March 4, 1958 D. O. NORTH 2,825,817

X-RAY APPARATUS

Filed Oct. 28, 1954 2 Sheets-Sheet 1

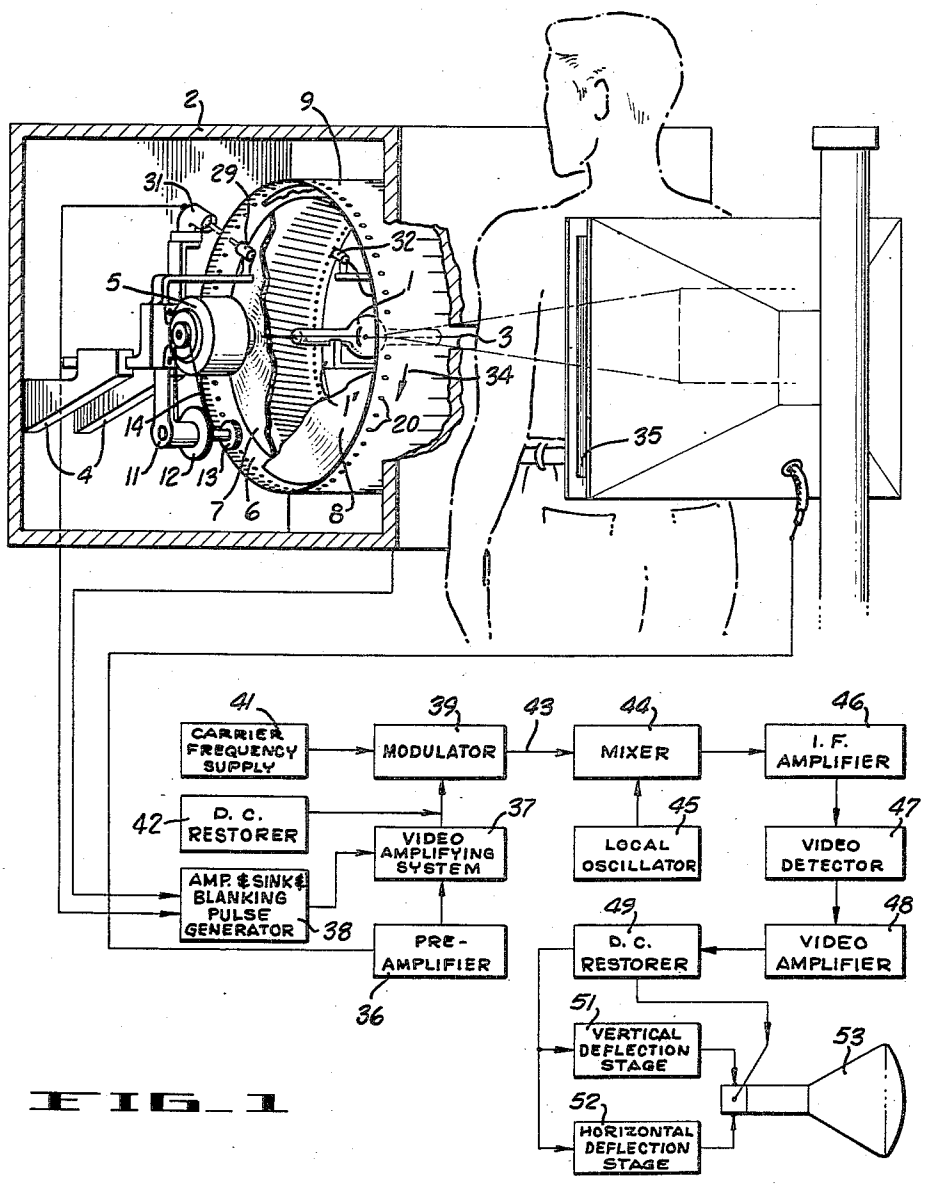



FIG. 1

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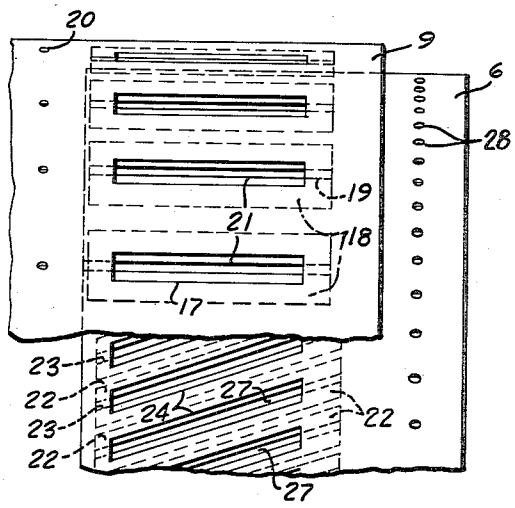



FIG. 2

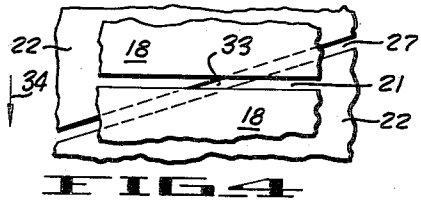



FIG. 4

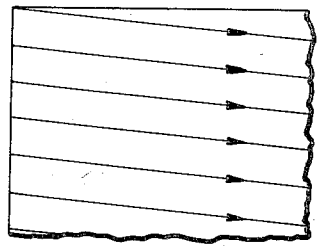


FIG. 5

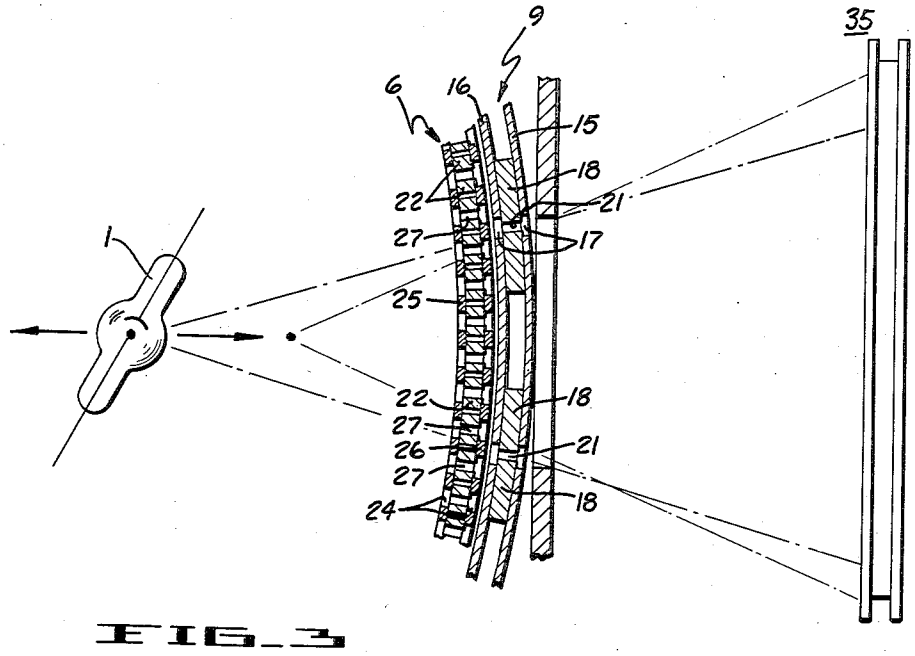



FIG. 3

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2,825,817

Patented Mar. 4, 1958



2,825,817

# X-RAY APPARATUS

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Application October 28, 1954, Serial No. 465,215

8 Claims. (Cl. 250—105)

This invention relates in general to X-ray methods and apparatus and, more particularly, to novel improved fluoroscopic and fluorographic systems.

There presently exist various types of fluoroscopic and fluorographic apparatus for the examination of objects or bodies, such as the human body, with penetrating X-rays. Basically, the fluoroscopic system includes a fluorescent screen, for example one of zinc sulfate with suitable activators, which fluoresces in a dark room when exposed to the action of the X-rays. When bodies of varying densities are interposed between the source of X-rays and the screen, the differing degrees of density are observed by variations in the brightness of the fluorescence of the screen. This occurs because X-rays are absorbed by the interposed body to different degrees by the different densities. This same effect may be displayed on a photographic plate or film for study and permanent recording.

The exposure of the human body to X-rays results in the destruction of tissue cells in flesh, bone and blood, producing a general effect on the organism, which may result in severe lesions very difficult to heal. The effects of X-rays are cumulative, each succeeding exposure or dose adding to the last. This cumulative effect is particularly serious in regard to those who are frequently exposed, such as medical personnel operating such X-ray apparatus.

It is therefore the object of the present invention to provide a novel X-ray apparatus which operates in such a manner that the exposure to the X-rays of both the body under investigation and the operator is limited to a degree well below that of presently existing X-ray apparatus.

The principal feature of this invention is the provision of an X-ray system in which the body under investigation is systematically scanned by a narrow beam of X-rays, the beam sweeping horizontally to produce lines and simultaneously sweeping vertically to produce frames, in the same manner as present day television picture signals are produced. The X-ray beam, after passing through the body, impinges upon an X-ray detector which produces a voltage signal output proportional to the densities of the body. This signal voltage is amplified and transmitted to a receiver system of the standard television type including a cathode ray tube to control the light intensity of the electron beam spot as it traces horizontally to produce lines and vertically to produce frames in synchronization with the X-ray beam.

Since the X-ray beam is extremely small, the body under investigation is exposed to a very small amount of X-rays compared to the exposure of other X-ray systems even though the area covered by the examination is as large as in other systems. The cathode ray apparatus and screen on which the X-ray picture appears, since it is similar in character to a regular television receiver, may be located at any remote spot from the X-ray source, for example, in the next room, another building, etc., and the controls for the X-ray source may be remotely placed,



so that the operator of the system may avoid all exposure to the X-rays.

Another feature of the present invention is the provision of a novel method and apparatus for causing the beam to sweep horizontally and vertically which comprises two hollow cylinders, one positioned within the other with their axes coinciding, the drums being rotatably mounted and having the X-ray tube positioned within both drums. One drum has a plurality of equally spaced slots in its surface running parallel to the axis and the other a plurality of equally spaced slots extending slightly diagonal to the axis, the two groups of slots interacting to produce the sweeping beam of X-rays as subsequently explained.

Another feature of the present invention is the provision of a novel apparatus for synchronizing the cathode-ray beam with the X-ray beam and also for providing the necessary blanking pulses to the receiver.

These and other features and advantages of this invention will become more apparent from a perusal of the following specification taken in connection with the accompanying drawings wherein:

Fig. 1 is a diagrammatic view of one embodiment of the present invention including the X-ray beam producing device and the cathode-ray tube and associated electronic system,

Fig. 2 is a front view of a portion of the two rotatable drums or cylinders which interact to produce the sweeping beam of X-rays,

Fig. 3 is a partial view in side section of the drums and associated detector apparatus,

Fig. 4 is a partial view of the drums showing the manner in which the slots in the drums interact to produce the sweeping beam aperture, and

Fig. 5 shows the path followed by the sweeping beam.

Similar elements in the different figures of the drawings bear similar reference numerals.

Referring now to the drawings, the preferred embodiment of the present invention includes a suitable source of X-rays 1, in this instance a Coolidge type X-ray tube, suitably mounted by brackets 1' within a lead shielded cabinet 2 having an aperture 3 in one wall. Brackets 4 extend from the rear wall of the cabinet 2, these brackets serving to mount an electrical motor 5. Fixedly secured on the shaft of this motor 5 is a hollow cylindrical drum 6, the motor shaft being secured in the closed end 7, shown fragmentarily, of the drum 6 at the drum axis. Mounted on the motor shaft in its closed end 8, shown fragmentarily, is a second drum 9 which encompasses the drum 6, the axes of the two drums coinciding. This drum 9 is rotatably mounted on the motor shaft by suitable bearing means (not shown) which allows the drum 9 to rotate on the motor shaft. An arm 11 extends from the motor mount, this arm holding a rotatably mounted pulley wheel 12 and associated drum drive gear 13. A pulley belt 14 couples the motor shaft to the pulley wheel 12 whereby the drive gear 13 may be driven by the motor 5, the gear 13 in turn driving the outer drum 9 at a reduced rotational speed with respect to the motor speed.

The drum 9 is made up of two hollow cylinders 15 and 16 of a good structural material such as steel, one cylinder 16 being closely fitted within the other 15 (see Fig. 3). The cylinders 15 and 16 have an equal number of equally spaced wide slots 17 in the surface running parallel to the axis of the cylinders, giving the cylinders a ladder appearance. Sandwiched between the two cylinders 15 and 16 are a plurality of rectangular pieces of lead 18, these lead slugs 18 being separated by small spacers 19 (Fig. 2) located near the ends of the lead slugs. There is therefore formed a plurality of narrow slots 21 of equal width between the adjacent lead slugs 18, the exact width of the slot being determined by the

width of the spacers 19. The slugs 18 and cylinders 15 and 16 are so positioned that each of the narrow slots 21 between the lead pieces 18 coincide with an associated pair of wider slots 17 in the two cylinders. The slugs 18, spacers 19 and cylinders 15 and 16 are all rigidly fastened into a complete drum unit. A plurality of small holes 20 are equally spaced in a row around one of the outer edges of the drum 9, the number of holes being equal to the number of slots 21.

The inner drum 6 is constructed in the same manner as the outer drum using slugs of lead 22 and spacers 23, the difference being that the slots 24 in the cylinders 25 and 26 and the slots 27 between the lead slugs 22 are greater in number and run diagonally to the drum axis as seen in Figs. 1 and 2. A row of holes 28 equal in number to the slots 27 are located along one edge of the drum 6.

A source 29 of a narrow light beam is mounted within the outer drum 9 in alignment with the path traveled by the holes 20 in this drum. A light sensitive detector 31 such as a photoelectric tube is positioned outside of the drum 9 in alignment with the light source. A similar light source 32 and detector (not shown) are associated with the row of holes 28 in the inner drum 6.

In one particular instrument constructed in accordance with this invention, the outer drum 9 has fifty-two slots 21 and revolves at the motor speed of 30 R. P. M. The inner drum 6 has six hundred and twenty-four diagonal slots 27, this drum 6 being geared to run at 1300 R. P. M. The lead slugs 22 used in the inner drum 6 are approximately .002" thick x .125" wide x 2.5" long and are spaced apart by about .003" wide spacers 23. The outer drum 9 has .003" slots 21 spaced apart by 1.5", the slots 21 being 1.5" long. The aperture 3 in the cabinet wall is 1.5" x 1.5".

The operation of the beam forming and sweeping apparatus set forth above will now be described after which the remainder of the apparatus and system along with its operation will be discussed. The X-rays emitted from the tube 1 are directed at the aperture 3 and that portion of the rays which is not intercepted by the lead slugs 18 and 22 and the steel in the drums 6 and 9 passes through the aperture 3. Since the slots 21 in the outer drum 9 are 1.5" apart and the aperture 3 is 1.5" high, only one slot 21 at a time is aligned with any part of the aperture 3. These slots 21 pass the aperture 3 at the rate of approximately 26 per second. During the period that one slot 21 in the outer drum 9 is passing the aperture 3, approximately 520 slots 27 in the inner drum 6 pass the aperture 3. The slots 27 in the inner drum 6 are so separated that only one slot 27 coincides at any instant of time with the slot 21 in the outer drum 9. When the slots coincide, the X-rays pass through the aperture and, since the slots 27 are diagonal, only a very small opening 33 through the slots is provided (see Fig. 4).

The drums 6 and 9 rotate in the direction shown by the arrows 34 and, therefore, the lower left-hand end (as seen in Figs. 1 and 2) of any diagonal slot in the inner drum aligns with a slot in the outer drum initially, the diagonal slot passing the slot in the outer drum until the upper right-hand end of the slot aligns with the outer drum slot a short period afterwards. As the right-hand end of any one diagonal slot passes the slot in the outer drum, the left-hand end of the immediately succeeding diagonal slot becomes aligned with the respective slot in the outer drum. There is thus produced a small opening 33 which emits from the cabinet 2 a very small beam of X-rays, the opening 33 sweeping across the aperture 3 from left to right (see Fig. 4) as it simultaneously sweeps in a vertical direction from top to bottom. In the above example, the resultant beam of X-rays will sweep horizontally 520 times as it makes one sweep vertically. As the slot in the outer drum 9 passes below the bottom edge of the aperture 3, the next succeeding slot passes below the upper edge of the aperture 3 and the beam again starts its sweeping motion at the upper left-hand corner. Fig. 5 illustrates the scanning paths followed by the beam of X-rays.



It should be noted that this scanning resembles the scanning utilized in the television art. A common practice in television is to use interlaced scanning, i. e., scanning along every other horizontal line at first and then scanning along the horizontal lines in between during each frame. This practice increases the 30 cycle flicker frequency to a more unnoticeable 60 cycle flicker. To accomplish interlaced scanning by the X-ray beam in the present invention, it is only necessary to double the speed of the outer drum 9 such that two slots pass the aperture 3 during the period 520 diagonal slots are passing the aperture. By increasing the speed of the outer drum 9 fourfold, increased interlacing and improved flicker characteristics may be obtained.

The diagonal slots are so spaced that there is a slight period, which is termed a blanking period, between the termination of one horizontal sweep of the beam and the initiation of the succeeding sweep. The slots in the outer drum are also spaced-apart in a manner such that there is a slight blanking period between each frame or vertical sweep. During these blanking periods, suitable blanking pulses and synchronizing pulses are produced and transmitted to the indicator apparatus as will be subsequently described.

At approximately the time one of the slots in the outer drum 9 passes the upper edge of the aperture 3 to start a new frame, the light beam emitted from the light source 29 passes through a corresponding hole 20 in the drum edge and energizes the light detector 31. A signal voltage is this triggered to serve to produce a synchronizing pulse for the indicator system to be subsequently described. A similar trigger signal is produced by the light source 32 and associated detector through the holes 28 in the inner drum as each of the diagonal slots first engages the slot in the outer drum aligned with the aperture.

After passing through the aperture 3, the sweeping beam of electrons passes through the body under investigation and impinges on a detector plate 35 located behind the body. This detector comprises a rectangular plate of a material, such as, for example, selenium, which conducts electrical energy in proportion to the amount of X-rays striking its surface. This plate may be made by depositing a very thin layer of amorphous selenium on a metal plate, such as aluminum, and then depositing a very thin transparent layer of conducting material such as aluminum over the selenium. A voltage is applied across the two conducting surfaces. Since the selenium conducts in direct proportion to the strength of the X-rays striking it, the signal output from this selenium detector 35 is a measure of the densities of the body under examination. The signal output from the detector is transmitted to a preamplifier 36 where the signal is amplified and transmitted to a video amplifying system 37.

The triggering pulses received from the light detectors associated with the two revolving drums are transmitted to the electronic generator circuitry 38 which operates to generate the synchronizing and blanking pulses transmitted to the receiver. These synchronizing and blanking pulses are of the same type generated and utilized in standard television practice. The pulses generated are transmitted to the video amplifier 37. The picture signal from preamplifier 36 and the pulses from generator 38 are combined and transmitted to a modulator circuit 39 where they are imposed on the carrier signal from the carrier frequency supply 41. The standard D. C. restorer circuit 42 for introducing the appropriate direct-current level at the input to the modulator 39 is also shown.

The resultant carrier signal is transmitted, in the present instance over a cable 43, to the receiver stage of this particular system which includes the mixer 44 and associated local oscillator 45. The carrier signal is

modulated by the signal from the local oscillator 45 to produce the standard intermediate frequency signal. This signal is transmitted to the I. F. amplifier stages 46 and then to the video detector 47 where the picture signal and blanking and synchronizing signals are removed from the carrier. These signals are again amplified in video amplifier 48 and transmitted to the D. C. restorer 49 where the D. C. level is restored. The synchronizing signals are transmitted to the vertical and horizontal deflection stages 51 and 52, respectively, coupled to the vertical and horizontal deflection plates in the cathode ray tube 53. The picture signal and blanking pulses are transmitted to the beam controlling elements in the cathode ray tube 53.

The cathode ray beam is thus caused to trace the horizontal and vertical sweeping paths in synchronization with the X-ray beam, this cathode ray beam reproducing the light intensities produced in the X-ray beam. The blanking pulses serve to turn the cathode ray beam off while it is sweeping in its return paths.

This picture signal transmitter and receiver system has been shown as a "closed circuit" system utilizing the connecting cable 43. A carrier wave has been employed to render this system as closely resembling a standard television system as possible. By substituting suitable transmitting and receiving antennas and associated apparatus in place of the cable 43, thus system is rendered suitable for long distance transmission through space of the X-ray studies.

This system permits the operator to observe the X-ray studies from a room separated from the X-ray source. The X-ray source 1, drum motor 5 and other apparatus may be energized by controls all located outside of the X-ray room. Also, because the person being X-rayed is subjected only to a very small sweeping beam of X-rays rather than a large amount of continuous X-rays over a continuous area, the exposure of the person to the X-rays is greatly reduced.

It should be noted that by moving the X-ray tube closer to the aperture 3 in the cabinet, an enlarged area on the body under examination may be viewed. By moving the X-ray tube further from the aperture, a close-up view of the body may be obtained. The reason for this may be explained with reference to Fig. 3 which shows that the X-ray line-of-sight through the aperture 3 covers a progressively smaller area outside the aperture the further away the X-ray source is located from the aperture 3. This movement of the X-ray source 1 may be accomplished by providing that the bracket 1' on which the X-ray tube 1 is mounted is slidably mounted in the cabinet 2.

This system has been described utilizing 26 frames per second and 520 lines per frame since this closely corresponds to the standards employed in the United States. If desired, however, the present system may be slightly modified to increase the lines per frame and also the frames per second so that the definition of the picture may be improved.

It should be noted that another advantage of this X-ray system is that the electrical signal produced by the X-ray detector is amplified to any desired degree by the electronic circuitry before application to the cathode ray tube and therefore the brightness of the picture produced is very much better than that obtained with other fluoroscopic or fluorographic systems.

Since many changes could be made in the above construction of the novel invention and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An X-ray scanning apparatus comprising a source of X-rays, a first shielding member positioned in the path of the X-rays having a frame opening therein, a second shielding member positioned in the path of the X-rays having a slot therein, and a third shielding member positioned in the path of the X-rays having a slot therein, the slot in said third shielding member being positioned diagonally with respect to the slot in the second member, and driving means for moving said second and third members relative to said first member whereby the slots in said second and third members pass the frame opening in said first member, said driving means including means for moving said third shielding member faster than said second member whereby the diagonal slot in the third member passes the slot in the second member to form a small aperture through the shielding members for the X-rays which moves along the slot in the second member and across the frame opening in said first member.

2. An X-ray scanning apparatus as claimed in claim 1 wherein said third shielding member has a plurality of diagonal slots therein which successively pass the slot in said second member during the time period said latter slot is passing the frame opening in said first member whereby there is formed a small aperture through the shielding members which sweeps across the frame opening in one direction a plurality of times as it simultaneously sweeps more slowly across the frame opening in a direction normal to said first direction.

3. X-ray scanning apparatus comprising a first cylindrical member of X-ray shielding material having a plurality of slots running longitudinally therein equally spaced around the cylinder, a second cylindrical member of X-ray shielding material having a plurality of slots therein running in a direction diagonal with respect to the longitudinal direction equally spaced around the second cylinder, means for rotatably mounting said cylinders for rotation about a common longitudinal axis, one of said members being positioned within the other in axial alignment, a source of X-rays within the cylindrical members adapted to direct a beam of X-rays at a spatial point on the inside surface of the cylindrical members, and driving means for rotating said cylinders about said common axis, the second cylindrical member being rotated at a faster speed than said first cylinder whereby an aperture for the passage of said X-rays is formed through the aligned slots in said members at said spatial point, which aperture sweeps along the longitudinal slot in said first cylindrical member as the diagonal slot in said second cylindrical member passes the longitudinal slot, the aperture moving substantially normal to the sweeping direction as said longitudinal slot moves past said spatial point.

4. An X-ray scanning apparatus as claimed in claim 3 including an X-ray shielding cabinet enveloping the X-ray source and cylindrical members and having a frame opening in one wall thereof aligned with the beam of X-rays and slots in the two cylindrical members, the formed aperture sweeping across the frame opening in one direction rapidly as it sweeps more slowly across the frame opening substantially normal to said one direction.

5. An X-ray apparatus as claimed in claim 3 wherein each of said cylindrical members comprises a first cylinder of X-ray shielding material having a plurality of slots therein, a second cylinder of X-ray shielding material having a plurality of slots therein, the second cylinder being fixedly secured within the first cylinder with the slots in alignment and a plurality of pairs of slugs of X-ray shielding material sandwiched between the two cylinders, the slugs being so positioned that each pair forms a slot therebetween in alignment with the slots in the two cylinders, the spacing between the slugs in each pair determining the width of the slot therebetween and thus ultimately determining the size of the X-ray aperture through the cylindrical members.

6. An X-ray system comprising an X-ray shielding member having a frame opening therein, a first cylindrical member of X-ray shielding material having a plurality of slots running longitudinally therein and equally spaced around the cylinder, a second cylindrical member of X-ray

shielding material having a plurality of slots therein running in a direction diagonal with respect to the longitudinal direction and equally spaced around the second cylinder, means for rotatably mounting said cylinders for rotation about a common longitudinal axis with their slots and said frame opening in alignment, one of said members being positioned within the other in axial alignment, a source of X-rays within the cylindrical members adapted to direct a beam of X-rays at the slots in the cylindrical members and said frame opening, driving means for rotating said cylindrical members about said common axis so that the slots in each cylindrical member pass said frame opening, one of said cylinders rotating at a faster rate than the other whereby the slots in said one cylinder rapidly pass the slots in said other cylinder thereby forming a small aperture for an X-ray beam through the cylindrical members which sweeps across the frame opening in one direction a plurality of times to produce lines as it simultaneously sweeps more slowly across the frame opening in a direction normal to said first direction to produce frames, an X-ray detector aligned with said beam for producing a signal voltage proportional to the strength of the X-rays striking the detector, means for coupling said detector to a cathode ray tube for controlling the intensity of the cathode ray beam in response to the signal voltage, and synchronizing means coupling the horizontal and vertical sweep plates of said cathode ray tube to said cylindrical members operative to sweep the cathode ray beam in one direction to produce lines and in a direction perpendicular to said one direction to produce frames in synchronism with the X-ray beam.

7. An X-ray system as claimed in claim 6 wherein said detector comprises material which conducts electrical energy in accordance with the intensity of the X-rays striking the material, a source of electrical energy coupled to the material such that the electrical energy output from the material is proportional to the intensity of the X-rays, and means for amplifying said electrical energy output before transmittal to said cathode ray tube.



8. An X-ray system as claimed in claim 6 wherein said synchronizing means comprises a photo-electric system associated with each cylindrical member, each photo-electric system including a light source and a photosensitive device, each cylindrical member having a plurality of apertures therein corresponding to the slots therein, said apertures being arranged to pass between the associated light source and photosensitive device to thereby produce a plurality of energy output pulses from said photosensitive device for use in triggering the line and frame sweeping of said cathode ray tube.


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