact divides the resistor **7**, a third by one portion of the resistor **8**, and the fourth by the other portion of the resistor **8** in series with the resistor **9**.

The amplifier and motor (shown within the dotted outline **2**) derive their power supply from a secondary winding **12** on the same transformer as that which carries the winding **5**, and this winding is connected across a bridge-connected rectifier **13** having a reservoir condenser **14** of large capacity for smoothing purposes.

The output of the bridge circuit drawn from the movable contacts of the potentiometer-type resistors **7** and **8** is applied through a pair of current-limiting resistors **15** and **16** to the bases of a pair of matched transistors **17, 18**, which in turn drive a matched pair of power output transistors **19, 20**, connected to the reversible motor **3** and providing the energising means for driving it in one or the other direction according to the polarity of the bridge out-of-balance signal. The bases of the transistors **17** and **18** constituting the input terminals of the amplifier are returned through rectifiers **21, 22** to a suitable tapping on a voltage-dividing resistor **23** connected across the power supply to the transistors from the capacitor **14**, the tapping being so selected that in the quiescent state of the amplifier, that is to say with no input voltage from the bridge, the transistors **19** and **20** carry very little current.

In operation, when the bridge is unbalanced by a movement of the setting lever altering the position of the movable contact of the potentiometer-type resistor **8** the base of one or the other of the transistors **17, 18** is driven negative with respect to the reference potential established by the tapping point on the potential divider **23** by reason of the presence of the rectifiers **21** and **22**. This negative potential is amplified by the transistor and applied to one or other of the transistors **19, 20**, energising the motor **3** and causing it to rotate in such a sense as to open or close the leaves of the diaphragm as the case may be, and also to move the movable contact of the potentiometer type resistor **7** which is coupled to them in such a sense as to restore the balance of the bridge.

The adjustable resistor **9** similarly unbalances the bridge on relative movement of the X-ray tube and fluorescent screen, and thereby causes the amplifier and motors to come into operation to restore balance, and in doing so to open or close the diaphragm leaves so that the area of screen irradiated by the X-ray beam remains substantially of the same size.

The bridge network constituted by the adjustable resistor **9** and the potentiometer-type resistors **10, 11**, in conjunction with the transistor amplifier and motor (shown within the dotted outline **4**), are precisely similar to the bridge network and amplifier just described, and function in a similar way to operate a second pair of diaphragm leaves at right-angles to the first pair.

FIGURE 3 shows diagrammatically, and in a very simplified schematic form, the means whereby the reversible motor **3** is coupled to the diaphragm leaves, and how the potentiometer type resistor **7** is adjustable in response to the position of these leaves. In this figure corresponding portions of the apparatus are correspondingly numbered to those in FIGURE 2.

The diaphragm leaves consist of two rectangular sheets of lead alloy **24** and **25**, each attached to a metal slide carrying a toothed rack which engages a small pinion wheel **26**. Rotation of the pinion wheel **26** moves the two leaves in opposite directions so that they always remain symmetrical about the axis of the X-ray beam.

The pinion **26** is coupled through gearing **27** to the output shaft of the small D.C. motor **3** and the gearing also is coupled to a further pinion wheel **28** mounted on a shaft which is coupled to the operating spindle of the potentiometer-type resistor **7** constituting two arms of the impedance bridge network as shown in FIGURE 2. Rotation of the armature of the motor **3** therefore opens or closes the leaves **24, 25**, and at the same time, via the pinion wheel **28**, moves the adjustable contact of the potentiometer-type resistor **7**. The sense of connection of the motor and the resistor **7** are such that this movement tends to restore balance of the bridge.

An exactly similar pair of leaves similarly coupled to a further driving motor and to the potentiometer type resistor **10** and working in a direction at right-angles to the leaves **24** and **25** is provided, so that both the height and the width of the X-ray beam may be masked to any suitable size. The variable resistor **9** is similarly coupled by gearing to the counterweight mechanism of the pillar carrying the fluorescent screen or cassette changer.

FIGURE 4 is an end view of an X-ray table in which the diaphragm operating arrangements are as described above with reference to FIGURES 1 to 3. The table is shown partly broken away in order to indicate more clearly the position of the essential components.

The table top **38** is carried on a support **39** which provides the usual tilting and sliding motions for the table top, the operating details of which are conventional and are not concerned with the present invention. The support **39** is shown partly broken away so as to reveal the

position of the X-ray tube 40. This tube is carried on a box 41 bolted to a pair of sliding rails 42 which carry a pair of sleeves each bearing a counterweight tower. In the end view shown in the drawing one sleeve 43 and its counterweight tower 44 are visible.

The screen assembly 45 is borne on a pair of rails, one of which, 46, is visible, and which passes through the sleeve 43, and to this rail is attached a roller-link chain 47 passing over sprocket wheels 48, 49, in the counterweight tower 44. The ends of this chain are attached to a sliding counterweight 50 which works on guide rails within the tower 44. The lower sprocket wheel 49 is coupled by gearing to a potentiometer-type resistor so that the resistance of this resistor varies in accordance with the focus-to-screen distance of the apparatus. The resistor and gear assembly is indicated at 51 in FIGURE 4, and shown in more detail in FIGURE 7. The other rail supporting the screen assembly 45 is coupled to a similar counterweight in a similar counterweight tower which is not visible in the drawing (being directly behind the tower 44) but which is identical except that the assembly of the resistor and gearing 51 is not duplicated.

The screen assembly 45 carries various controls for the X-ray table, including the manual controls for operation of the diaphragm leaves. These consist of a pair of setting levers 52, 53, each of which is coupled to a separate potentiometer-type resistor, as will be explained in more detail below with reference to FIGURE 6.

The two pairs of diaphragm leaves for limiting the extent of the X-ray beam in accordance with the settings of the levers 52, 53 and the focal distance of the X-ray screen are held within the box 41 in the form of a single assembly indicated by the dotted outline 54 and which will now be described in detail with reference to FIGURE 5 of the drawings.

The diaphragm assembly in FIGURE 5 is viewed looking down on it from above and showing one pair of diaphragm leaves together with the motor gearbox and potentiometer-type resistor associated with them. Where appropriate the references to the components shown in this figure are numbered similarly to the corresponding components in FIGURES 2 and 3.

The assembly is mounted on a plate 55 on the other side of which a pair of rectangular lead diaphragm leaves 24, 25 are arranged to slide in a pair of guides, one formed by a rod 56 and the other by a channel section 57. The leaves 24, 25 are each attached to a toothed rack, 58, 59 respectively, which is engaged by a small pinion wheel 26, and rotation of this wheel moves the two leaves equally in opposite directions so that they remain symmetrical about the axis of the X-ray beam.

On the plate 55 is mounted a gearbox 60 which carries the small D.C. motor 3. Gearing within the box couples the output shaft of this motor to the pinion wheel 26 and to the potentiometer-type resistor 7 also mounted on a bracket on top of the gearbox 60. There are more gear wheels in the train than indicated in FIGURE 3 (which is somewhat simplified for clarity), and the first wheel engaged by the pinion on the motor shaft is coupled to its shaft by a friction slip device so as to avoid the possibility that the inertia of the motor when the leaves meet on closing will be sufficient to cause any of the gear wheels to jump out of engagement.

The underside of the plate 55 carries a similar pair of leaves and a similar gearbox, motor, and potentiometer-type resistor, all rotated through a right-angle with respect to those on the upper side, so that the two pairs of leaves work in directions at right-angles to one another and between them mask the beam to a rectangular section. The potentiometer of the arrangement on the underside corresponds to item 10 of FIGURE 2. Also on the underside of the plate 55 are mounted a pair of insulating panels carrying the components of the two transistor amplifiers shown in FIGURE 2, one for the

operation of the pair of diaphragm leaves on the upper side of the plate 55, and the other for the pair of diaphragm leaves on the lower side of that plate.

The manual control for operating the diaphragm leaves is shown in FIGURE 6. This consists of a pair of setting levers 52, 53, which are assembled on the control panel next to the fluoroscopic screen as shown in FIGURE 4. Each of these setting levers has its lower part of part-circular form pivoted at its centre and toothed to engage a pinion, one of which, 60, appears in FIGURE 6. This pinion is coupled to a potentiometer-type resistor 8 forming part of the bridge circuit for the operation of one pair of leaves as described with reference to FIGURE 2.

The means of adjusting the diaphragm leaves in response to the focal distance of the X-ray tube from the screen is shown in FIGURE 7. This is a plan section through the bottom of one counterweight tower of FIGURE 4, showing the sprocket wheel 49 over which runs the roller-link chain coupling the screen assembly 45 to its counterweight 50. As the screen assembly is moved up or down the sprocket wheel 49 rotates. The shaft 61 which carries this wheel has a pinion 62 mounted on it engaging a further wheel 63. This wheel 63 is coupled to the operating spindle of a variable resistor 9 which forms a part of one arm of each of the two bridge circuits associated with the two pairs of diaphragm leaves as is shown in FIGURE 2. Raising the screen, and so increasing the focus-to-screen distance, increases the resistance of the variable resistor 9, and thereby alters the balance of the bridge in such a sense as to cause both pairs of diaphragm leaves to close slightly, thereby limiting the extent of the beam to keep it within the screen.

When the apparatus is assembled the components are connected as indicated in FIGURE 2, and the operation is as has already been described with reference to FIGURES 2 and 3.

I claim:

1. Means for selectively positioning at least one pair of diaphragm leaves in an X-ray apparatus, said means comprising a manual control, a first impedance which is continuously variable over a predetermined range and is coupled to the manual control for enabling said first impedance to be set to any seelcted value within said range, a second impedance which is continuously variable over a predetermined range and is coupled to the diaphragm leaves so as to be varied with the extent of the opening of the leaves, an electric impedance bridge network including both said impedances, a reversible direct current electric motor coupled to the diaphragm leaves for opening and closing the leaves, and motor energizing means including a transistor amplifier having input and output terminals, circuit means connecting said input terminals to the output of the electric impedance bridge network and circuit means connecting the output terminals to said motor for driving the motor in response to an out-of-balance signal obtained from the bridge network to alter the extent of opening of the diaphragm leaves in such a sense as to reduce the out-of-balance signal.

2. X-ray apparatus comprising an X-ray tube; a screen assembly mounted for irradiation by the tube; two pairs of adjustable diaphragm leaves disposed in the path of the X-ray beam so as to limit the cross-section of the beam; a pair of manual controls, a different one for setting the extent of opening of each different pair of diaphragm leaves; and for each pair of diaphragm leaves and its associated manual control, a first impedance which is continuously variable over a predetermined range and is coupled to the manual control for enabling said first impedance to be set to any selected value within said range, a second impedance which is continuously variable over a predetermined range, and is coupled to the diaphragm leaves so as to be varied with the extent of the opening of the leaves, an electric impedance bridge network including both said impedances, a reversible direct current electric motor coupled to the respective pair of diaphragm

leaves for opening and closing the leaves, and motor energizing means including a transistor amplifier having input and output terminals, circuit means connecting said input terminals to the output of the electric impedance bridge network and circuit means connecting the output terminals to said motor for driving the motor in response to an out-of-balance signal obtained from the bridge network to alter the extent of opening of the respective pair of diaphragm leaves in such a sense as to reduce the out-of-balance signal.

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