

- [54] **X-RAY IMAGE INTENSIFIER SYSTEM**
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- [21] Appl. No.: **289,691**
- [52] **U.S. Cl. 250/512; 250/513; 250/272**
- [51] **Int. Cl. G21f 5/02**
- [58] **Field of Search 250/105, 65, 77, 512, 513,**
250/272

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| [56] | References Cited |
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| 3,126,480 | 3/1964 Bouwers 250/65 |

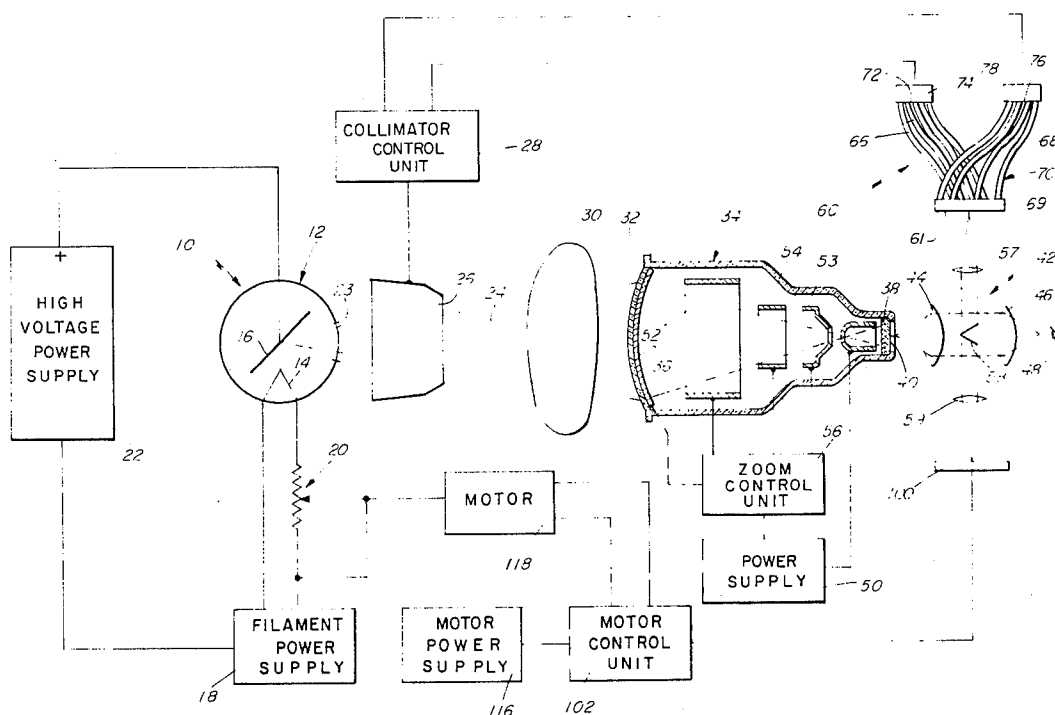
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| 3,417,242 | 11/1968 | WinDeBank..... | 250/83.3 |
| 3,546,461 | 11/1970 | Craig | 250/95 |

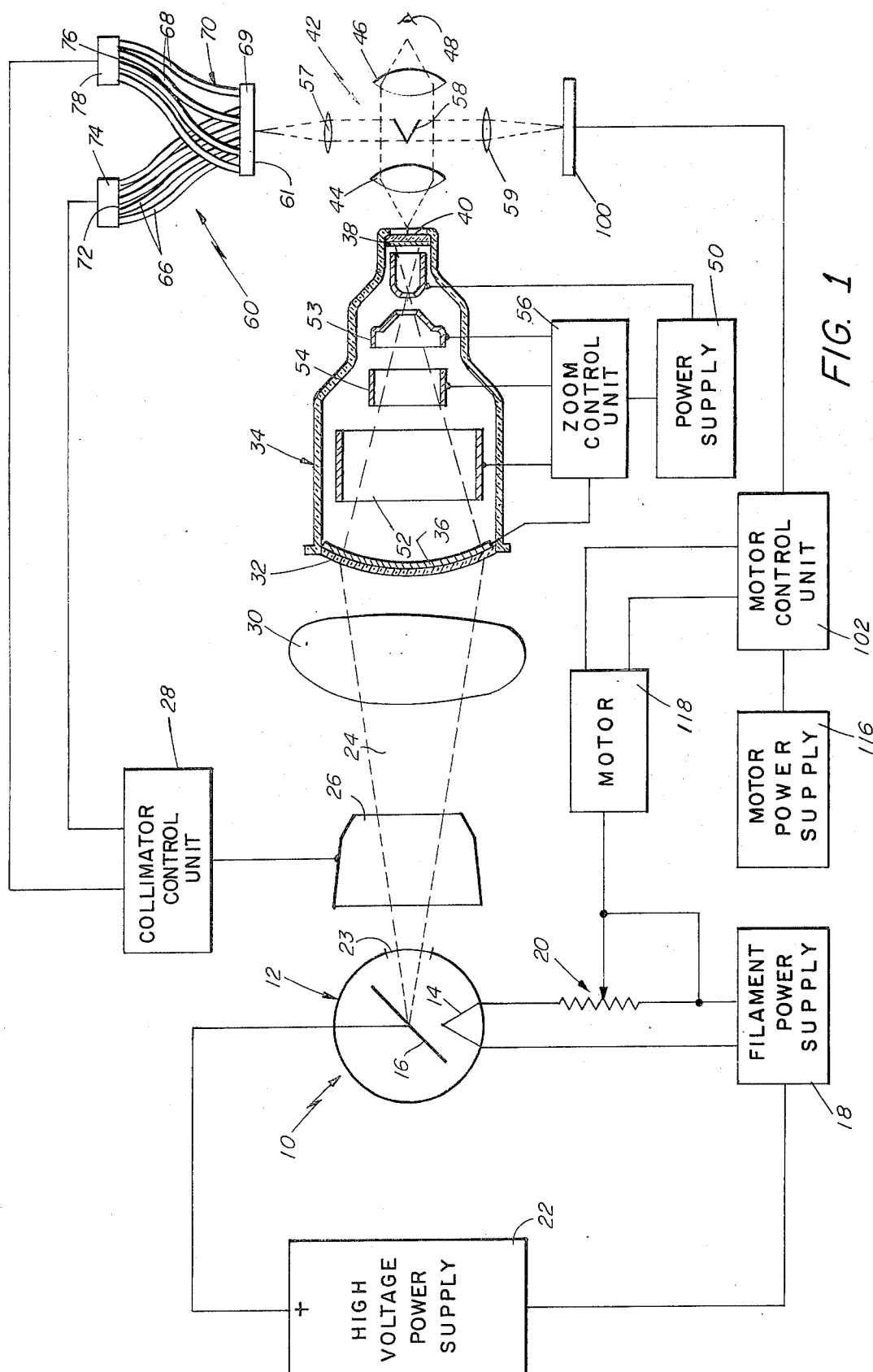
Primary Examiner—James W. Lawrence
Assistant Examiner—B. C. Anderson
Attorney, Agent, or Firm—John T. Meaney; Harold A. Murphy; Joseph D. Pannone

[57] **ABSTRACT**

An X-ray system including an X-ray generator disposed to direct an X-ray beam through an adjustable collimating means and onto the input end of an image intensifier tube, the output end of the intensifier tube being disposed adjacent sensing means for detecting the size of the output image, and control means for actuating the collimating means to adjust the X-ray beam in accordance with electrical signals received from the sensing means.

14 Claims, 9 Drawing Figures





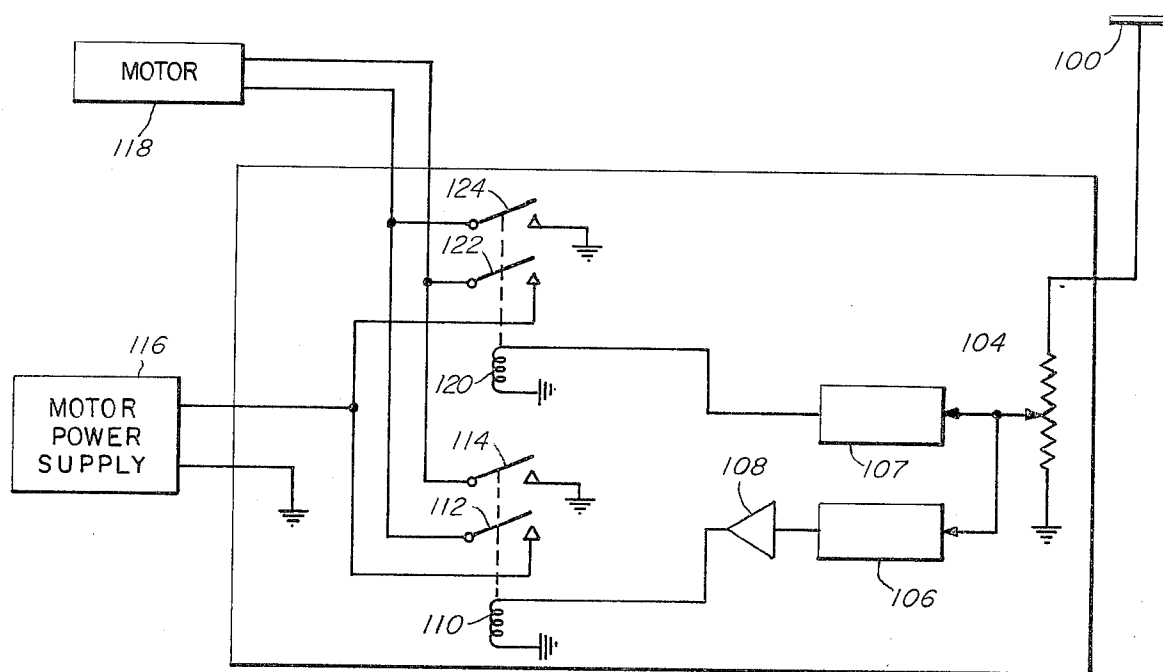


FIG. 2

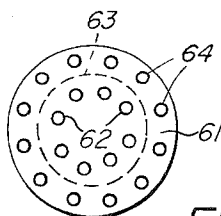


FIG. 3

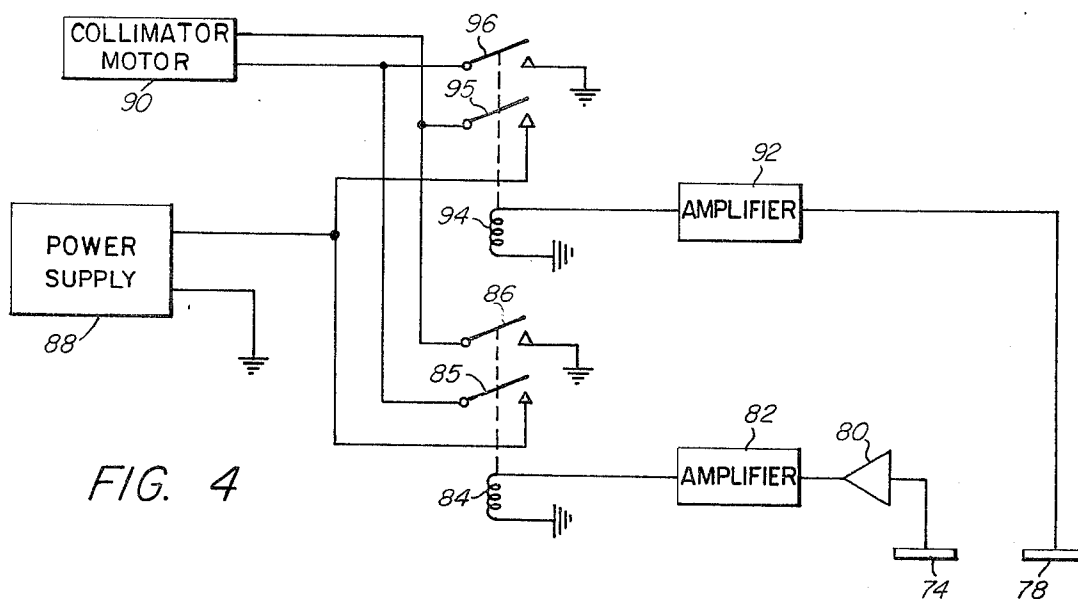


FIG. 4

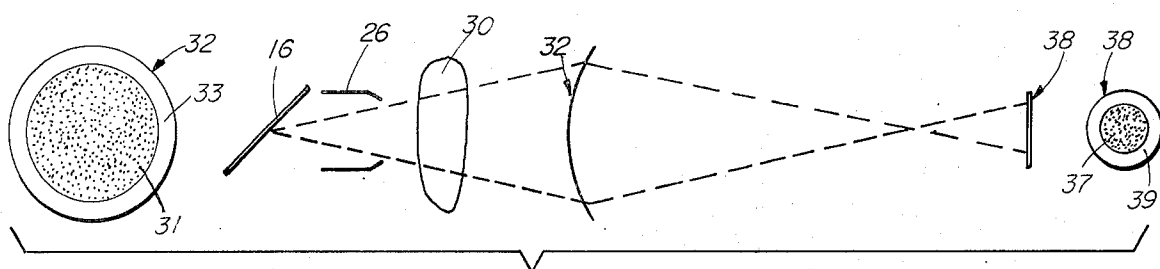


FIG. 5

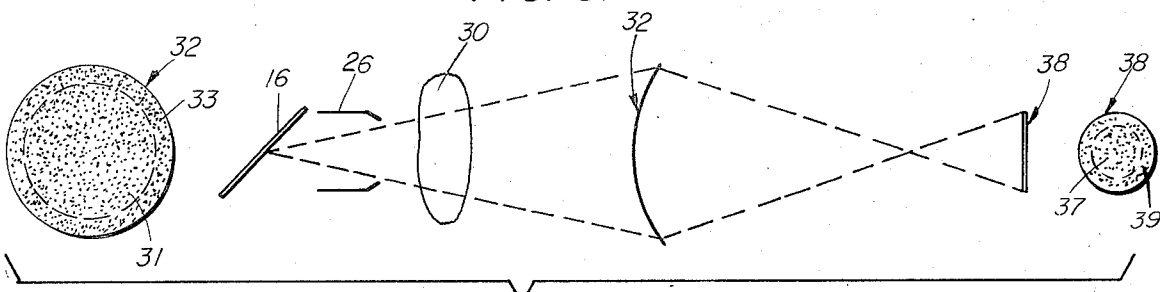


FIG. 6

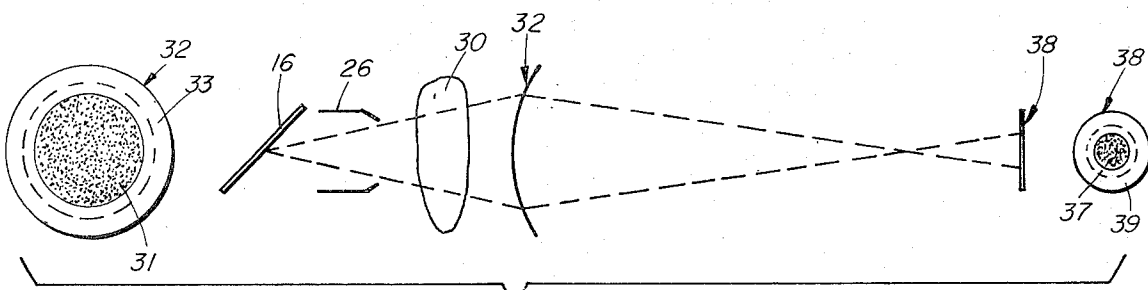


FIG. 7

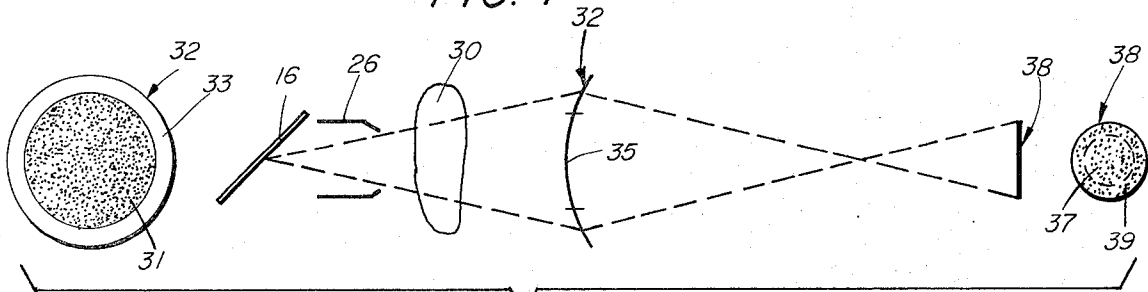


FIG. 8

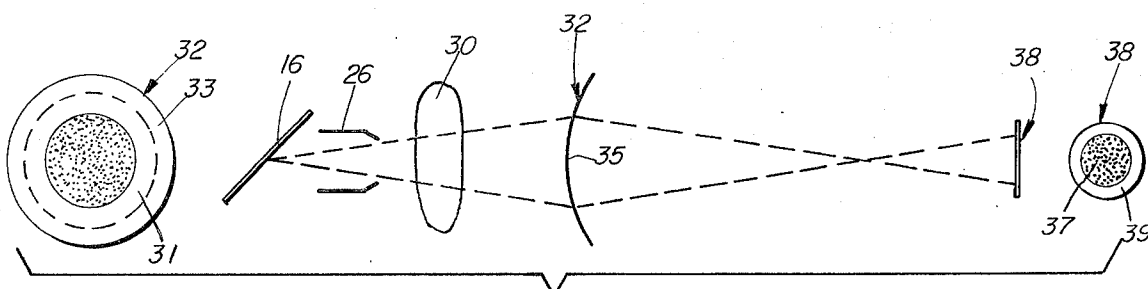


FIG. 9

X-RAY IMAGE INTENSIFIER SYSTEM**BACKGROUND OF THE INVENTION**

This invention relates generally to X-ray apparatus and is concerned more particularly with an X-ray system wherein an X-ray image intensifier tube is associated with image size sensing means and adjustable beam collimating means for protecting a patient from overexposure to X-radiation.

It is well-known that internal organs of a human body, for example, may be examined by exposing a preselected region of the body to X-rays for a limited period of time. However, the X-ray intensity and exposure time must be carefully controlled, particularly when a human subject is involved, to avoid injury due to overexposure. Furthermore, the X-rays should be confined substantially to the region of the body selected for examination, in order to minimize exposure of the patient to X-radiation.

One type of X-ray apparatus particularly suitable for achieving this objective is shown and described in U.S. Pat. No. 3,581,094 granted to L. F. Peyser and G. Bavor and assigned to the assignee of this invention. The apparatus disclosed therein includes an automatic collimating means having orthogonally arranged pairs of opposing pivotal plates forming an opening through which an X-ray beam passes to impinge on an X-ray film. In accordance with electrical signals produced by sensing means suitably located in the apparatus, the collimating means adjusts the cross-sectional size and shape of the X-ray beam to conform substantially to the size and orientation of the film being used. Thus, when a patient is positioned between the collimating means and the X-ray film, only the portion of the patient's body selected for study is irradiated and recorded on the film.

Another type of collimating means, which is more suitable for limiting the diametric size of an X-ray cone is shown and described in U.S. Pat. No. 3,448,270 granted to L. F. Peyser and assigned to the assignee of this invention. Briefly, this referenced patent discloses a collimator device having at the exit end thereof a thimble-like shutter means comprising a plurality of leaves of X-ray absorbent material arranged longitudinally in partially overlapping relationship to form a frustoconical structure. The leaves are pivotally mounted and simultaneously adjustable to move into greater or lesser overlapping relationship thereby defining the diametric size of a variable aperture at the small diameter end of the structure. Thus, this collimator device may be adjusted to provide an X-ray cone passing through it with the proper diametric size for irradiating only a preselected region having a corresponding configuration.

Accordingly, the described collimator device is particularly well adapted for use in an X-ray system having means for directing a cone of X-radiation through the collimator device and onto the generally circular, input faceplate of an image intensifier tube. Thus, when a patient is positioned between the collimator device and the image intensifier tube, the X-ray cone will irradiate only a preselected portion of the patient's body and convey a generally circular image thereof to the input faceplate of the image intensifier tube. By well-known techniques, the X-ray image will be converted and amplified within the intensifier tube to produce a bright visual image thereof on the output screen of the tube.

In this manner, internal organs within the irradiated region of the patient may be viewed directly, without the aid of X-ray film. However, in order to minimize exposure of the patient to X-radiation, the collimator device should be adjusted to limit the X-ray cone to the portion of the patient's body being imaged on the useful area of the output screen.

The described X-ray system may employ an image intensifier tube of the zoom type whereby the normal image appearing on the output screen is greatly enlarged. A tube of this type is shown and described in U.S. Pat. No. 3,417,242 granted to R. W. Windebank and assigned to the assignee of this invention. As disclosed therein, magnification may be achieved by varying the voltages applied to respective intermediate electrodes and thereby altering the electron focussing fields established between the input faceplate and the output screen of the image intensifier tube. As a result, the normal image is expanded such that only a portion thereof is displayed on the useful area of the output screen. In this manner, small details in the normal image of the irradiated region may be magnified for further examination and study. However, since only a portion of the irradiated region of the patient is occupying the entire useful area of the output screen, the collimator device should be adjusted during magnification intervals to limit the X-ray cone to a diametric size conforming to the portion of the patient's body being displayed on the useful area of the output screen.

This objective may be achieved by gang-controlling the collimator device and the magnification actuating means. However, this approach does not provide a means for continuously monitoring the image being displayed on the useful area of the output screen to determine if the patient is being exposed to excessive X-radiation. As a result, the patient can be exposed unnecessarily when the image intensifier tube is moved relative to the collimator device and the X-ray beam will not be limited to protect the patient from overexposure. For example, after the collimator device is adjusted properly for a normal image, the image intensifier tube may be moved further away from the collimator device. Consequently, the input faceplate of the image intensifier tube will intercept only a portion of the X-ray cone passing through the patient.

Thus, the described X-ray system requires means for continuously monitoring an image displayed on the output screen of the image intensifier tube and for adjusting the collimator device correspondingly.

SUMMARY OF THE INVENTION

In accordance with this invention, an X-ray system having an X-ray generator disposed for directing an X-ray beam through an automatic collimating means and onto the input faceplate of an image intensifier tube is provided with image sensing means disposed adjacent the output end of the image intensifier tube. The sensing means comprises inner and outer concentric arrays of light sensitive devices which define an optimum image diameter therebetween and which produce electrical signals indicative of the size of an image appearing on the output screen of the image intensifier tube. The inner array detects when the image diameter is less than optimum and produces electrical signals which causes the automatic collimating means to increase the diametric size of the X-ray beam. The outer array detects when the image diameter exceeds the op-

timum value and produces an electrical signal which causes the automatic collimating means to decrease the diametric size of the X-ray beam. The signals produced by the inner and outer arrays are fed to a control unit for operating the collimator device.

The image intensifier tube may be of the variable magnification type, and the sensing means may include a photosensitive device for measuring the brightness of the image.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objectives and advantages of the present invention will be apparent from the following detailed description when taken in conjunction with accompanying drawings, wherein:

FIG. 1 is a diagrammatic view of an X-ray system embodying the invention;

FIG. 2 is a schematic view of a circuit suitable for use with this invention;

FIG. 3 is an elevational end view of the sensing means of this invention;

FIG. 4 is a schematic view of another circuit suitable for use with this invention;

FIG. 5 is a diagrammatic view showing the proper mode of operation for this invention;

FIG. 6 is a diagrammatic view showing the image intensifier tube moved further away from the collimator device;

FIG. 7 is a diagrammatic view showing the image intensifier tube located too close to the collimator device;

FIG. 8 is a diagrammatic view showing the image intensifier tube in the zooming mode of operation; and

FIG. 9 is a diagrammatic view showing the corrective action of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more particularly to the drawings wherein like characters of reference designate like parts throughout the several views, there is shown in FIG. 1 an X-ray system including an X-ray generator 10 which may comprise an X-ray tube 12 of the conventional type, for example. Thus, within the envelope of tube 12, a filamentary cathode 14 is disposed to direct a stream of emitted electrons onto an inclined target surface of an anode 16. The cathode 14 is heated to electron emitting temperatures by an electrical current which may flow from a suitable power supply 18, through a series connected resistive element of a potentiometer 20, through the cathode 14 and return to the power supply 18.

The cathode 14 also is connected electrically to a negative terminal of a high voltage power supply 22 which has a positive terminal connected electrically to the anode 16. Thus, with a high voltage applied between the cathode 14 and the anode 16 within the tube 12, electrons emitted by the cathode 14 impinge on the target surface of anode 16 to produce X-rays which radiate from the tube through a suitable port 23. The target surface of anode 16 is disposed at an angle with the port 23 such that X-rays leaving the tube envelope through the port 23 appear to be emanating from a small focal on the target surface of anode 16.

These X-rays form a cone 24 which passes through a collimator device 26 having means for limiting the cross-sectional size of the cone when actuated by a suit-

able collimator control unit 28. Shown and described in the aforementioned U.S. Pat. No. 3,448,270 granted to L. F. Peyser is a preferred collimator device having means for limiting the diametric size of the cone 24 of X-radiation. Although this collimator device is illustrated in the referenced patent as being manually operated, it should be readily apparent to those skilled in the art that it is adaptable for automatic adjustment in accordance with electrical signals received by the collimator control unit 28. These signals may be produced by properly located sensing means and fed to the collimator control unit 28, as taught in the aforementioned U.S. Pat. No. 3,581,094 gnted to L. F. Peyser and G. Bavor.

After passing through the collimator device 26, the X-ray cone 24 impinges on a generally circular input faceplate 32 of an image intensifier tube 34. Thus, a subject 30 may be positioned between the collimator device 26 and the image intensifier tube 34 such that the cone 24 of X-radiation passes through a preselected portion of the subject 30 and conveys an X-ray image thereof, by well-known means, to the input faceplate 32 of the image intensifier tube 34. The input faceplate 32 is transparent to X-rays and, generally, supports on its inner surface a photocathode layer 36, which emits electrons from incremental areas thereof in proportion to the density of impinging X-rays. Thus, the photocathode produces an electron image which corresponds to the incident X-ray image.

Within the image intensifier tube 34, the electron image emitted by the photocathode 36 is electrostatically accelerated and focussed on a luminescent phosphor screen 38 at the opposing end of tube 34. As a result, the electron image impinges on the phosphor screen 38 with sufficient energy to produce a bright visual image which may be viewed through an adjacent output faceplate 40. Aligned with the faceplate 40 may be a suitable optical system 42 which may comprise a collimator lense 44 for focussing the image on infinity and an imaging lense 46 for focussing the image on the eye 48 of an observer. In this manner, the irradiated region of the subject 30 may be viewed directly, without the aid of X-ray film. However, it should be noted that, in order to minimize exposure of the subject 30 to X-radiation, the collimator device 26 must be adjusted to restrict the X-ray cone 24 to the portion of subject 30 being displayed on the output screen 38 of tube 34.

In order to accelerate the electron image within the image intensifier tube 34, the photocathode 36 and the output screen 38 are connected electrically to a power supply 50, which applies suitable voltages to these electrodes for establishing a strong electrostatic field therebetween. However, this electrostatic field may be altered for magnification purposes, as taught in the aforementioned U.S. Pat. No. 3,417,242 granted to R. W. Windebank, by providing intermediate electrodes, such as 52, 53 and 54, for examples, which are electrically connected to a zoom control unit 56. By means of the zoom control unit 56, variable voltages may be applied to each of the intermediate electrodes 52-54 to enlarge the normal image on the output screen 38 to such an extent that only a centralized portion of the image occupies the entire useful area of the output screen. In this manner, interesting details in the normal image may be magnified for more careful study. However, a marginal annular portion of the normal image has expanded radially beyond the periphery of the useful area

of the output screen 38 and, therefore, represents excessive X-radiation passing through the subject 30. Consequently, during magnification intervals, the collimator device 26 should be readjusted to restrict the diametric size of the X-ray cone 25 to only that portion of the subject 30 being displayed on the useful area of the output screen 38.

Since the image on the output screen 38 is focussed at infinity by the collimating lens 44, a beam splitter 58, made of partially reflecting glass, for example, may be positioned between the collimating lens 44 and the imaging lens 46 without adversely affecting the image being transmitted to the eye 48 of an observer. In accordance with this invention, the beam splitter 58 is positioned so as to reflect a true replica of the image through a second imaging lens 57 and onto a substantially planar end facing 61 of an image size sensing means 60. As shown in FIG. 3, the end facing 61, which may be made of suitably rigid material, such as phenolic sheet, for example, comprises an apertured mask having inner and outer concentric arrays of symmetrically spaced holes, 62 and 64, respectively. Aligned with each of the holes 62 is one end of a respective fiber optic bundle 66 and similarly aligned with each of the holes 64 is one end of a respective fiber optic bundle 68. The ends of the fiber optic bundles 66 and 68, respectively, may be fixedly attached into the aligned holes by any convenient means, such as epoxy cement, for example. The adjacent end portions of the fiber optic bundles, 66 and 68, respectively, may be clamped to one another by conventional means, such as a diametrically adjustable collar 69, for example, thereby forming a common end of an optical fiber harness 70.

The fiber optic bundles 66 branch out of the harness 70 and form a common end 72 facing a light responsive device 74, such as a photomultiplier tube, for example. The fiber optic bundles 68 are routed to form a common end 76 facing another light responsive device 78, such as a photomultiplier tube, for example. Each of the light responsive devices, 74 and 78 respectively, produce an electrical signal when light is incident upon it and each has an output connected electrically to the collimator control unit 28.

Alternatively, the fiber optic bundles 66 and 68 may be replaced by respective light sensitive devices, such as photodiodes, for example, which may be operatively mounted in associated holes 62 and 64 of the apertured mask 61 (FIG. 3) to form the required inner and outer arrays, respectively. Moreover, the photodiodes of an array may have their respective outputs connected in parallel to the associated input terminal of the collimator control unit 28 thereby eliminating the need for light responsive devices 74 and 76. Thus, when light is incident on any one of the photosensitive diodes in an array, an electrical signal will be sent to the appropriate input terminal of the collimator control unit 28, a result which is similar to that achieved with the fiber optic bundles 66, 68 and the light responsive devices 74, 76.

As shown in FIG. 4, within the collimator control unit 28, the output of the light responsive device 74 may be connected through a conventional inverter 80 to the input of an amplifier 82. The output of amplifier 82 may be connected to the coil 84 of a relay having contact arms 85 and 86, respectively, which may be actuated to connect a power supply 88 to the field winding of a collimator motor 90 such that its shaft rotates in a preferred angular direction, such as clockwise, for

example. The output of the light responsive device 68 may be connected to the input of an amplifier 92. The output of the amplifier 92 may be connected to the coil 94 of a relay having contact arms 95 and 96, respectively, which may be actuated to connect the power supply 88 to the field winding of collimator motor 90 such that its shaft rotates in the opposite angular direction, such as counterclockwise, for example. In this manner, electrical signals produced by the image size sensing means 60 may be utilized to actuate the collimator device 26 and thereby limit the diametric size of the X-ray cone 25.

In operation, as shown in FIG. 5, the collimator device is adjusted to limit the X-ray cone 24 diametrically such that it impinges on only a centralized useful area 31 of the input faceplate 32 of image intensifier tube 34. Thus, the X-ray cone 24 is restricted from impinging on a marginal annular area 33 of the input faceplate 32. Accordingly, an X-ray image impinging on the useful area 31 of input faceplate 32 is converted by the intensifier tube 32 and displayed as a visual image on a centralized useful area 37 of output screen 38. Thus, the electron image is restricted from impinging on a marginal annular area 39 of the output screen 38. Consequently, when a true replica of the visual image is reflected to the end facing 61 of image size sensing means 60, light will enter the fiber optic bundles 66 in holes 62 but will not enter the fiber optic bundles 68 in holes 64. An optimum image diameter is indicated by the dashed circle 63. As a result, light travelling through the optical bundles 66, by well-known means, will be incident on the light responsive device 74 which will produce an electrical signal. As shown in FIG. 4, the inverter 80 will prevent the coil 84 from being energized and, consequently, the collimator device 26 will not be adjusted to modify the diametric size of X-ray cone 24.

As shown in FIG. 6, when the image intensifier tube 34 is moved away from the collimator device 26, the input faceplate 32 will intercept a larger cross-sectional area of the cone 24. Therefore, the X-ray image also will impinge on the outer annular area 33 of the input faceplate 32 and will be displayed on the outer annular area 39 of the output screen 38. Consequently light will enter the light bundles 68 in the holes 64 of the image size sensing means 60. As shown in FIG. 4, the resulting electrical signal produced by the light responsive device 78 will be increased by the amplifier 92 to energize the coil 94 thereby actuating contact arms 95 and 96, respectively. Thus, the power supply 88 will be connected to the field winding of the collimator motor 90 in such a manner that it will adjust the collimator device 26 to decrease the diametric size of the X-ray cone 24, until the cone impinges on only the centralized useful area 31 of the input faceplate 32. As a result, the image on input screen 38 will not extend radially onto the outer annular area 39 and will no longer enter the fiber optic bundles 68 to activate the light responsive device 78. When the light responsive device 78 no longer produces an electrical signal, the coil 94 will be de-energized and the relay will open, thereby disconnecting the power supply 88 from the collimator motor 90. Thus, the collimator device 26 will be properly adjusted for irradiating only the portion of the subject 30 which is being displayed on the useful output area 37 of output screen 38, as shown in FIG. 1.

Thus, it may be seen that the marginal annular area 33 of the input screen 32 and the marginal annular area 39 of the output screen 38 need not be continuous. Alternatively, for example, each of the annular areas 33 and 39, respectively may be replaced by a circular array of spaced indentations which extend from the central useful area into an otherwise opaque band surrounding the useful area. These indentations may have any configuration desired, such as arcuate, rectangular or V-shaped slots extending from the useful area into the encircling band of opaque material. Furthermore, any number of indentations may be used. However, the greater the number of indentations, the greater the accuracy in detecting changes in the image size.

As shown in FIG. 7, when the image intensifier tube is moved closer to the collimator device 26, the X-ray image does not fill the entire useful area 31 of the input faceplate 32. As a result, the electron image does not fill the entire useful area 37 of output screen 38, and light does not enter the optic fiber bundles 66 in holes 62 of image size sensing means 60. Thus, the light responsive device 72 ceases to produce a signal and, as shown in FIG. 4, this zero voltage signal causes the inverter 80 to send a suitable positive signal to the amplifier 82. The amplified positive signal energizes the coil 84 of the associated relay whereby the contact arms 84 and 86, respectively, are actuated. As a result, the power supply 88 is connected to the field winding of collimator motor 90 in such a manner that the collimator device will be adjusted to increase the diametric size of the X-ray cone 25. Accordingly, the X-ray image will increase in diameter on the input faceplate 32 until it fills the entire useful area 31 of the input faceplate 32, and the resulting visual image will increase in diameter until it fills the entire useful area 27 of input screen 38. Thus, light will enter the fiber optic bundles 66 in holes 62 of the image size sensing means 60 and activate the light responsive device 72 to produce an electrical signal, which will be reduced to zero by the inverter 80. Consequently, the coil 90 will be de-energized and the power supply 88 will be disconnected from the collimator motor 90. In this manner, the collimator device 26 will be properly adjusted for irradiating only the portion of subject 30 which is displayed on the useful area 37 of output screen 38.

When the normal image displayed on the useful area 37 of output screen 38, as shown in FIG. 5, is magnified by means of the zoom control unit 58, it expands radially toward the periphery of the output screen 38, as shown in FIG. 8, and may even expand beyond it. During such magnification intervals, the X-ray cone 24 is restricted to the useful area 31 of input faceplate 32, but only a centralized portion, such as 35, for example, of the useful area 31 is being displayed on the useful area 37 of output screen 38. Consequently, light from the surrounding annular area 39 of output screen 38 enters the fiber optic bundles 68 of image size sensing means 60. As a result, the light responsive device produces an electrical signal and, in a manner similar to that described in connection with FIG. 6, the collimator device is actuated to decrease the diametric size of the X-ray cone 24 until it impinges only on the centralized portion 35 of the useful area 31 of input faceplate 32, as shown in FIG. 9. Accordingly, the resulting visual image is restricted to the useful area 37 of output screen 38, and the light responsive device 78 will cease producing the electrical signal thereby disconnecting

the collimator motor 90 from the power supply 88. Thus, the image size sensing means 60 functions as a continuous monitor of the output image of image intensifier tube 34 to adjust the diametric size of the X-ray cone 24 for irradiating only the portion of the subject 30 which conforms to the useful area 37 of the output screens 38 and thereby protecting the subject 30 from excessive X-radiation.

If the zoom-control unit 58 should be actuated to return the image intensifier tube 34 to the normal operating mode while the collimator device 26 is adjusted for the magnification mode of operation, the resulting image appearing on the output screen 38 would be similar to the output image shown in FIG. 6. Consequently, light would not enter the fiber optics bundles 66 and the light responsive device 74 would cease producing an electrical signal. As described more fully in the discussion relating to FIG. 6, the inverter 80 shown in FIG. 4 would operate to energize the relay coil 84 and actuate the contact arms 85 and 86. Accordingly, the collimator device 26 would be readjusted for the normal operating mode and the resulting output image would return to the condition shown in FIG. 1.

Referring again to FIG. 1, the beam splitter 58 also may be utilized to reflect a true replica of the image on output screen 38 through a third imaging lense 59 and onto a light measuring device 100, such as a photoelectric cell, for example. The device 100 produces an electrical signal which corresponds to the intensity of light incident on it and is electrically connected to a motor control unit 102. As shown in FIG. 2, within the motor control unit 102, the electrical signal from the device 100 may pass through a resistive element of a gain control device 104 which has a wiper arm connected electrically to the input terminals of respective signal level detecting devices, such as Schmitt triggers 106 and 107, for example, which may be of conventional design. The output of the Schmitt trigger device 106 is connected through a conventional inverter device 108 to a relay coil 110 which actuates contact arms 112 and 114, respectively. When actuated, the contact arms 112 and 114 connect a power supply 116 to the field winding of a motor 118 such that the wiper arm of potentiometer 20, shown in FIG. 1, is rotated in a preferred angular direction, such as clockwise, for example. The output of the Schmitt trigger device 107 is connected to a relay coil 120 which actuates contact arms 122 and 124, respectively. When actuated, the contact arms 122 and 124 connect the power supply 116 to the field winding of the motor 118 such that the wiper arm of potentiometer 20 is rotated in the opposite angular direction.

In operation, the electrical signal from the device 100 passes through the gain control 104 and produces a corresponding voltage signal between the wiper arm of gain control 104 and electrical ground. When this voltage signal is below a predetermined range of values, the Schmitt trigger device 106 and the inverter device 108 operate to energize the relay coil 110. As a result, the contact arms 112 and 114 are actuated and connect the power supply 116 to the motor 118 in such manner that the wiper arm of potentiometer 20 moves to short out more of the resistive value in the circuit supplying current to the cathode 14 of X-ray tube 12. Consequently, the current flowing through the filamentary cathode 14 increases, thereby producing more emitted electrons which, in turn, generate more X-rays. Therefore, the

intensity of X-rays within the X-ray cone 24 increases and causes a brighter visual image to appear on the output screen 38 of image intensifier tube 34. Accordingly, the electrical signal from the device 100 produces a higher voltage which falls within the predetermined range of value and thereby switches the inverter device 108 to a non-conducting condition to deenergize the relay coil 110 and disconnect the power supply 116 from the motor 118.

The trigger device 107 is designed to operate when the voltage signal produced by device 100 is above the predetermined range of values thereby energizing the relay coil 120. As a result, the contact arms 122 and 124 are actuated to connect the power supply 116 to the motor 118 such that the wiper arm of potentiometer 20 moves to increase the resistive value in the circuit supplying current to the cathode 14 of X-ray tube 12. As a result, the cathode 14 emits less electrons and, consequently, less X-rays are generated at the anode 16. Accordingly, the intensity of X-ray cone 24 decreases thereby causing the image produced on output screen 38 to decrease in brightness. Therefore, the voltage signal produced by the device 100 falls within the predetermined range of values and the trigger device 107 switches to a non-conductive condition. As a result, the relay coil 120 is deenergized and the power supply 116 is disconnected from the motor 118. In this manner, the light measuring device 100 functions to control the brightness of the image on output screen 38 and thereby the intensity of X-rays passing through the subject 30.

Thus, there has been disclosed herein a novel X-ray image intensifier system having an X-ray generator disposed to direct a cone of X-radiation through an automatically adjustable collimating means and onto the input faceplate of an image intensifier tube which may be of the variable magnification type. An image size sensing means disposed adjacent the output faceplate of the image intensifier tube detects changes in image size which indicate that the irradiated portion of a patient does not conform to the useful area of the intensifier tube output screen and produces corresponding electrical signals which cause the collimating means to adjust the X-ray beam so as to protect the patient from excess radiation. An image brightness measuring means disposed adjacent the output faceplate of the image intensifier tube detects changes in image brightness and produces an electrical signal which causes the intensity of an X-ray beam to be regulated so as to protect the patient also. The electrical signals from the sensing means are processed by control means so as to modify the X-ray beam only the amount required to protect the patient and produce clear images of the irradiated area on the output screen of the image intensifier tube.

The image size sensing means includes two concentric arrays of light sensitive devices which define an optimum image diameter therebetween. Each array may comprise any convenient number of light sensitive devices which may be spaced a suitable distance apart. However, the sensitivity of each array in detecting changes in image size increases in proportion to the number of light sensitive devices used in the array.

From the foregoing, it will be apparent that all of the objectives of this invention have been achieved by the structures shown and described. It will be also apparent, however, that various changes may be made by those skilled in the art without departing from the spirit

of the invention as expressed in the appended claims. It is to be understood, therefore, that all matter shown and described is to be interpreted as illustrative and not in a limiting sense.

We claim:

1. An improved X-ray imaging system including:
an X-ray generator having means for directing an X-ray beam through an externally located subject;
an X-ray collimator device operatively disposed between the X-ray generator and the subject and having adjustable means for regulating the cross-sectional size of the X-ray beam;

an X-ray image intensifier tube including an input screen disposed to receive an X-ray image of the subject and having means for emitting a corresponding electron image, an output screen having means for converting an incident electron image into a corresponding visual image, and means for focussing an electron image emitted by the input screen onto the output screen; and

wherein the improvement comprises means optically coupled to the output screen of the image intensifier tube for monitoring the size of the visual image.

2. An X-ray imaging system as set forth in claim 1 wherein the image size sensing means includes a plurality of light sensitive devices, each device being disposed in optical communication with a respective portion of the output screen.

3. An X-ray imaging system as set forth in claim 1 wherein the image size sensing means includes two concentric arrays of light sensitive devices defining an optimum image size therebetween.

4. An X-ray imaging system as set forth in claim 3 wherein the monitoring means includes a marginal area of the input screen electron-optically aligned with a marginal area of the output screen which, in turn, is disposed in optical communication with light sensitive devices in one of the concentric arrays.

5. An X-ray imaging system as set forth in claim 1 wherein the image size sensing means includes means for producing electrical signals indicative of the size of the visual image on the output screen.

6. An X-ray imaging system as set forth in claim 5 wherein the monitoring means includes control means electrically connected to the image size sensing means and coupled to the adjustable means of the collimator device for electrically evaluating the signals produced by the image size sensing means and operating the adjustable means of the collimator device accordingly.

7. An improved X-ray imaging system including:

an X-ray generator having means for directing an X-ray beam through an externally located subject;
an X-ray collimator device operatively disposed between the X-ray generator and the subject and having adjustable means for regulating the cross-sectional size of the X-ray beam;

an X-ray image intensifier tube including an input screen disposed to receive an X-ray image of the subject and having means for emitting a corresponding electron image, an output screen having means for converting an incident electron image into a corresponding visual image, and means for focussing an electron image emitted by the input screen onto the output screen;

wherein the improvement comprises image size sensing means optically coupled to the output screen

for producing electrical signals indicative of the size of a visual image on the output screen; and control means electrically connected to the image sensing means and coupled to the adjustable means of the collimator device for evaluating electrical signals received from the image size sensing means and in accordance therewith operating the adjustable means of the collimator device.

8. An X-ray imaging system as set forth in claim 7 wherein the image size sensing means includes a plurality of light responsive devices, each being disposed in optical communication with a respective portion of the output screen and having means for an electrical signal in response to light received therefrom.

9. An X-ray imaging system as set forth in claim 8 wherein the image size sensing means also includes an optical fiber harness comprising a plurality of fiber optic bundles, each terminating at one end of the harness in a common facing on which an optical image of the output screen is projected and terminating at their respective other ends adjacent on operatively disposed, light responsive devices.

10. An X-ray imaging system as set forth in claim 9 wherein the ends of the fiber optic bundles in the common facing are disposed in inner and outer concentric arrays, the fiber optic bundles having ends in the inner array terminate at their other ends in a common facing operatively coupled to a first light responsive device and the fiber optic bundles having ends disposed in the

outer array terminate at their other ends in a common facing operatively coupled to a second light responsive device.

11. An X-ray imaging system as set forth in claim 10 wherein the fiber optic bundles in the outer array are disposed in optical communication with respective marginal areas of the output screen and the fiber optic bundles in the inner array are disposed in the inner array are disposed in optical communication with respective portions of a central area of the output screen.

12. An X-ray imaging system as set forth in claim 11 wherein said marginal areas of the output screen are electron-optically aligned with respective marginal areas of the input screen.

13. An X-ray imaging system as set forth in claim 10 wherein the control means includes first circuit means electrically connected to the first light responsive device and interruptingly coupled to the adjustable means of the collimator device for operating the adjustable means in response to a predetermined minimal signal from the first light responsive device.

14. An X-ray imaging system as set forth in claim 11 wherein the control means also includes second circuit means electrically connected to the second light responsive device and interruptingly coupled to the adjustable means of the collimator device for operating the adjustable means in response to a signal from the second light responsive device.

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