

[54] **THREE DIMENSIONAL AND/OR TIME
SEQUENCE X-RAY APPARATUS**

[72] Inventor: John Jacques Fouquart, Northport, N.Y.
[73] Assignee: Photosystems Corporation, Hauppauge,
N.Y.
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[52] U.S. Cl. 250/61, 250/55, 250/61.5
[51] Int. Cl. G01n 23/04, H01j 37/22
[58] Field of Search 250/55, 60, 61, 61.5

[56] **References Cited**

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Primary Examiner—William F. Lindquist
Attorney—Posnack, Roberts and Cohen

[57] **ABSTRACT**

X-ray apparatus including a cradle or platform unit, X-ray recording unit and an X-ray source. The cradle unit supports a patient and provides for rotating the same about a horizontal axis through an arc either clockwise or counterclockwise. The cradle is driven by a motor. The recording unit includes a cassette and a cassette support in which is located part of a control unit. The cassette includes a part which selectively operates switches controlling, at least partially, the taking of three-dimensional or action sequence X-rays. These switches select panels on a rotatable drum which are constituted by two groups respectively controlling operation of the cradle motor and the duration of the X-ray exposure. The aforesaid drum is driven by a motor through the intermediary of a slip clutch with which is associated a cam having the purpose of causing relative movement between a film and grid in the recording unit to provide for recording a sequence of exposures on adjacent strips of the film. The drum is either automatically operated or alternatively is stepped through a sequence of operations under manual or operator control.

12 Claims, 17 Drawing Figures

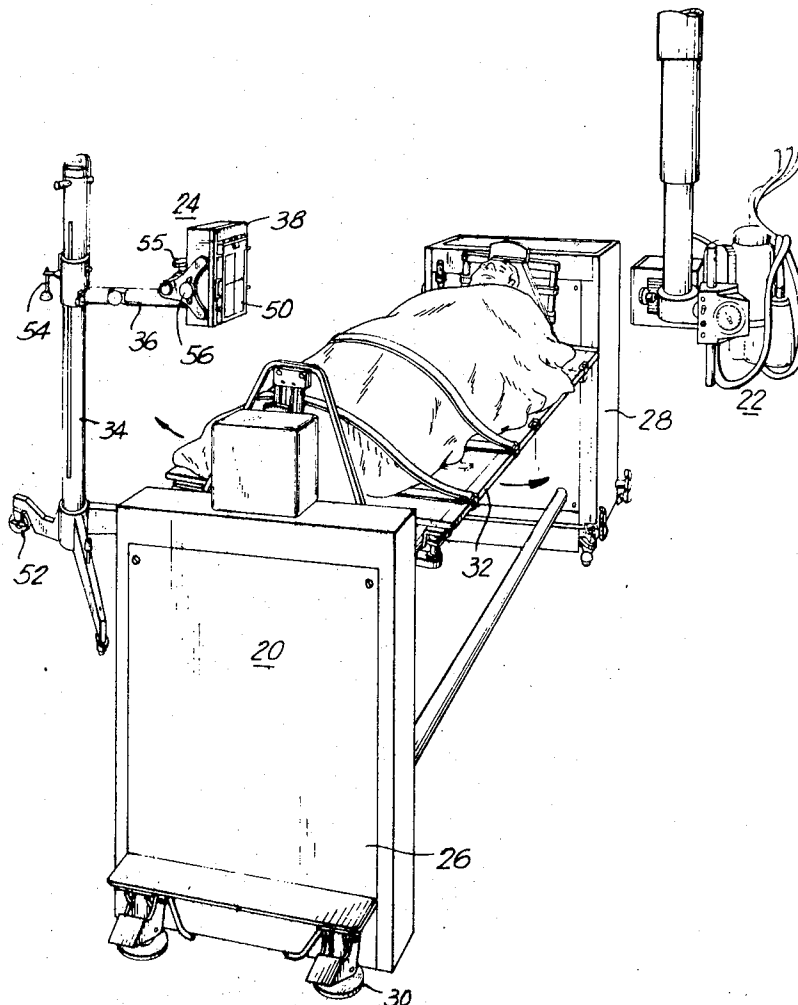
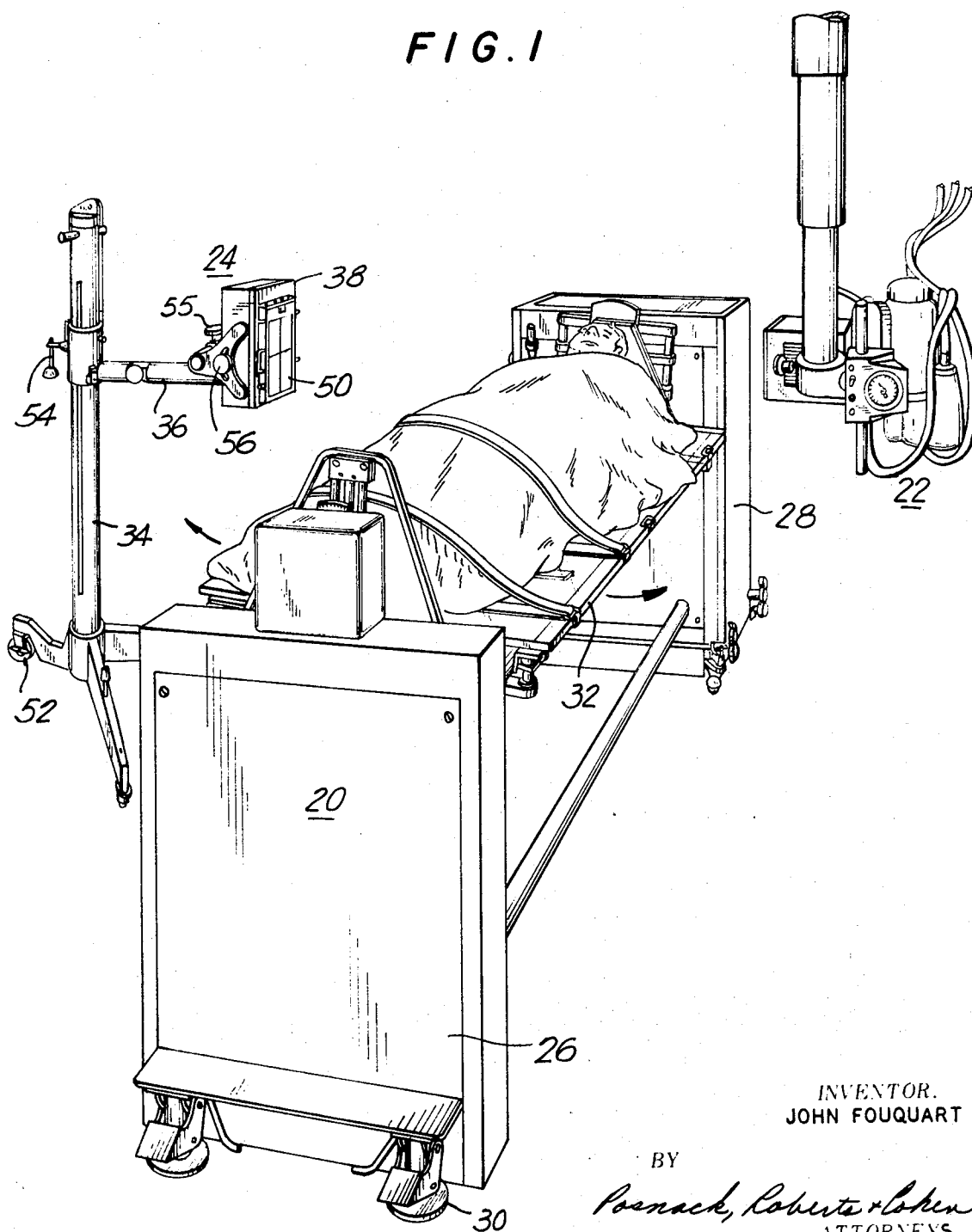


FIG. 1



INVENTOR.
JOHN FOUQUART

BY
Posnack, Roberts & Cohen
ATTORNEYS

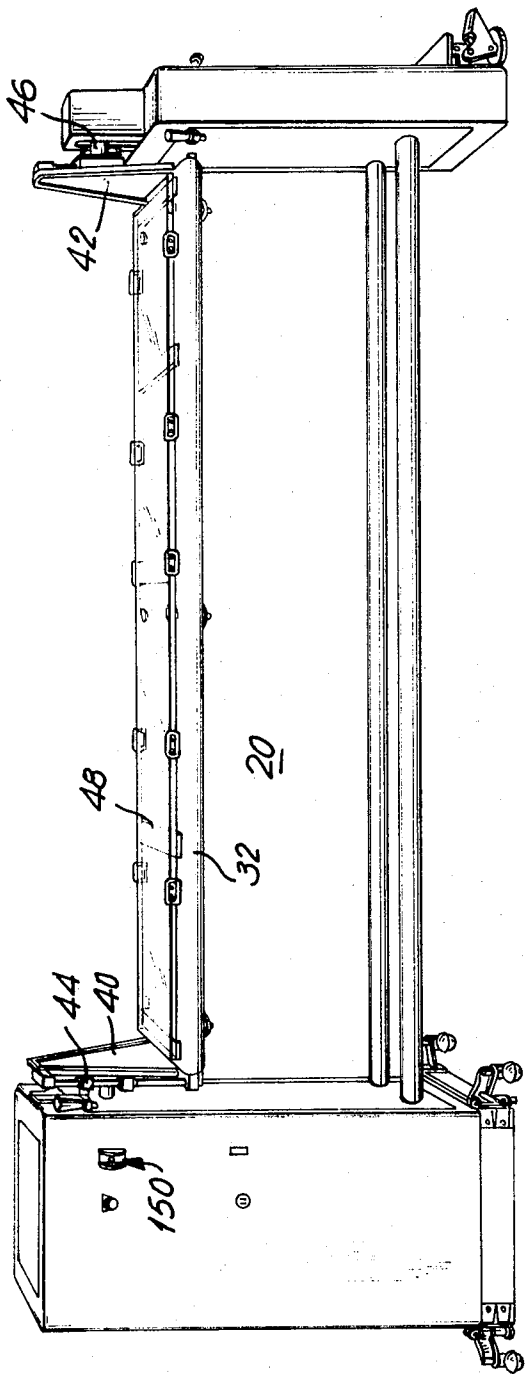


FIG. 2

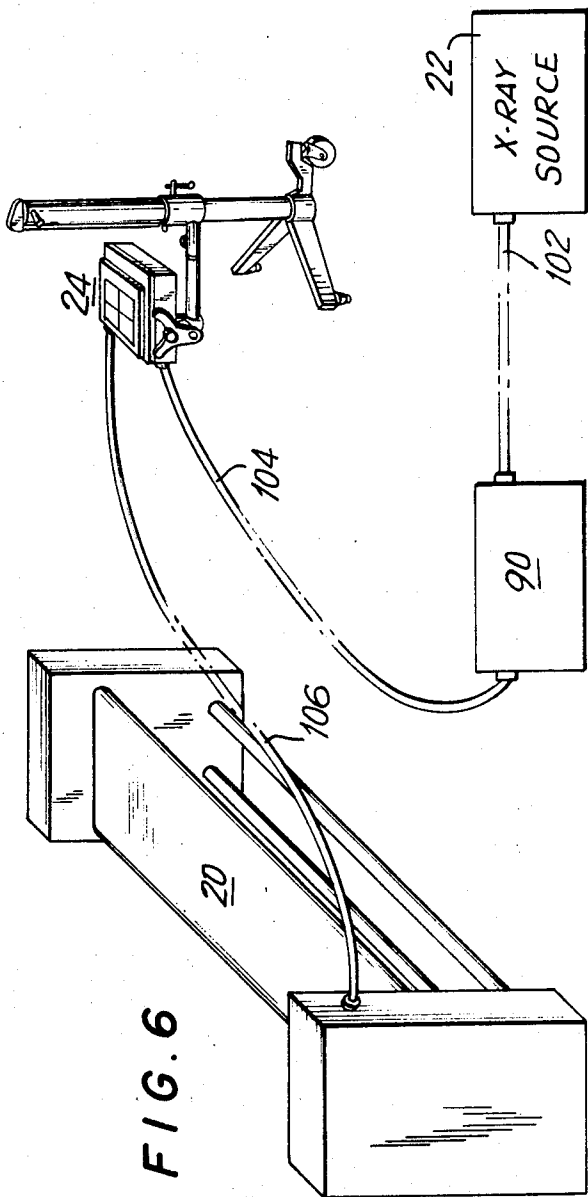
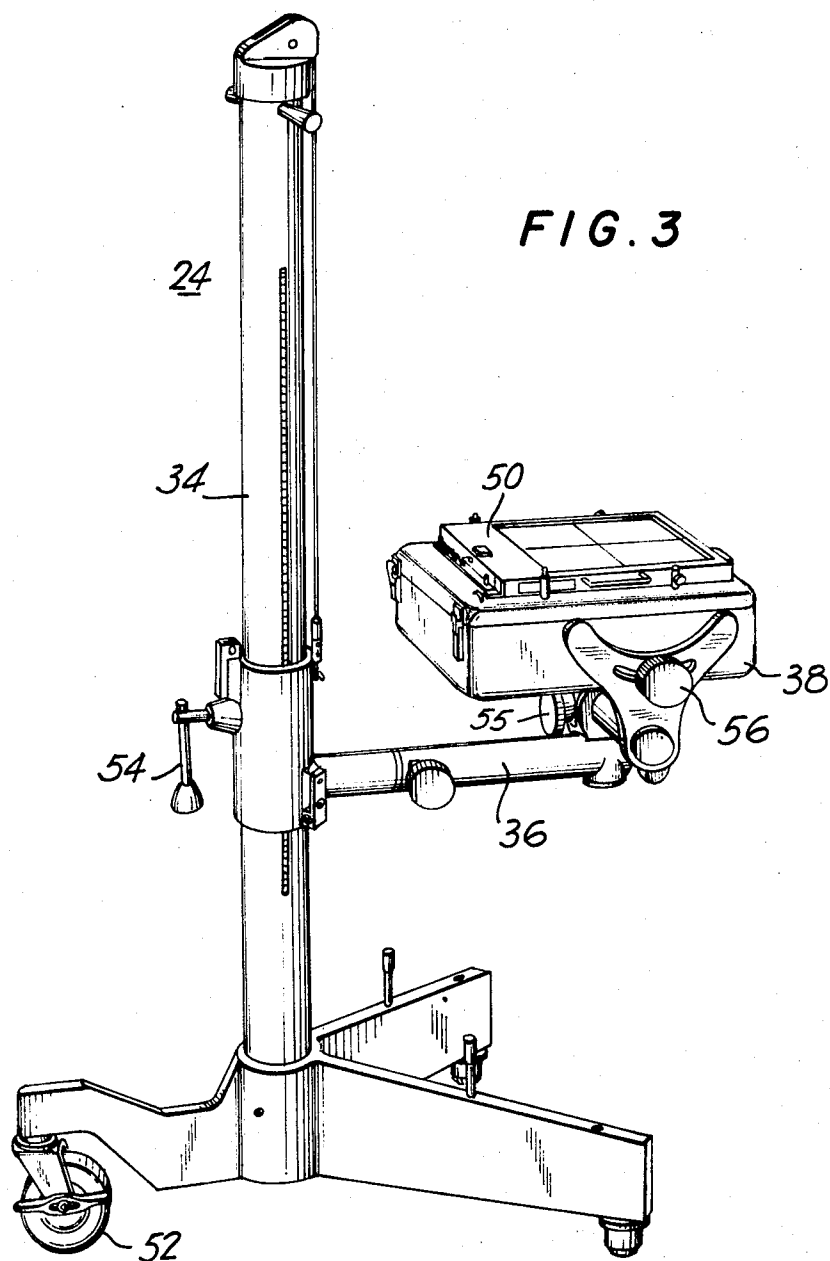


FIG. 6

INVENTOR.
JOHN FOUQUART

BY
Posnach, Roberts & Cohen
ATTORNEYS



INVENTOR.
JOHN FOUQUART

BY

Posnack, Roberts & Cohen
ATTORNEYS

FIG. 4

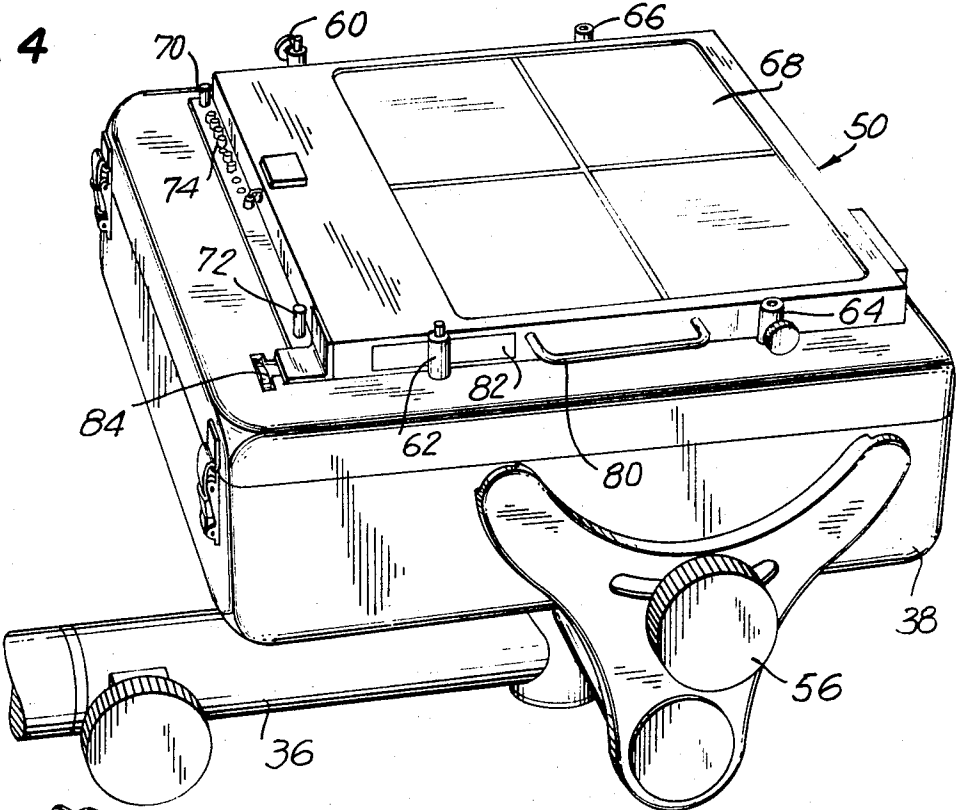
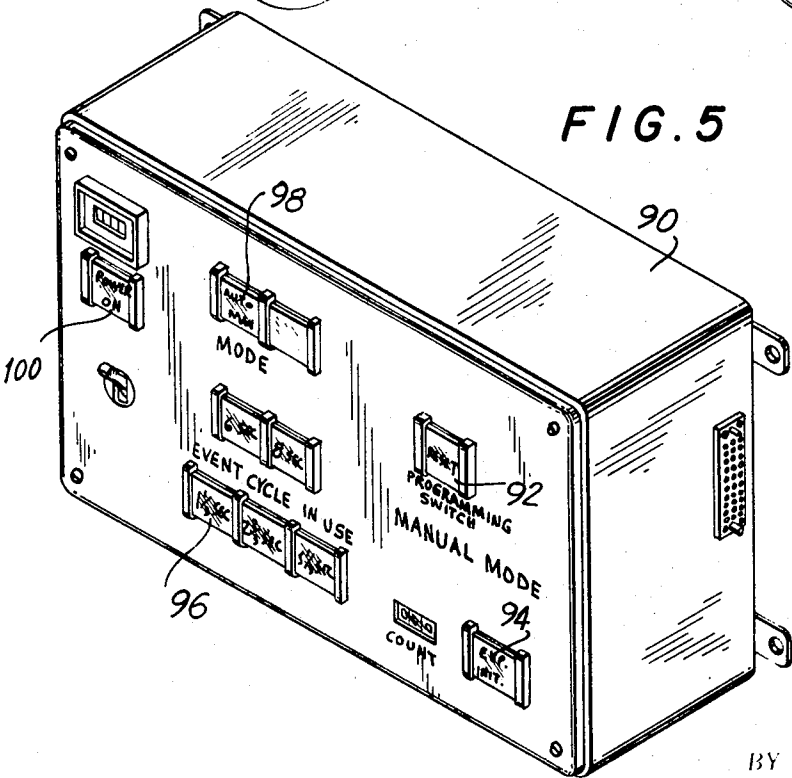


FIG. 5



INVENTOR.
JOHN FOUQUART

BY
Posnack, Roberts & Cohen
ATTORNEYS

FIG. 7

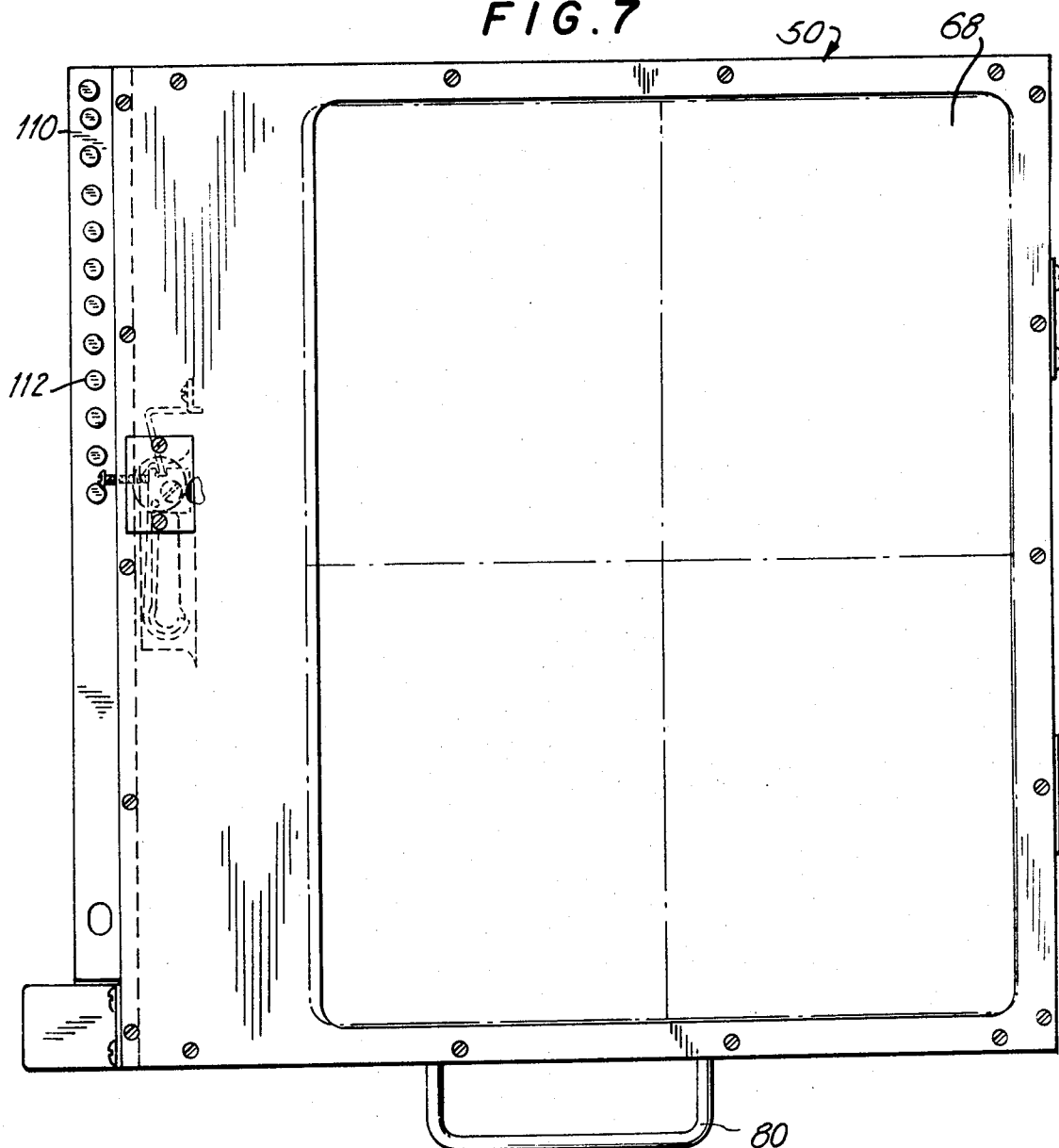
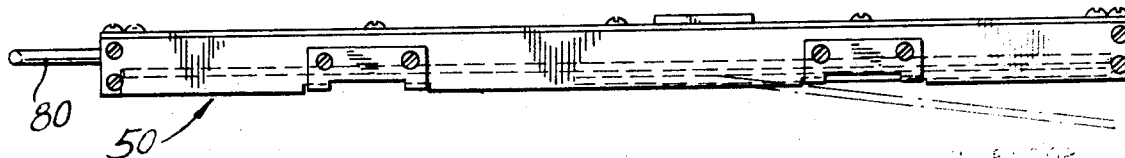


FIG. 8



INVENTOR
JOHN FOUQUART

BY

Posnack, Roberts & Cohen
ATTORNEYS

FIG. 9

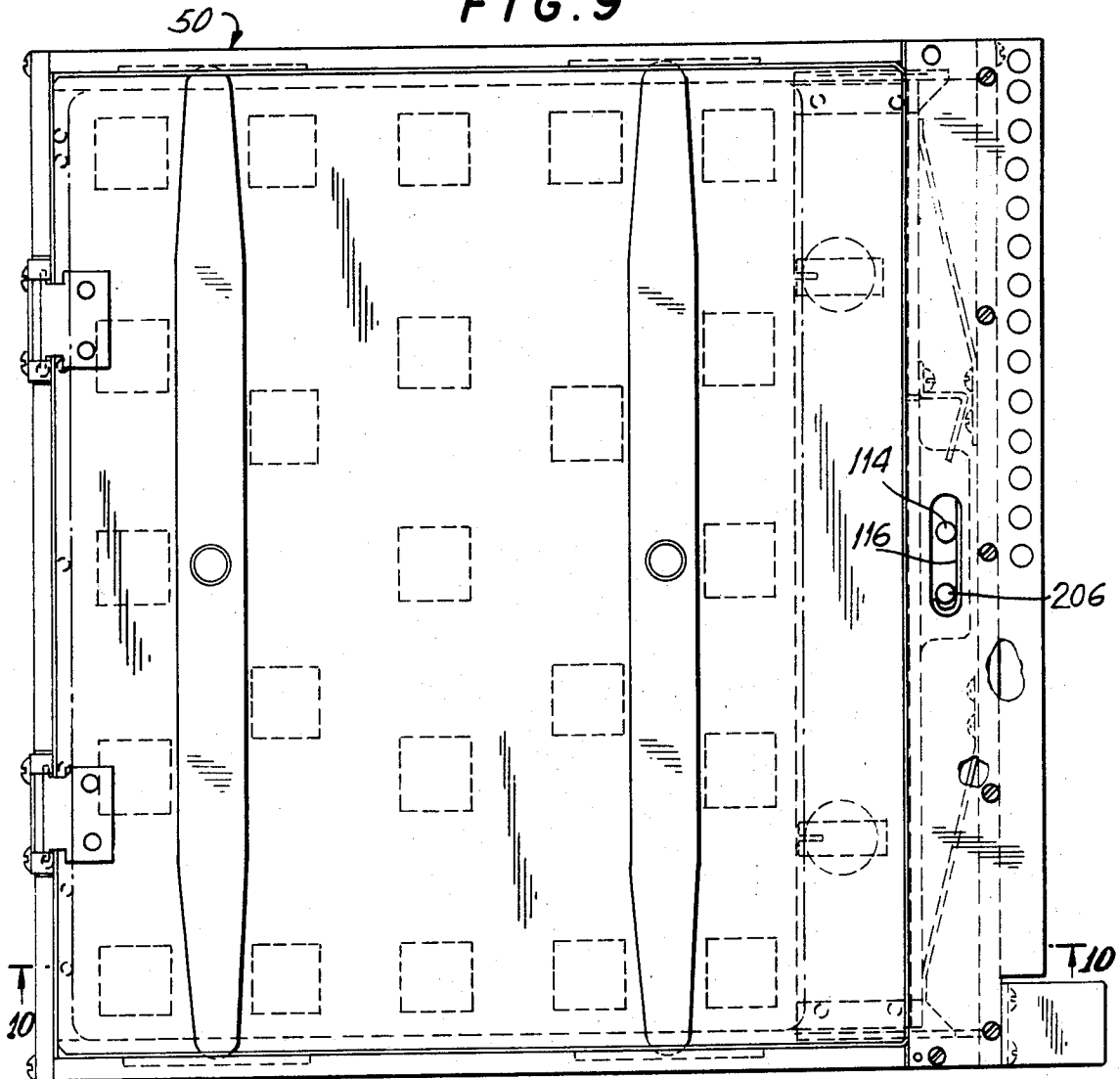
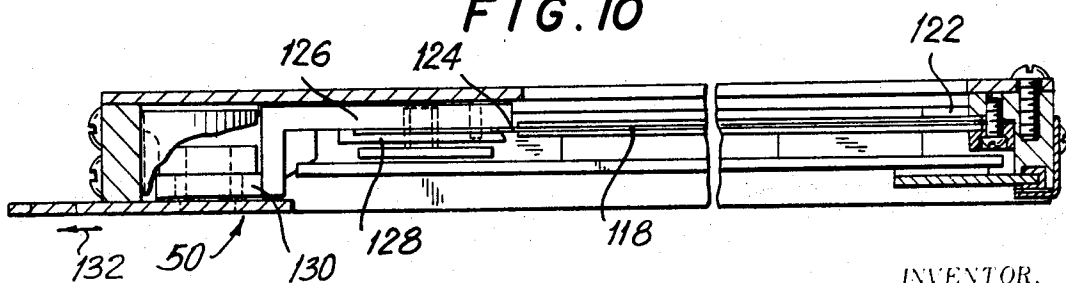


FIG. 10



INVENTOR.
JOHN FOUQUART

BY

Posnack, Roberts & Cohen
ATTORNEYS

FIG. 11

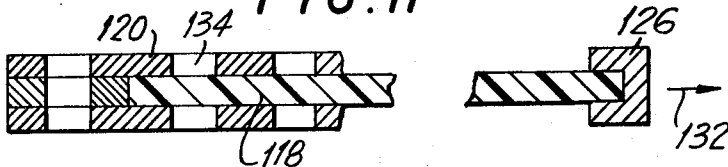


FIG. 12

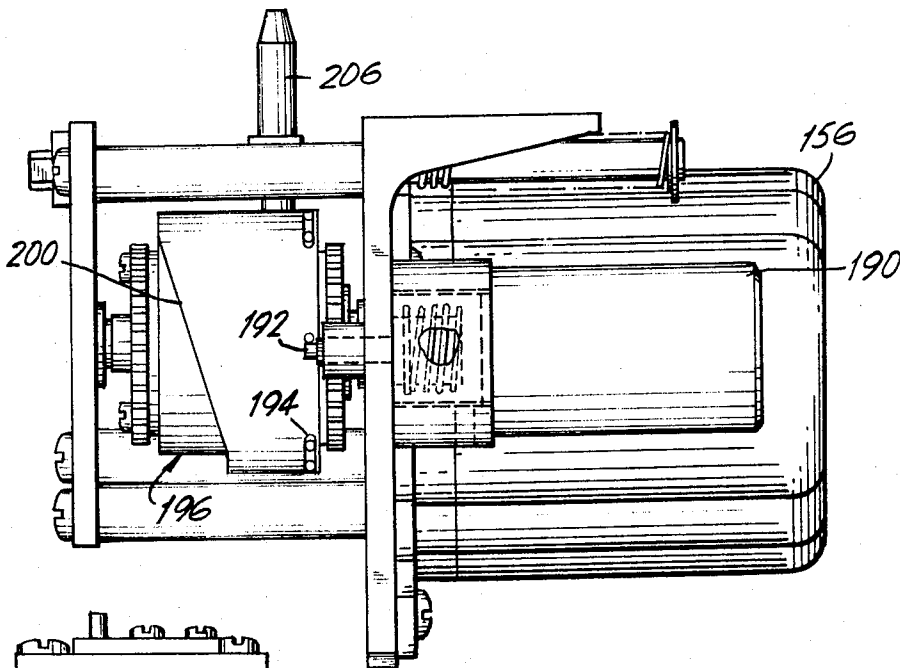
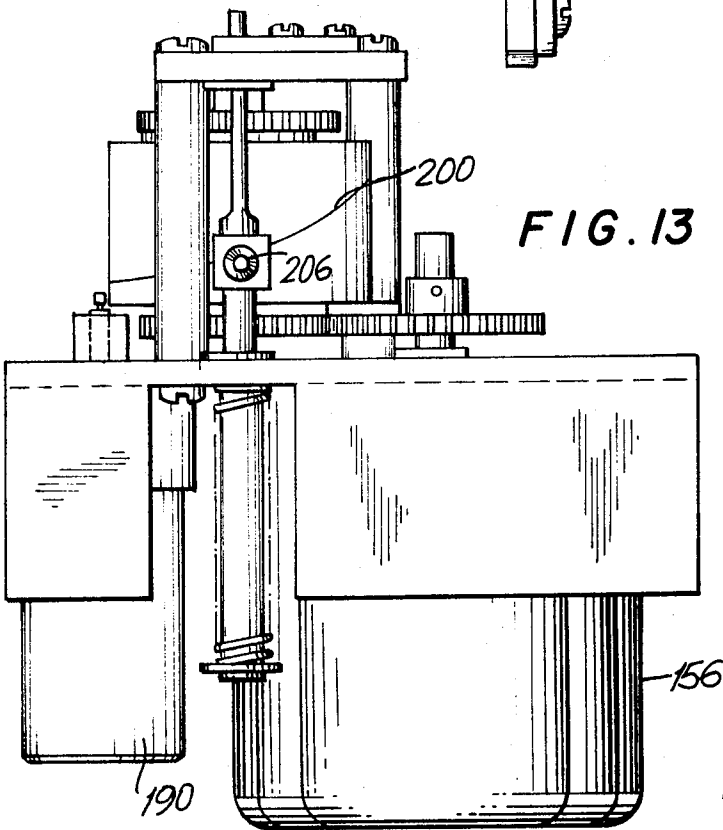


FIG. 13



INVENTOR.
JOHN FOUQUART

BY

Posnack, Roberts & Cohen
ATTORNEYS

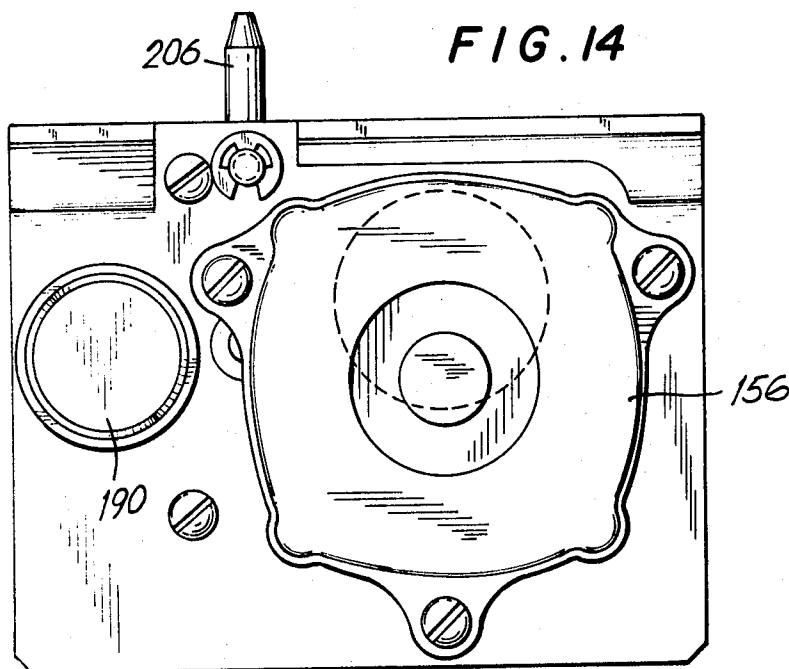


FIG. 15

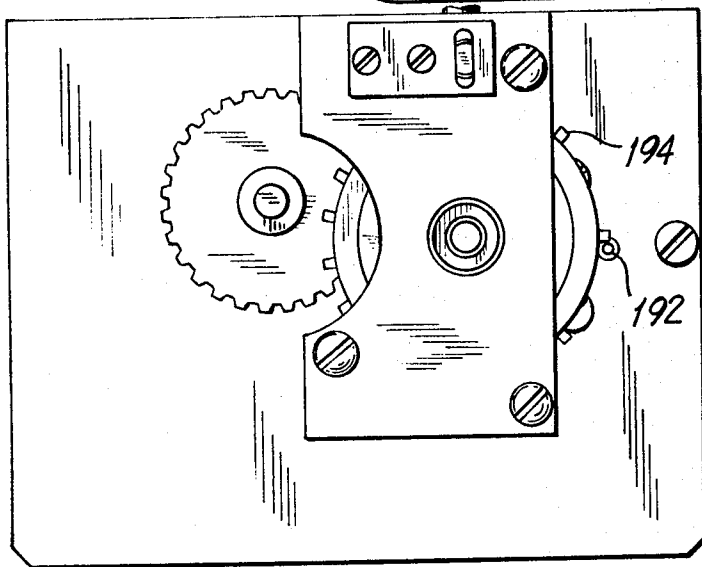
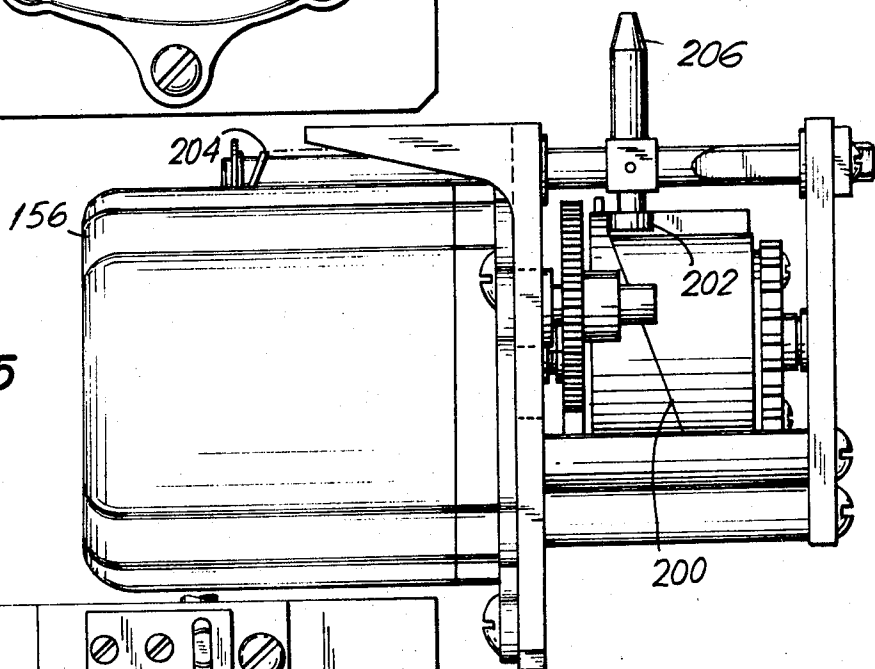


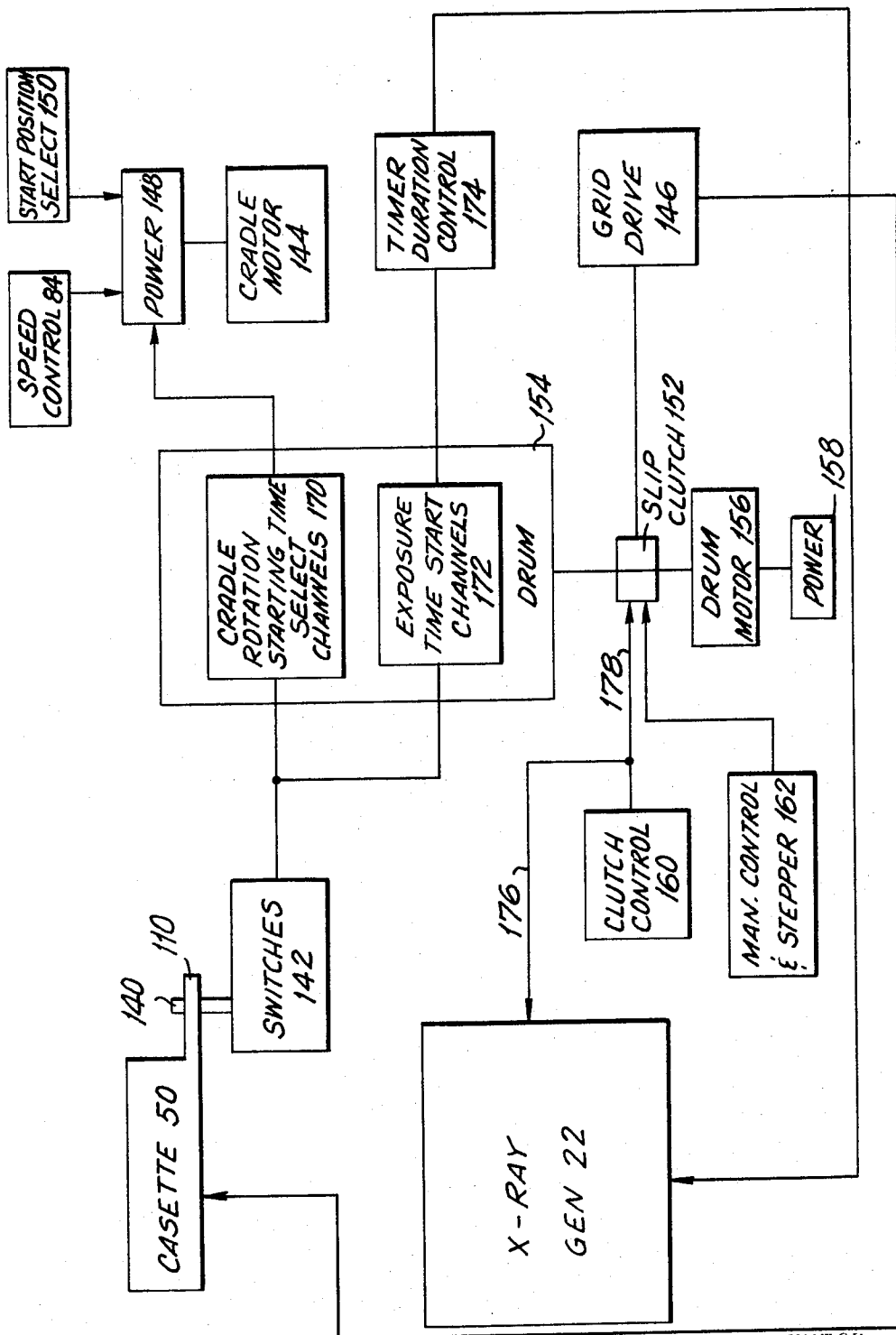
FIG. 16

INVENTOR.
JOHN FOUQUART

BY

Pomack, Roberts & Cohen
ATTORNEYS

FIG. 17



INVENTOR.
JOHN FOUQUART

BY

Pasnick, Roberts & Cohen
ATTORNEYS

THREE DIMENSIONAL AND/OR TIME SEQUENCE X-RAY APPARATUS

BACKGROUND

1. Field of Invention

This invention relates to X-ray apparatus and more particularly to apparatus adapted for the production of three-dimensional X-rays, action sequence X-rays and the like.

Prior Art

Apparatus is known for the production of stereoscopic X-ray images such as, for example, the apparatus disclosed in British Pat. No. 449,213 granted to Etienne Piot. X-ray stereo-shift mechanisms are also known as shown, for example, in U.S. Pat. No. 2,518,884 (R. L. Guentner et al.). Techniques for making stereoscopic X-ray pictures also appear in U.S. Pat. No. 1,447,399 (L.W. Pease). U.S. Pat. No. 2,208,215 (P. Gonzales Rincones) discloses techniques relating to stereoscopic fluoroscopy.

Other patents relating to stereoscopic X-ray photographs and the like include U.S. Pat. Nos. 2,046,543, 1,992,894, Reissue No. 21,964, 2,521,154, 2,468,963, 3,244,878, 3,004,159, 2,712,608 and various others. The above noted devices are, however, limited in use because they fail to provide convenient techniques which facilitate the taking of three-dimensional X-rays or action sequence X-rays or the like and because they require highly developed technical skills for purposes of operation and in order to obtain acceptable results.

SUMMARY OF INVENTION

It is an object of the invention to provide improved apparatus for the taking of three-dimensional X-rays, action sequence X-rays and the like.

Another object of the invention is to provide improved X-ray apparatus of the above noted type adapted for providing extreme convenience in the processing of patients.

Still another object of the invention is to provide improved X-ray apparatus of the above noted type which is selectively automatic or operator controlled and in which the various parameters essential to the provision of acceptable X-rays can be automatically established.

In achieving the above and other of the objects of the invention, there is provided an X-ray apparatus comprising generally a source of X-rays, recording means to record a radiographic image, a platform or cradle located between the source and recording means to support a subject or patient therebetween and displacement means to enable the platform or cradle to be rotated about an axis of rotation during exposure of the subject to X-rays.

As will be seen hereinafter, the axis of rotation referred to above is preferably a horizontal axis and the patient or object is suspended at a controllable distance relative thereto, the patient or subject being selectively rotated clockwise or counterclockwise depending upon the type of views desired (e.g., from the tube side or the film side).

In further accordance with the invention, control means are provided which are coupled to the source and recording means to enable a sequence of exposures to be made during movement of the platform.

According to a feature of the invention, the recording means include a cassette detachably supported upon a support in which is located control circuitry. The cassette is provided with a portion suitably cooperating with control switch operators such that when the cassette is placed into position various operating parameters of the apparatus are conveniently established.

In accordance with another feature of the invention, the cassette is provided with a grid and an associated X-ray film between which relative displacement is possible. This relative displacement is provided in convenient manner, as will hereinafter be explained.

Further control means provided in accordance with the invention include a drum including two groups of channels

respectively intended to control cradle rotation starting time and the commencement of exposure time. The control switches referred to hereinabove operated by the cassette select specific of these channels which in turn control circuits related to the cradle motor or operation of the X-ray source or generator. The drum is driven by a drum motor through the intermediary of a slip clutch with which is associated a cam and cam follower capable of functioning to displace the film and grid relatively as referred to hereinabove.

The slip clutch is provided with a plurality of radially extended pins or the like, the interception of which by a solenoid controlled trip independently blocks rotation of the aforementioned drum thereby bringing the grid and film to relatively fixed positions at which point exposures can be made.

The above and other further features of the invention will be found in the following detailed description of a preferred embodiment as illustrated in the accompanying drawing.

DRAWING

FIG. 1 is a perspective view of a cradle unit, a recording unit and an X-ray source provided in accordance with the invention, there being illustrated a patient located in the cradle unit;

FIG. 2 is a side view of the cradle unit of FIG. 1;

FIG. 3 is a side view of the recording unit of FIG. 1;

FIG. 4 is an enlarged perspective view of the cassette and cassette support of the unit in FIG. 3;

FIG. 5 illustrates the control panel;

FIG. 6 diagrammatically illustrates electrical connections between the various units of the invention;

FIG. 7 is a top plan view of the cassette referred to above;

FIG. 8 is a side view of the cassette;

FIG. 9 is a bottom view of the cassette;

FIG. 10 is a side sectional view of the cassette illustrating the film therein;

FIG. 11 diagrammatically illustrates the film and grid of the cassette, and indicates how the film is displaced relative to the grid;

FIG. 12 is a side view of a slip clutch unit by means of which cradle rotation starting time, exposure starting time and relative displacement between the grid and film is controlled;

FIG. 13 is a side view of the unit of FIG. 12;

FIG. 14 is an end view of the unit of FIG. 12;

FIG. 15 is another side view of the unit of FIG. 12;

FIG. 16 is another end view of the unit of unit of FIG. 12; and

FIG. 17 is a block diagram of the circuitry through which the results of the invention are achieved and by means of which the aforesaid units are interconnected.

DETAILED DESCRIPTION

The X-ray apparatus illustrated in FIG. 1 comprises a cradle or platform unit 20, a source 22 of X-rays, and a recording unit 24.

The source 22 may be any conventional X-ray source adapted for connection to the system to be described hereinafter.

Cradle or platform unit 20 consists of end sections 26 and 28 mounted on feet 30 and including cradle or platform 32 rotatable in clockwise or counterclockwise direction by means of controls to be indicated hereinafter. One of the end units 26 or 28 houses part of the control circuitry of the invention and the other houses a motor suitable for rotating the platform 32 about a horizontal axis.

Unit 24 includes a stand 34 from which projects an arm 36 supporting the cassette support 38.

It will be readily appreciated from what has been stated hereinabove that the units are comparatively mobile and relatively adjustable with respect to each other so that it is quite convenient to X-ray any part of a patient or subject located on platform 32.

As illustrated in FIG. 12, the platform unit 20 provides that the platform 32 be suspended by suspensions 40 and 42 with

the height of platform 32 being rendered adjustable by adjustment control 44. This means that the radius of rotation of platform 32 relative to the horizontal axis defined by pivots 46 is adjustable. The platform 32 is moreover provided with a plurality of straps 48 by means of which a patient or subject can be strapped into position.

FIG. 3 illustrates the position 34 referred to hereinabove with arm 36 supporting cassette support 38. On top of the cassette support 38 appears the detachable cassette 50, the details of which will appear hereinafter. Mobility of unit 24 is assured by the provision of wheels 52, the height of arm 36 being adjustable under control of lock 54. Cassette support 38 is pivotable into vertical position under the control of lock 55.

FIG. 4 illustrates the cassette and the cassette support with greater particularity and shows mount elements 60, 62, 64 and 66, as well as window 68, through which the X-rays penetrate to record a radiographic image on the film in the cassette. Elements 70 and 72 are locating pins. Pins 74 include the actuators for interlock switches as well as other actuators 74, reference to which will be made hereinafter.

The cassette 50 is provided with a handle 80 to facilitate carrying of the same, the parameters established by cassette 50 being listed on any plate 82. A control 84 is provided on the cassette support, this control being a control for the speed of the cradle motor referred to hereinabove.

The control channel 90 illustrated in FIG. 5 provides for automatic and manual mode. A reset button 92 provides for resetting the programming unit under manual mode, and indicator 94 provides for indicating the initiating of an exposure. Buttons 96 indicate the length of cycles occurring during the operation such as, for example, the stepping of the film from one position to the next relative to the associated grid and the effecting of an exposure. Control 98 provides for selecting automatic or manual operation and for indicating a clockwise or counterclockwise rotation of the platform or cradle as selected by the operator. Button 100 provides simply for the connecting in of a power source.

FIG. 6 diagrammatically illustrates platform unit 20, recording unit 24, X-ray source 22 and control channel 90. Cable 102 connects the control channel to X-ray source 22. Cable 104 connects channel 90 to recording unit 24. Cable 106 connects record unit 24 to cradle or platform unit 20.

FIGS. 7-10 illustrate the details of the cassette 50 referred to hereinabove. The cassette 50 is made of a structurally strong frame provided as noted above with handle 80 and having a window 68 through which X-rays penetrate for purposes of exposing the film within the cassette. The frame has a lip 110 through which are perforated a coded arrangement of holes occupying some of the positions indicated at 112. From what has been stated hereinabove, it will appear that those switch actuators coinciding with holes in lip 110 will not be depressed when the cassette 50 is moved into position, whereas the remaining actuators will be depressed to actuate the corresponding switches (not shown).

On the bottom of the cassette is provided a slot 114 within which is located the slanted cam surface 116. When the cassette 50 is placed into position on the cassette support a rod extending from the cassette support enters into the slot 114 and displacement of this rod along the length of the slot 114 will operate to engage the cam surface 116 to serve a purpose which will be indicated below.

Referring also to FIG. 10, it is seen that a film 118 suited for X-ray exposure is accommodated within a grid envelope such as that indicated at 120 in FIG. 11. The grid envelope is fixed in position by clamp 122, whereas the end 124 of the film is clamped against a holder 126 by clamping member 128.

Element 126 is attached to member 130 in which is formed cam surface 116. It thus results that movement of the aforesaid rod in slot 114 will displace element 126 in the direction indicated by arrow 132 whereupon film 118 will be displaced in the same direction.

Clamp 126 is indicated diagrammatically in FIG. 11 along with arrow 132, it appearing therefrom that the film 118 may

be withdrawn from the envelope 120 under the control mechanism referred to above.

In accordance with known stereoscopic techniques and the like grid envelope 120 is provided with slots 134 by means of which selective strip-like exposures of film 118 are effected to provide in turn for three-dimensional or action sequence techniques, or the like. From a comparison of FIGS. 1, 3, 9 and 11, it can be noted that the grid slots (i.e., those portions which are permeable to the X-rays) are parallel to the axis of rotation of platform 32.

Before examining the details of FIGS. 12-16, reference is first made to the block diagram of FIG. 17, wherein appears the cassette 50 and the lip 110 thereof which selectively displaces switch actuators 140 in turn controlling switches 142 diagrammatically indicated.

Also appearing in FIG. 17 are the X-ray generator or source 22, cradle motor 144 and grid drive 146 (it should be noted that either the grid or the film may be displaced), which generally indicates the mechanism by which relative displacement is effected between the X-ray film and the grid envelope.

FIG. 17 illustrates a source 148 of power for cradle motor 144, speed control 84 (see also FIG. 4) and start position select 150.

The circuit moreover involves slip clutch 152, the details of which appear in FIGS. 12-16, drum 154, drum motor 156 and power source 158 therefor.

To control slip clutch 152 there are provided a clutch control 160 and manual control and stepper 162.

The drum 154 is a commercially available program controlled drum of well known type, the function of which is to control one or more circuits for selected periods of time dependent upon the speed of rotation of the drum. The drum may contain a plurality of channels as is well known, each of which is adapted to control the operation of an associated circuit. The drum 154 is provided with a first plurality of drum channels indicated at 170 and bearing the notation "cradle rotation starting time select channels." A second plurality of channels 172 is indicated, these bearing the notation "exposure time start channels." One channel of each of these groups is selected by switches 150 under the control of cassette 50 upon a locating of the latter on the cassette support. The selected channel of group 170 controls power source 148 and thereby the starting time of the rotation of the cradle driven by motor 144. Control 84 controls the speed of rotation of motor 144 and select control 150 provides for operator adjustment of the position of the cradle at the start of the operation.

The selected channel from group 172 operates through timer duration control 174 to initiate the generation of X-rays by generator 22 and the duration for which the exposure is to last.

As stated hereinabove, clutch control 160 is provided for slip clutch 152. This control is a well known two-step switch which operates through line 176 to prime X-ray generator 122 and thereby allow the same to come up to operating conditions before an attempt is made to effect an exposure and also operates via line 178 to connect drum 154 to motor 156. For automatic operation the drum will make one complete 360° circle and will effect all of the controls in the selected channels of groups 170 and 172. For manual control, the stepper 162 is employed and the drum 154 will step from one angularly displaced position to the next as enabled to do so by operator control.

Referring now to FIGS. 12-16, there is seen a solenoid 190. This solenoid controls the position of pin 192 which when it protrudes, assumes a position of interference with radially protruding pins 194. For automatic operation, solenoid 190 is operated and pin 192 is withdrawn until the mechanism to be described hereinafter exclusive of the slip clutch, makes a complete circle. For manual operation, pin 192 is only temporarily withdrawn to permit one pin 194 to escape past pin 192 which then is re-extended to occupy a position of interference to intercept the next sequential radial pin 194.

The slip clutch itself is indicated at 196. Its function is to couple the input shaft connected to motor 156 to the output shaft connected to drum 154. Encircling this clutch is a cam 200 against which is urged a cam follower 202 under the pressure of spring 204. As the clutch and therefore drum 154 are rotated, the cam follower moves upwardly along cam surface 200 carrying therealong rod 206. This rod is the rod which has been referred to hereinabove as extending into slot 114 (FIG. 9) and thereby has the function of displacing the film relative to the grid envelope in which it is housed.

In operation, a patient is placed on the cradle or platform 32 and is strapped into position. The start position select is operated by the operator who may select clockwise or counterclockwise rotation of the platform. At this time the operator may also select the radius of rotation of the platform relative to the horizontal axis about which rotation is to take place.

This operation presupposes the loading of a cassette 50 into its appropriate position on support 38. Automatic or manual modes of operation may be selected by use of control panel 90.

The conventional X-ray generator switch 160 is operated. This is effective in slip clutch 152 to withdraw pin 192 and permit rotation of drum 154.

On drum 154 appropriate selection has been made of channels 170 and 172 through operation of switches 142. The speed of cradle motor 144 is selected by operation of speed control 84 (FIGS. 4 and 17).

For manual mode, drum 154 commences rotation. Power from source 148 is supplied to motor 144 under the control of one of the channels 170. Timer duration control 174 is actuated under the control of one of channels 172. Thus, the cradle is rotated and an exposure initiated. This exposure is, however, delayed by appropriate design of drum 154 so that the cradle can reach a position of rest so that the exposure can be made while the patient is also stationary.

Grid drive 146, which is actually rod 206 of FIGS. 12-16, is moved under the control of clutch 152 so that appropriate selection is made of a multitude of parallel strips on film 118 for the recording of a stereoptic X-ray image or action sequence image according to known techniques.

From what has been stated above, it will be seen that X-ray apparatus of the invention includes a source of X-rays, recording means to record a radiographic image, a platform or cradle between the source and recording means and displacement means to enable the platform to rotate about a horizontal axis of rotation during a period in which the subject is exposed to X-rays. It has been shown that the cradle or platform is displaced through an arc clockwise or counterclockwise selectively. It has also been shown that the radius of the platform relative to its axis of rotation is adjustable. A feature of the invention as discussed hereinabove is the use of a cassette support and a replaceable cassette which serves to interact with and program a control which is coupled to the source and recording means to enable a sequence of exposures to be made during displacement of the cradle or platform.

For automatic mode, a cassette is placed on support 38. The choice of a particular cassette is made by referring to plate 82. After the cassette is in position, the choice may be confirmed by pressing corresponding button 96. Button 98 is pressed for automatic mode. The trigger for the X-ray source is then depressed and the film drive starts. Cradle rotation starts, for

example, about one second later. The X-ray tube fires in a continuous or pulsed mode depending on the cassette employed. Thereafter, the tube stops firing and the cradle stops. The film drive stops and repositions itself at the starting position.

What is claimed is:

1. X-ray apparatus comprising a source of X-rays, recording means to record a radiographic image, a platform between said source and said recording means to support a subject therebetween displacement means to enable said platform to be displaced about an axis of rotation and control means coupled to said source and recording means to enable a sequence of exposures to be made during movement of said platform about said axis, said recording means including a cassette support and a replaceable cassette including means to interact with and program said control means; said cassette including a grid and X-ray responsive film and means to displace the grid and film relative to each other, said control means including means to synchronize the displacement of the grid and film with rotation of the platform, said grid having X-ray permeable slots which are parallel to said axis of rotation.

2. Apparatus as claimed in claim 1, wherein said displacement means includes means to enable said platform to be rotated through an arc selectively towards or away from said source.

3. Apparatus as claimed in claim 1 comprising means to adjust the radius between said platform and axis.

4. Apparatus as claimed in claim 1, wherein said platform is an elongated bed-like structure including straps to hold a patient thereon.

5. Apparatus as claimed in claim 1 wherein said support is a mobile stand.

6. Apparatus as claimed in claim 1 comprising means for adjusting the positions of the recording means and source relative to the platform and relative to each other.

7. Apparatus as claimed in claim 1, wherein control means includes means to operate said source periodically and means to synchronize the relative movement of the grid and film and the operation of said source.

8. Apparatus as claimed in claim 1 wherein said control means includes a rotatable drum including a first plurality of channels to control said displacement means to select platform rotation starting time and a second plurality of channels to control said source with respect to exposure time, and switch means to select said channels, said cassette including means to control said switch means.

9. Apparatus as claimed in claim 8 comprising a power source for rotating said drum, a slip clutch connecting said power source to said drum, a cam and cam follower connected to said slip clutch, said record means including means operated by the cam follower to effect relative displacement between the film and grid.

10. Apparatus as claimed in claim 9, wherein the latter said means includes a pin and groove arrangement coupled to the film or grid to displace the same.

11. Apparatus as claimed in claim 9 comprising a plurality of radially extending pins coupled to said clutch and a solenoid including a pin displaceable into a position of interference with the laterally extending pins to decouple the power source from the drum.

12. Apparatus as claimed in claim 1 wherein the grid is located on both sides of said film.

* * * * *