

April 22, 1969

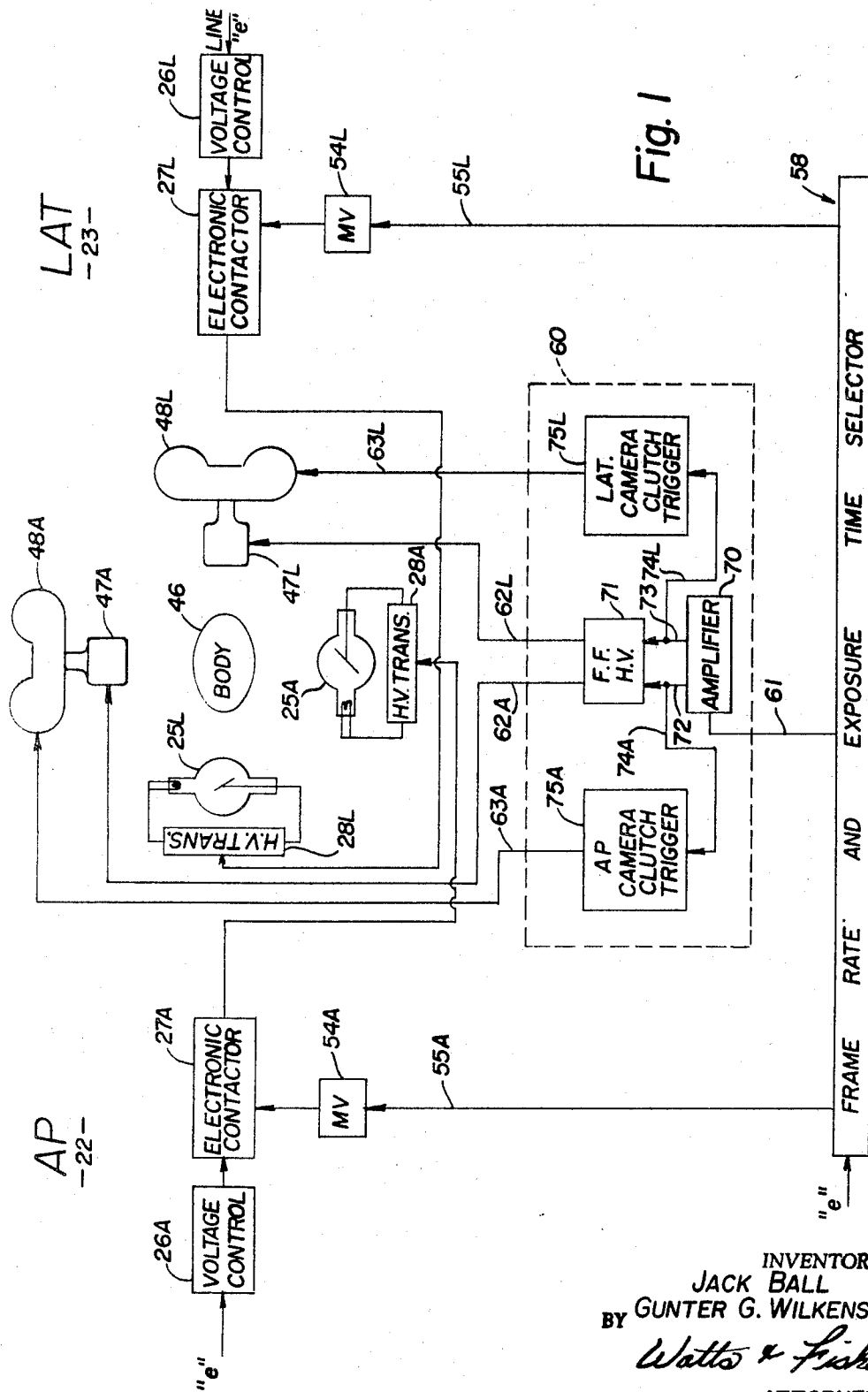
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3,440,422

BIPLANE X-RAY IMAGE SYSTEM

Filed June 24, 1965

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BIPLANE X-RAY IMAGE SYSTEM

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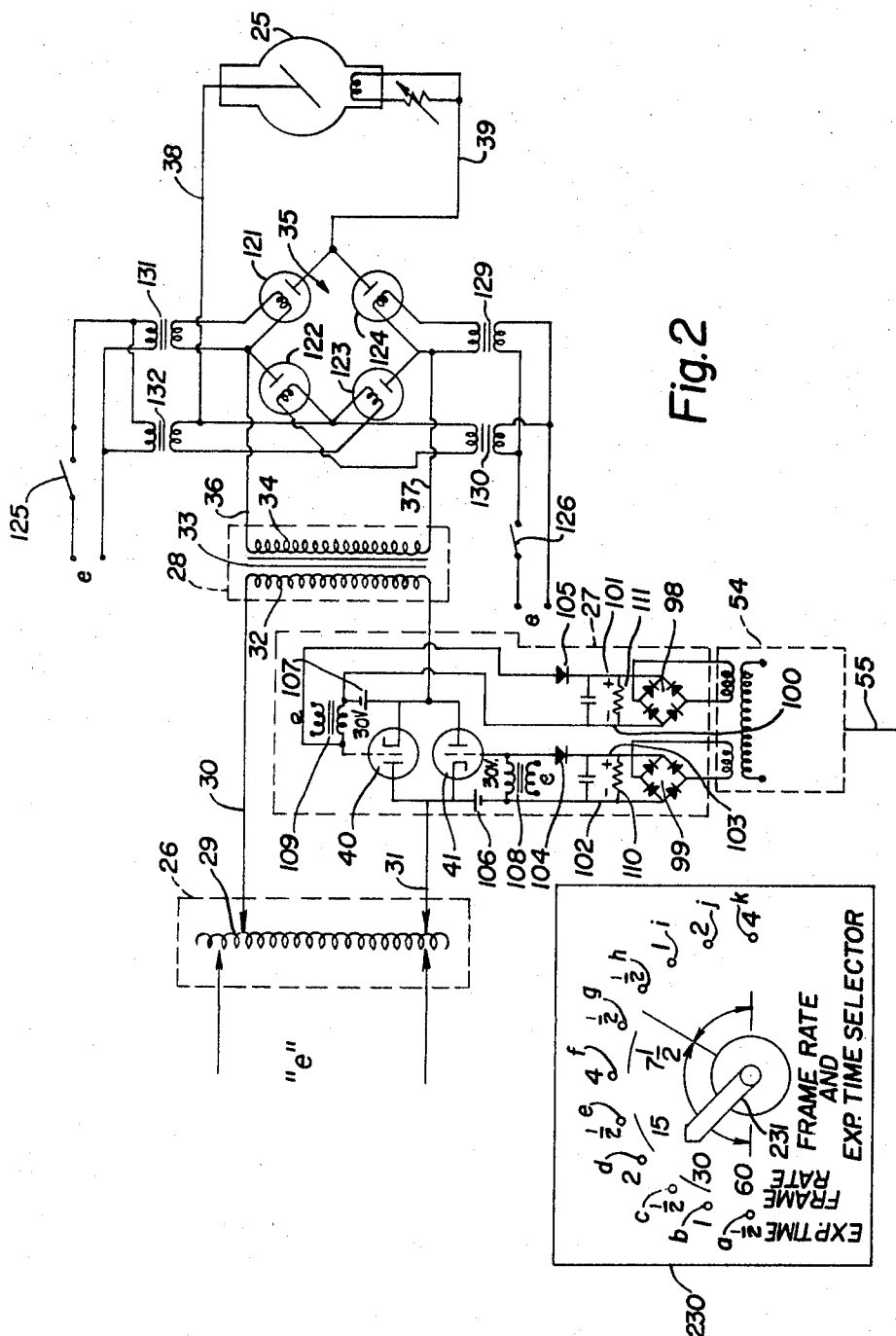


Fig. 4

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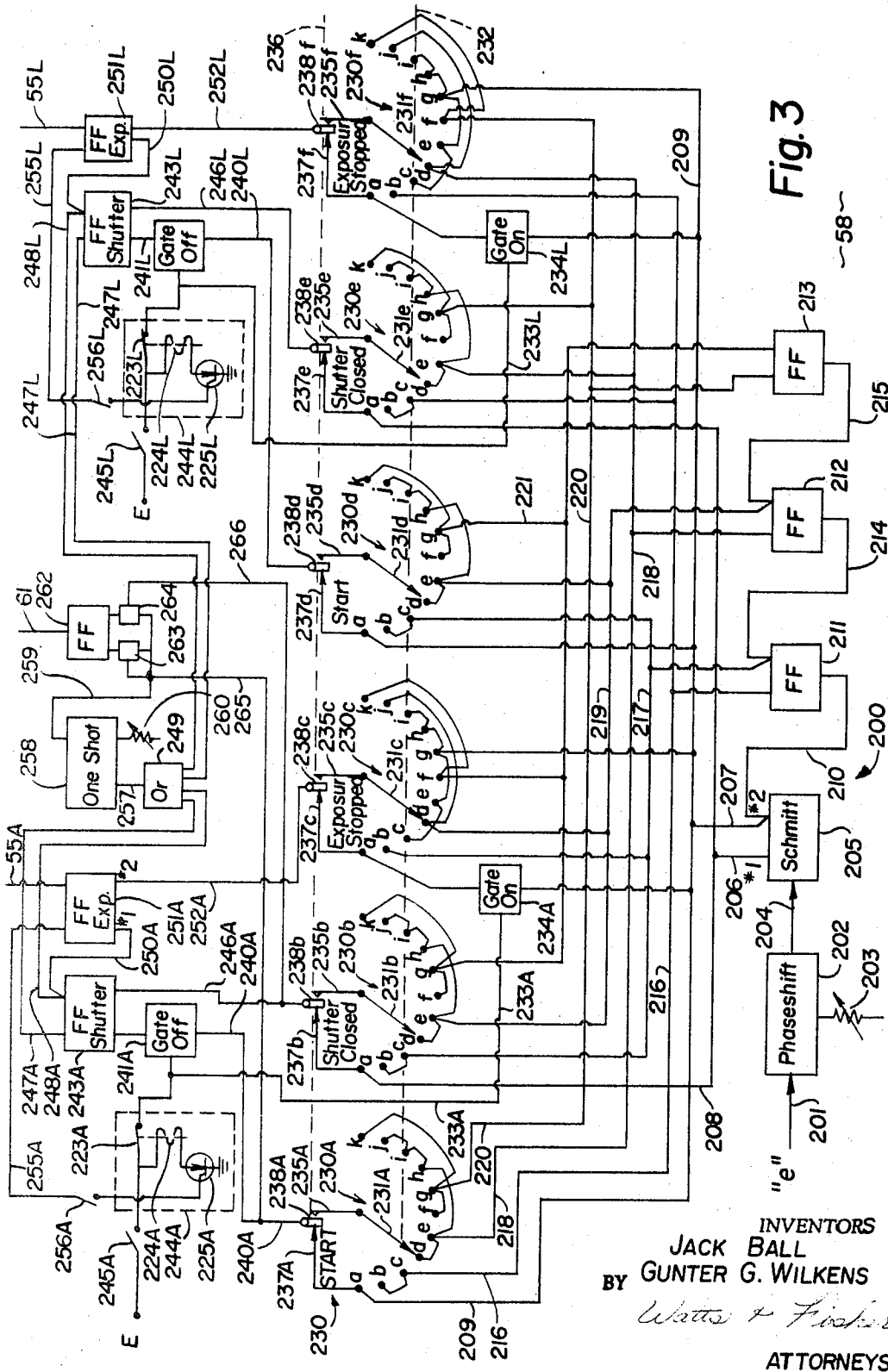
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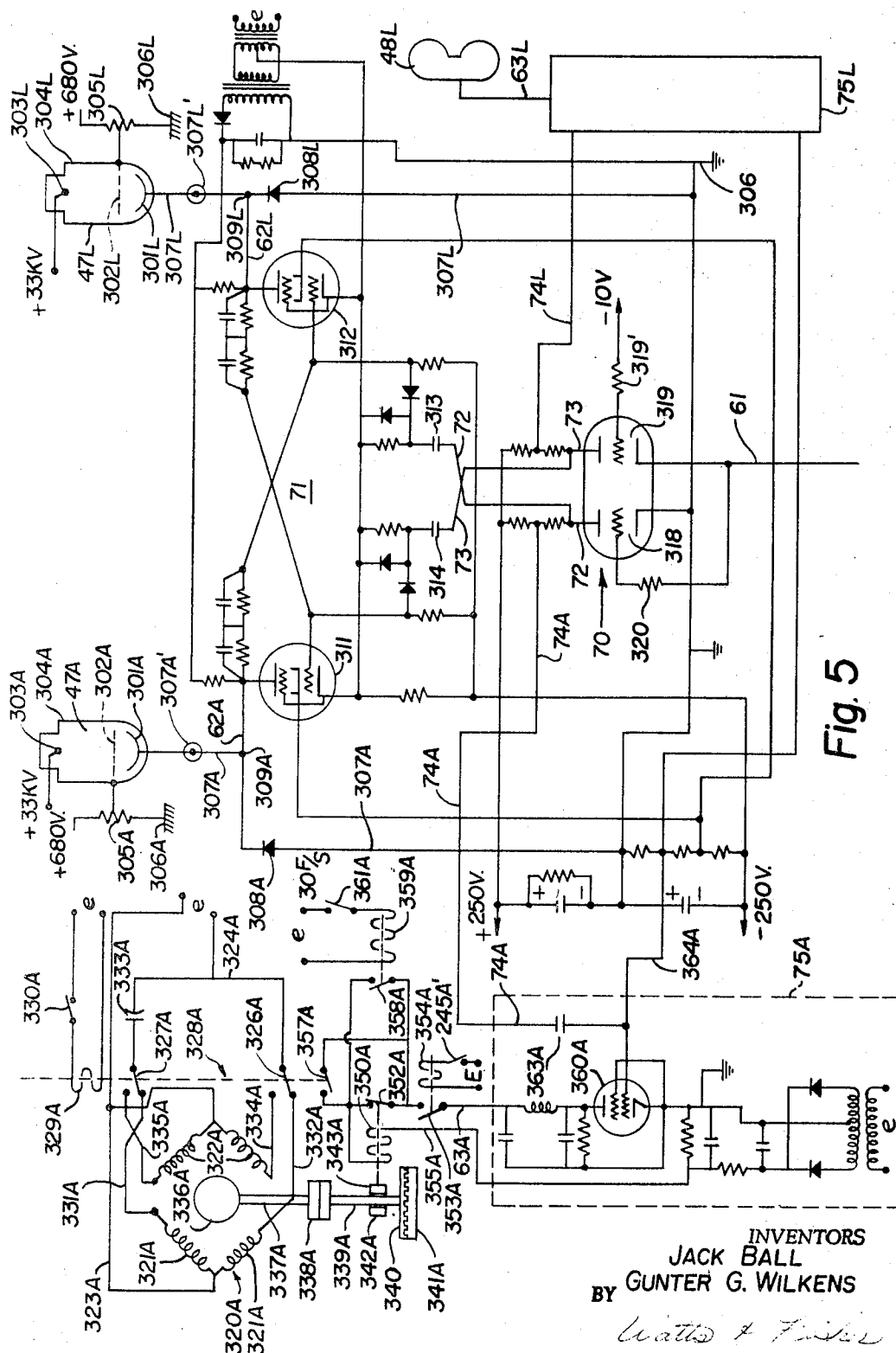
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Sheet 4 of 4



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BIPLANE X-RAY IMAGE SYSTEM

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17 Claims

ABSTRACT OF THE DISCLOSURE

Operation of an image amplifier tube is controlled so that it operates as an electronic shutter. The tube photocathode is normally biased positively to prevent electron flow to the anode output phosphor. The image amplifier tube is turned on in synchronism with an X-ray tube. Thus, no electrons traverse the image amplifier tube except when the X-ray tube is turned on.

In a biplane system employing a plurality of X-ray tubes and associated image amplifier tubes, the individual combinations of X-ray and amplifier tubes are alternately turned on and off, so that each amplifier tube responds to and intensifies radiation only from its associated X-ray tube when the latter is also turned on.

Mechanical shutters are not required on cameras photographing the intensified images, and film is transported in each camera while its associated image intensifier and X-ray tubes are turned off.

The present invention relates to X-ray systems and more particularly to biplane X-ray apparatuses.

In medical studies of the conditions of parts or organs of the human body, particularly for diagnostic purposes, it is sometimes desired and oftentimes necessary to make X-ray film exposures of the body parts or organs from both a frontal or nearly frontal direction, generally referred to as an anterior-posterior or AP exposure, and a side or nearly side direction at right angles to the frontal direction generally referred to as a lateral exposure.

Biplane X-ray systems generally comprise two separate X-ray systems each having an X-ray tube and an X-ray sensitive film or other X-ray exposure image receiver positioned on the side of the body opposite of the source of X-rays, i.e., the X-ray tube. The path or beam of the X-rays from one X-ray tube through the body or subject to its associated image receiver is therefore at right angles to the beam of X-rays in the other X-ray system so that one is used for making AP exposures and the other is used for making lateral exposures.

In such biplane systems, the AP and lateral exposures are generally made at different intervals, i.e., alternately, to avoid exposing the patient to large simultaneous doses of X-rays and to prevent one X-ray tube system from interfering with the other system so as to achieve maximum clarity and sharpness in their respective film images. Prior systems have operated the AP X-ray tubes and image receivers alternately with the lateral X-ray tubes and image receivers. The alternate operation may comprise a rapid sequence of film exposures as in cine wherein a plurality of AP and lateral film images are recorded in rapid alternate sequence by AP and lateral cameras. In these cine systems, the lens of each camera is focused on the output phosphor of an associated image intensifier tube which is interposed between the subject and the camera to intensify the X-ray image passed to the film of the camera each time the camera shutter opens.

In many biplane systems using image intensifier or amplifier tubes, phototubes are provided and are focused on the output phosphors of the image amplifier tubes. The

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phototubes are connected to suitable control circuits which adjust the brightness of the images on the output phosphors to maintain a uniform brightness of the images presented to the cameras.

These prior biplane systems have experienced several problems which are attributable to extraneous X-rays scattering from one X-ray system into the other and to a "storage effect" in the image amplifier tubes. The inputs phosphors of the image amplifier tubes each receive primary radiation directly through the subject from its associated X-ray tube and secondary radiation which is extraneous scattered radiation from the other X-ray tube. For example, the lateral image amplifier receives primary radiation from the lateral X-ray tube during energization of the lateral X-ray tube and secondary radiation from the AP X-ray tube when the AP X-ray tube is energized.

The image amplifier tube has a retentive characteristic which tends to store or retain an image and emit it from its output phosphor after a primary X-ray beam is no longer incident upon its input phosphor. In addition, in any prior biplane system, one X-ray tube will interfere with the operation of the image tube of the other system. For example, when the lateral X-ray tube is energized after the AP X-ray system has been in operation, the image of the lateral image amplifier tube is affected by what might be described as a "noise" image produced by secondary radiation from the AP system. Thus, after the lateral X-ray tube is shut off, the image emitted by the output phosphor of the lateral image tube is initially continuous relatively bright and diminishes gradually. The "noise" image from scatter radiation from the AP image is superimposed on the retained image from the primary radiation. The noise image fogs film used to photograph the output phosphor and, in addition, the retained image blurs the photographic image because the film is moved at the time when the primary beam is shut off.

In the X-ray system having brightness control, the phototubes looking into the image amplifier tubes register the excessive brightness from the scattered radiation and the retained primary radiation in addition to the primary radiation. The automatic brightness control circuits do not, therefore, function properly to control the brightness of the images seen by the cameras looking at the output phosphors.

In the present system, these problems are circumvented by controlling operation of the image amplifier tube so that the image tubes function as electronic shutters in addition to intensifying the desired images. In the present system, photocathodes of the image amplifier tubes are initially biased several hundred volts positive relative to ground potential to prevent an electron flow through the image amplifier tubes to the output phosphors at its anodes and thereby turn the image tubes as electronic shutters "off." The image amplifier tubes are turned "on" as electronic shutters preferably by clamping the photocathodes to the ground potential.

It has been found that by placing the image amplifier tubes normally in a cut-off state to provide effectively closed shutters, no electrons can leave the photocathodes and reach the anodes. Thus, no electrons traverse the image amplifier tubes. The light output of the input phosphor from scatter radiation incident on the input phosphor of the cut-off or closed image tube of one system during operation of the other system is substantially completely dissipated by the cut-off image tube by the time it later opens to receive incident primary radiation as when its system is in operation and the other system is cut-off. In addition a latent image remaining after the image tube was shut off at the termination of a previous pulse is dissipated during the off period. Tests indicate that there is

no interference with the dissipation of the latent and noise images.

In the present system, by utilizing the image amplifier tubes as electronic shutters as well as intensifiers, the conventional mechanical shutters of the cameras are not required. The cameras are continuously open and are focused in light tight relation on the output phosphors of the image tubes. A suitable control system is provided for co-ordinating the shutter operation of the image amplifier tubes to the operation of film transport mechanisms in the cameras and to the energization of the X-ray tubes. The X-ray tubes are energized when the electronic shutters are turned on. The camera films are transported to new frame positions after the shutters are turned off. The control system alternately operates the AP and lateral X-ray systems so that, for example, the AP X-ray tube and electronic shutter are turned on when the lateral X-ray tube and electronic shutter are turned off.

In lower frame rate settings (i.e., frames per second) clutches in the film transport mechanisms are operated upon closure of the shutters to move the film for the next X-ray exposures. In high film rate applications, the cameras are caused to run continuously and the electronic shutters open and close in a synchronized, alternate relation with each other and in synchronism with the energization and de-energization of the X-ray tubes. Different exposure times, i.e., the duration of the X-rays, for the different frame rates are provided by controlling the duration of the energization of the X-ray tubes for each frame exposure. In the frame rate settings equal to line frequency the exposure time is provided by opening opposite sets of half wave rectifiers in bridge rectifier circuits located in the X-ray tube energization circuits so that the X-ray tubes are pulsed alternately by half wave rectified voltages.

In the present system, a high voltage flip-flop circuit is used to synchronize the operation of the image tubes, the cameras and the energization of the X-ray tubes. The high voltage flip-flop circuit has one of its outputs connected to control the shutter operation of the AP image amplifier tube and the other output connected to control the shutter operation of the lateral image amplifier tube. Since one output is always on when the other is off, the flip-flop automatically operates the image amplifier tubes alternately as shutters in proper biplane relation. The opening and closing of the electronic shutters are delayed slightly so as to coincide exactly with the energization of the X-ray tubes which is delayed by the high voltage transformation circuits in the X-ray tube energization systems.

Accordingly, an object of the present invention is to provide a new and improved biplane X-ray system.

Another object of the present invention is to provide a new and improved X-ray system wherein an image intensifier tube is operated as an intensifier and as an electronic shutter.

And another object of the present invention is to provide a new and improved biplane X-ray system wherein image amplifier tubes are maintained in cut-off condition during the periods that their respective X-ray tubes are de-energized to prevent the transfer of images incident on their input phosphors to the output phosphors and are turned on to permit electron conduction to their output phosphors when their respective X-ray tubes are energized for X-ray exposures.

Still another object of the present invention is to provide a new and improved biplane X-ray system wherein the image intensifier tubes are operated as electronic shutters as well as intensifiers and are operated alternately with the energization of their respective X-ray tubes in a delayed manner to coincide exactly with the energization of the X-ray tubes.

Yet another object of the present invention is to provide a new and improved biplane X-ray system wherein the image amplifier tubes function as electronic shutters which are opened and closed in alternate relation by alter-

nate states of energization of a single switching device.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims taken in conjunction with the accompanying drawings in which:

FIGURE 1 is a schematic drawing using block diagrams of the biplane X-ray tube energization and shutter control systems of the present invention.

FIGURE 2 is a detailed circuit drawing of an X-ray tube energization circuit from the systems of FIGURE 1.

FIGURE 3 is a schematic circuit drawing of a frame rate and exposure time selector control system for the systems of FIGURE 1.

FIGURE 4 is a front view of a selector panel for the selector system of FIGURE 3.

FIGURE 5 is a detailed circuit drawing of the systems of FIGURE 1.

Referring now to FIGURE 1, a biplane X-ray system includes an anterior-posterior (hereinafter referred to as AP) X-ray tube system 22 and a lateral X-ray tube system 23. The AP and lateral X-ray tube systems 22, 23 are substantially identical and like reference characters designate like parts in both systems with an additional reference character A being added to the numerical reference characters in the AP system 22 and an additional reference character L added to the numerical reference character designating parts in the lateral system 23.

The AP and lateral X-ray tube circuits are identical and include X-ray tubes 25A, 25L supplied from the same voltage source "e" through voltage control circuits 26A, 26L which set the voltage levels supplied to the X-ray tubes, electronic contactor circuits 27A, 27L for controlling energization of the X-ray tubes, and high voltage transformer and rectifier circuits 28A, 28L for stepping up the voltage levels and rectifying them to supply DC kilovoltages to the X-ray tubes. The details of both X-ray tube circuits are shown by the single X-ray tube circuit in FIGURE 2. The various parts of the X-ray tube circuit of FIGURE 2 are designated by numerical reference characters only for general description purposes here, it being understood that the same parts are designated by the additional reference characters A, L when described in connection with the AP and lateral systems respectively. For example, the X-ray tube is designated by the reference character 25 in FIGURE 2, by the reference character 25A in connection with the AP X-ray tube circuit, and by the reference character 25L in connection with the lateral X-ray tube circuit.

The voltage control circuit 26 includes an autotransformer 29 having its input terminals connected across the AC voltage source "e" and its output voltage taps 30, 31 connected to a primary winding 32 of a high voltage transformer in the transformer and rectifier circuit 28. The secondary winding 34 of the high voltage transformer 33 is connected to the input side of a full wave rectifier circuit 35 via conductors 36, 37. The output terminals of the full wave bridge rectifier circuit 35 are connected to the anode and cathode elements of the X-ray tube 25 via conductors 38, 39. Thyatron tubes 40, 41 in the electronic contactor circuit 27 are connected back-to-back between the primary winding 32 of the high voltage transformer 33 and the secondary tap terminal 31 of the autotransformer 29. As will be explained, the electronic contactor control circuit 27 controls conduction of the thyatron tubes 40, 41 which in turn control energization of the X-ray tube 25 from the voltage source "e".

As is shown by the drawing (FIGURE 1), the AP and lateral X-ray tubes 25A, 25L are positioned so that their X-ray beams impinge on a subject 46, e.g., a human body, at right angles to one another. The X-ray beam from the AP X-ray tube 25A impinge on the subject 46 so as to provide an anterior-posterior exposure. The X-ray beam from the lateral X-ray tube 25L impinge on the subject 46 so as to provide a lateral X-ray exposure.

The X-ray systems 22, 23 further include AP and

lateral image amplifier tubes 47A, 47L, and AP and lateral cine cameras 48A, 48L having their lenses focused in light tight relation on output phosphor screens of their associated image amplifier tubes 47A, 47L, respectively. The AP image tube 47A and the AP cine camera 48A are positioned in aligned relation with the X-ray beam from the AP X-ray tube 25A and on the opposite side of the subject 46 from the AP X-ray tube 25A. The lateral image amplifier tube 47L and the lateral cine camera 48L are arranged in a similarly aligned relation with the X-ray beam from the lateral X-ray tube 25L and on the opposite side of the body 46 from the lateral X-ray tube 25L. The aligned lateral X-ray system is at right angles to the aligned AP X-ray system. The input phosphor of the AP image tube 47A receives primary X-ray radiation from the output of the AP X-ray tube 25A and secondary radiation from the output of the lateral X-ray tube 25L. The input phosphor of the lateral image amplifier tube 47L similarly receives primary radiation from the lateral X-ray tube 25L and some secondary radiation from the AP X-ray tube 25A. The image amplifier tubes intensify images presented to their input phosphors and display the intensified images on their output phosphors. As will be explained, the image amplifier tubes 47A, 47L are controlled to function also as electronic shutters for the cine cameras 48A, 48L. The cine cameras 48A, 48L do not have the conventional camera shutters.

The electronic contactors 27A, 27L are turned "ON" to energize their respective X-ray tubes by control signals from AP and lateral multivibrators 54A, 54L, respectively. Operation of the multivibrators 54A, 54L is controlled by a frame rate and exposure time selector circuit 58 via lines 55A, 55L. The frame rate and exposure time selector circuit 58 also controls operation of the AP and lateral image tubes 47A, 47L and cameras 48A, 48L in synchronism with energization of the X-ray tubes through a shutter and camera control circuit 60. The shutter and camera control circuit 60 has its input connected to the frame rate and exposure time selector circuit 58 via conductor 61 and its outputs connected to the image amplifier tubes 47A, 47L via conductors 62A, 62L and to the cameras 48A, 48L via conductors 63A, 63L.

The frame rate and exposure time selector circuit 58 sends control signals alternately to the multivibrators 54A, 54L via conductors 55A, 55L so that the electronic contactors 27A, 27L are energized alternately to cause the AP and lateral X-ray tubes 25A, 25L to be energized and to provide AP and lateral exposures alternately. The selector circuit 58 also provides a control signal to the shutter and camera control circuit 60 via conductor 61 for each control signal provided to the AP and lateral multivibrators 54A, 54L, respectively. The lengths of these control signals and their frequency is determined by an exposure time and a frame rate set on a selector control panel 230 (FIGURE 4) for the selector circuit 58.

The shutter and camera control circuit 60 includes an amplifier circuit 70 having its input connected to the conductor 61 and two outputs connected to the first and second inputs respectively of a high voltage flip-flop 71 via conductors 72, 73. First and second outputs of the flip-flop 71 are connected to the image amplifier tubes 47A, 47L via the conductors 62A, 62L, respectively. The outputs of the amplifier 70 are also connected to the inputs of AP and lateral camera clutch trigger circuits 75A, 75L via conductors 74A, 74L, respectively. The outputs of the trigger circuits 75A, 75L are connected to clutch mechanisms of the cine cameras 48A, 48L via the conductors 63A, 63L.

The amplifier 70 provides an output signal on control conductor 72 in response to a voltage signal above a predetermined level on conductor 61 and an output signal on conductor 73 when the voltage signal on conductor 61 falls below such predetermined level. An out-

put signal on conductor 72 from the amplifier 70 triggers, the high voltage flip-flop to turn the AP image tube on and the lateral image tube off and causes the AP camera clutch trigger to send a film transport signal to the camera at the termination of the output signal from the amplifier 70. An output signal on conductor 73 from the amplifier 70 triggers the flip-flop 71 to turn the lateral image tube on, the AP image tube off, and causes the lateral camera clutch trigger circuit to send a film transport signal to the camera 48L at the termination of the control signal. Hence, the shutter control circuit 60 causes energization of the AP image tube and camera 47A, 48A in response to one control signal on conductor 61 and then energization of the lateral image tube and camera 47L, 48L in response to the next control signal on conductor 61. The first such control signal on conductor 61 corresponds to a control signal supplied to the AP multivibrator 54A. The next control signal on conductor 61 corresponds to a control signal supplied to the lateral multivibrator 54L. The image tubes 47A, 47L are therefore operated in synchronism with the operation of the electronic contactors 27A, 27L so that the AP image tube is shutter operated to provide an image to its output phosphor at the time the AP X-ray tube is energized and the lateral image tube is shutter operated to pass an image to its output phosphor when the lateral X-ray tube is energized. The shutter and camera control circuit 60 further operates film transport mechanisms in the cine cameras 48A, 48L alternately and after their respective image amplifier tubes have been turned off to transport their films to the next frame position so as to position unexposed portions of the film in the cameras' fields for the next exposure.

Referring to FIGURE 2, the multivibrators 54A, 54L are each conventional astable multivibrators which generate high frequency voltages, which are rectified by bridge rectifiers 98, 99, whenever the voltage level on conductors 55A, 55L is above a predetermined level. The DC output voltages on conductors 100-103 are applied to diodes 104, 105 to reverse bias them, thereby permitting the thyratron tubes 40, 41 to conduct and pass current to the transformer 28.

For example, batteries 106, 107 and the secondary windings of isolating transformers 108, 109 provide bias voltages to the control grids of the tubes 40, 41 which vary from a negative 90 volts to a positive 30 volts at the line frequency of voltage source "e". When the bias voltages go positive, conduction of the tubes 40, 41 is prevented by the diodes 104, 105 which are forward biased by the positive bias voltages and clamp the control grids to the negative 30 volts of the batteries 106, 107. Rectified voltages of 100 volts are provided by output conductors 100-103 of the multivibrators 54 in response to an input start trigger signal and are applied across resistors 110, 111 in the polarity shown to reverse bias diodes 104, 105 thereby releasing the clamp and permitting the tubes 40, 41 to fire alternately at line frequency to pass the supply voltage to the transformer 28.

The rectifier circuit 35 includes four rectifier tubes 121-124 arranged in a bridge circuit. Energization of the cathodes of the tubes 121-124 and hence conduction by the tubes is controlled by switches 125, 126 which connect isolation transformers 129-132 to the voltage source "e". If either switch 125 or switch 126 is open and the other is closed so that only one set of rectifier tubes is on, then a half wave rectified voltage is supplied to the X-ray tube 25 and effectively pulses the X-ray tube sixty times per second. Alternate biplane operation of the X-ray tubes is accomplished by turning different sets of the rectifier tubes off in the AP and lateral systems respectively so that one X-ray tube is on when the other X-ray tube is off.

Referring to FIGURE 3, the frame rate and exposure time selector circuit 58 includes a counter circuit 200 having an input conductor 201 connecting a phase shift

circuit 202 to the alternating current voltage source "e". The phase shift circuit 202 includes a phase shifting element 203 for shifting the phase of its output relative to the phase of its input. The output of the phase shift circuit 202 is connected to the input of a Schmitt trigger 205 via a conductor 204. The Schmitt trigger 205 is conventional and converts the sine waves introduced at its input via conductor 204 to square waves at its outputs connected to conductors 206, 207. A suitable Schmitt trigger comprises two transistors (not shown) arranged in a conventional regenerative bistable circuit. The first output of the Schmitt trigger 205 (connected to the conductor 206) is from the collector of one transistor and provides a positive square wave pulse for the negative half cycle of a sine wave introduced at its input on the conductor 204. The second output of the Schmitt trigger 205 is from the collector of the second transistor and produces a positive square wave for the positive half cycle of the sine wave introduced at its input via conductor 204. The conductors 206, 207 from the first and second outputs of the Schmitt triggers are connected to 60 pulses per second selector conductors 208, 209, respectively. As line voltage is supplied to the input of the Schmitt trigger, a series of positive square wave pulses are produced alternately at the rate of 60 pulses per second on each of the conductors 208, 209.

A conductor 210 connects the second output of the Schmitt trigger 205 to the input of the first of three flip-flops 211-213 interconnected as a counter with the second outputs of the flip-flops 211, 212 connected to the inputs of the flip-flops 212, 213 via conductors 214, 215, respectively. The flip-flops 211-213 are conventional bistable multivibrators with positive steering diodes (not shown) connected in the T-arrangement shown for base triggering. First and second outputs are taken from the collector elements of two transistors (not shown) in each flip-flop circuit. Suitable differentiating devices (not shown) are interposed in the conductors 210, 214 and 215 to change the square wave pulse outputs of the Schmitt trigger and the flip-flops 211, 212 to positive trigger pulses which are passed by the positive steering diodes of the flip-flops.

First and second outputs of the flip-flop 211 each provide 30 pulses per second and are connected to 30 pulses per second selector conductors 216, 217, respectively. First and second outputs of the flip-flop 212 each provide 15 pulses per second and are connected to the 15 pulses per second selector conductors 218, 219, respectively. The outputs of the flip-flop 213 each provide $7\frac{1}{2}$ pulses per second and are connected to $7\frac{1}{2}$ pulses per second selector conductors 220, 221, respectively. The outputs of the Schmitt trigger 205 and of the multivibrators 211-213 provide their respective pulsed outputs to the conductors 208, 209 and 216-221 as long as line voltage is supplied to the input conductor 201.

The pulsed output supply conductors 208, 209 and 216-221 are connected to the combined frame rate and exposure time selector unit 230 which has its front panel shown in FIGURE 4. The front panel of the selector 230 includes a pointed indicator 231 which is positionable at any one of several terminal positions *a* through *k*, each of which provides a different combination of frame rates, i.e., the number of frames of film exposed per second, and exposure time per frame expressed in the number of cycles of the line voltage "e" per frame. The terminals *a-g* are for cine operation wherein the system runs continuously making exposures at the frame rate selected with equal exposure times for each frame. For example, when the indicator 231 is positioned all the way counter clockwise to terminal *a*, the X-ray system will provide AP and lateral exposures each at the rate of 60 frames per second, each exposure time being $\frac{1}{2}$ cycle of the incoming line frequency or one hundred-twentieth of a second. Terminals *b* and *c* each provide a film rate of 30 frames per second with terminal *b* providing a one cycle exposure time and terminal *c* providing a half cycle ex-

posure time. Terminals *d* and *e* provide a film rate of 15 frames per second with terminal *d* providing an exposure time of two cycles per frame and terminal *e* providing a half cycle of exposure time per frame. Turning the selector indicator 231 to either terminal *f* or *g* will provide a frame rate of $7\frac{1}{2}$ frames per second with terminal *f* providing an exposure time of 4 cycles per frame and terminal *g* providing an exposure time of a half cycle per frame.

The terminals *h-k* provide several different exposure times for single frame operation of the X-ray tube system. The selector 231 is turned to one of the terminals *h-k* when the AP and lateral X-ray exposures are taken one set at a time, each set being separately initiated. As shown by the drawing, terminals *h-k* represent exposure time values of $\frac{1}{2}$, 1, 2 and 4 cycles, respectively.

Referring again to FIGURE 3, the frame rate and exposure time selector 230 has six selector switches 230*a*-230*f*. Each of the selector switches 230*a*-230*f* includes terminals *a-k* which correspond in position to the terminals *a-k* on the face panel of the selector unit 230. The selector switches 230*a*-230*f* include movable contacts 231*a*-231*f* which are all ganged together and to the selector indicator 231 as is indicated by the broken line 232. Positioning the indicator 231 at one of the terminals *a-k* also moves the movable contacts 231*a*-231*c* to a corresponding terminal in each of the switch banks 230*a*-230*f*.

The three selector switches 230*a*-230*c* on the left side of the drawing are for selecting frame rates and exposure times for the AP X-ray system 22. The three switches 230*d*-230*f* on the right side of the drawing are for selecting film rates and exposure times for the lateral X-ray system 23.

The first switches 230*a*, 230*d* in the AP and lateral switch groups are start trigger switches for producing starting trigger signals which initiate closure of the electronic contactors 27*A*, 27*L* for energization of the X-ray tubes and also initiate opening of the image tubes 47*A*, 47*L* as electronic shutters to provide an image to the cameras. The second switches 230*b*, 230*e* in the AP and lateral switch groups are shutter closed switches for timing the length of time the electronic shutter remains open and produce shutter closed signals at the end of the exposure time. The third switches 230*c*, 230*f* in the AP and lateral switch groups are "exposure stopped" switches and determine the period that the electronic contactors remain closed and consequently the period for which the X-ray tubes are energized. The exposure stop switches 230*c*, 230*f* produce an exposure stop signal at the end of the exposure time set by the selector switch indicator 231.

The movable contacts 231*a*-231*f* are each connected to a fixed contact 235*a*-235*f* of an OV-TV (optical viewing-television) and CINE selector switch indicated by the broken line 236. The OV-TV and CINE selector switch 236 includes fixed contacts 237*a*-237*f* connected to the *a* terminals of the selector switches 230*a*-230*f* and movable contacts 238*a*-238*f*. The contacts 238*a*-238*f* are movable as a unit to an OV-TV position engaging fixed contacts 237*a*-237*f* or to a CINE position engaging fixed contacts 235*a*-235*f*.

The terminals *a-k* of the switches 230*a*-230*f* are connected to the pulsed output supply conductors 208, 209, 216-221 from the Schmitt trigger 205 and the flip-flops 211-213 so as to provide the frame rates and exposure times shown on the face panel in FIGURE 4. The 60 frame rate terminals *a* of the AP and lateral "shutter open" or "start trigger" control switches 230*a*, 230*d* receive 60 square wave pulses per second from the second output of the Schmitt trigger 205 via conductor 209. The 60 frame rate terminals *a* of the AP and lateral "shutter closed" selector switches 230*b*, 230*e* receive 60 square wave pulses per second from the first output terminal of the Schmitt trigger 205 and therefore are out of phase by a half cycle with the pulses received by the *a* terminals of the start trigger switches 230*a*, 230*d*.

The 30 frames per second terminals *b* and *c* in the

AP start trigger selector switch 230a and in the lateral shutter closed selector switch 230e receive 30 square wave pulses per second from the first output of the flip-flop 211 while the 30 frames per second selector terminals b and c in the AP shutter closed selector switch 230b and in the lateral start trigger selector switch 230d receive 30 square wave pulses per second from the second output of the flip-flop 211. The 15 frames per second cine terminals d and e and single frame selector terminals h, i, and j of the AP start trigger switch 230a and of the lateral shutter closed selector switch 230e receive 15 square wave pulses per second from the first output of the flip-flop 212 while the corresponding terminals of the AP shutter closed selector switch 230b and of the lateral start trigger selector switch 230d receive 15 pulses per second from the second terminal of the flip-flop 212 via conductor 219. The 7½ frames per second selector terminals f, g, and the four cycle single frame terminals k of the AP start trigger selector switch 230a and of the lateral shutter closed selector switch 230e receive 7½ square wave pulses per second from the first output of the flip-flop 213 while the corresponding terminals in the AP shutter closed selector switch 230b and in the lateral start trigger switch selector switch 230d receive 7½ pulses per second from the second output of the flip-flop 213.

The AP and lateral exposure stopped selector switches 230c, 230f have half cycle exposure time terminals a connected through normally "off" AP and lateral gates 234A, 234L respectively to the second output of the Schmitt trigger 205 via the conductor 209 so that the terminals a receive exposure termination signal pulses at half cycle intervals through the gates 234A, 234L which are normally turned on. The control inputs of the gates 234A, 234L are connected to the control inputs of normally off AP and lateral gates 241A, 241L via conductors 233A and 233L, respectively.

The one cycle exposure time terminal b of the AP exposure stopped selector switch 230c is connected to the second output of the 30 pulses per second flip-flop 211 via conductor 217. The corresponding terminal b in the lateral exposure stopped selector switch 230f is connected to the first input of the flip-flop 211 via conductor 216. These terminals b thus receive exposure termination signal pulses at one cycle intervals in an opposite phase relation. The half cycle exposure time terminals c, e, g and h and the one cycle terminal i of the AP and lateral exposure stopped selector switches 230c, 230f are connected to the second output of the Schmitt trigger 205 and receive exposure termination signals at half cycle intervals.

The two cycle exposure time terminals d and j of the AP exposure stopped selector switch 230c are connected to receive exposure "stop" or "termination" signal pulses at two cycle intervals from the second output of the flip-flop 212 via conductor 219 and the corresponding terminals in the lateral exposure stopped selector switch 230f are connected to receive exposure termination signal pulses at two cycle intervals from the first output of the flip-flop 212. The four cycle exposure time terminals f and k of the AP selector switch 230c are connected to the second output of the flip-flop 213 to receive pulses at four cycle intervals. The corresponding four cycle terminals f and k in the lateral exposure stopped selector switch 230f are connected to the first input of the flip-flop 213 and receive pulses at four cycle intervals in phase spaced relation, i.e., out of phase, to the four cycle pulses received by the AP exposure terminals f and k.

Positioning the selector indicator 231 to one of the terminals a-k, for example at the two cycle terminal d, will result in control pulses appearing on the conductors 252A, 252L at intervals corresponding to the selected exposure time, two cycle intervals in the example given. The phase relationship of the exposure termination signal pulses on the lateral conductor 252L will always be out of phase to the signal pulses on the AP conductor 252L except when terminal a is selected. If terminal a is se-

lected the signal pulses on conductors 252A, 252L are in phase.

When the selector switches 230a-230f are set by the selector control indicator 231 to a particular frame rate setting, a shutter open signal appearing on the conductor 240A from the AP trigger selector switch 230a is followed by a delayed shutter closed signal on AP conductor 246A such that the number of cycles delay between the signals provides the frame rate selected. For example, if the control selector 231 is set to one of the 15 frames per second terminals d, e, the shutter open or start trigger signal appearing on the AP conductor 240A is followed two cycles later by a shutter closed signal on the AP conductor 246A.

This same relationship is true in the lateral control portion of the selector 230. A start trigger signal appearing on the conductor 240L to close the electronic contactor and to open the electronic shutter (image tube 47L) will be followed by a shutter closed signal on the conductor 246L by the number of cycles required to provide the desired frame rate.

Also, if terminals b-k are selected, a start trigger signal on the lateral conductor 240L will follow a start trigger signal on the AP conductor 240A by the same delay. For example, with the 15 frame rate settings, the start trigger signal on conductor 240L will follow the start trigger signal on the AP conductor 240A by two cycles. Thus, when the AP control system closes its electronic contactor 27A to energize the X-ray tube 25A and opens the electronic shutter of the AP image tube to receive radiation from the X-ray tube, the lateral control system opens its electronic contactor 27L and closes its electronic shutter. When the lateral control system closes its electronic contactor 27L and opens its electronic shutter, the AP control system closes its electronic shutter and opens its electronic contactor.

The conductors 240A, 240L connect the movable contacts 238a, 238d to the inputs of normally off AP and lateral gates 241A, 241L, respectively. The outputs of the AP and lateral gates 241A, 241L are connected to the first inputs of AP and lateral shutter flip-flop circuits 243A, 243L, respectively. Control inputs of the gates 241A, 241L are connectable to an energizing source E through lock-in gates 244A, 244L and normally open, foot controlled AP and lateral exposure initiating switches 245A, 245L, respectively.

The lock-in gates 244A, 244L comprise normally closed control relay contacts 223A, 223L in series with the foot switches 245A, 245L and the control inputs of the gates 241A, 241L. Control relay coils 244A, 244L are connected to voltage sources E through foot switches 245A, 245L and to ground connections through controlled rectifiers 225A, 225L. Control electrodes of the controlled rectifiers 225A, 225L are connected to the first outputs of exposure control flip-flops 251A, 251L via conductors 255A, 255L and through single frame selector switches 256A, 256L.

The second inputs of the shutter flip-flops 243A, 243L are connected via conductors 246A, 246L to the movable contacts 238b and 238e of the shutter closed switches 230b, 230e. The first and second output of the shutter flip-flops 243A, 243L are connected via conductors 247A, 247L, 248A, 248L to the inputs of an OR circuit 249. Conductors 250A, 250L connect the second outputs of the shutter flip-flops 243A, 243L to the first inputs of the X-ray exposure control flip-flops 251A, 251L. The second inputs of the X-ray exposure control flip-flops 251A, 251L are connected via conductors 252A, 252L to the movable contacts 238c, 238f of the exposure stop switches 230c, 230f. The second outputs of the X-ray exposure control flip-flops 251A, 251L are connected to the inputs of the multivibrators 54A, 54L via conductors 55A, 55L.

The output of the OR circuit 249 is connected via a conductor 257 to the input of a shutter delay single shot multivibrator 258. The function of the single shot multivibrator 258 is to delay a signal provided at its output at

conductor 259 in response to a signal introduced to its input via conductor 257. The delay compensates for the slowness inherent in the high voltage transformation system as compared to the quickness of the shutter system. By this delay, the electronic shutters are made to operate precisely with energization of their respective X-ray tubes. The length of the delay is adjusted as is indicated schematically by a shutter delay adjustment control element 260.

The output of the multivibrator 258 is selectively connected to the first and second inputs of a final output flip-flop 262 through either one of two normally off gates 263, 264. The control inputs of the normally off gates 263, 264 are connected via conductors 265, 266 to the movable contacts 238a, 238b of the start trigger switch 230A and the shutter closed switch 230b, respectively. The gate 263 is turned on by a control pulse appearing on conductor 240A and causes trigger pulses to pass only to the first input of the final output flip-flop 262 while a control signal appears on conductor 240A. The gate 264 is turned on by a control pulse on conductor 246A and causes control pulses to pass only to be second input of the final output flip-flop 262 while a control signal is on conductor 264A. The output of the final output flip-flop 262 is connected by the control conductor 61 to the shutter and camera control circuit 260. An input pulse passed by the gate 263 to the first input of the final output flip-flop 262 will cause the final output flip-flop to switch its state and connect the conductor 61 to a predetermined negative voltage source. An input pulse passed by the gate 264 to the second input of the final output flip-flop 262 will flip the flip-flop 262 into its other stable state wherein the voltage level on the conductor 61 is at a zero voltage level and above the predetermined level of the negative voltage source.

Referring now to FIGURE 5, the image amplifier tubes 47A, 47L respectively include photocathode elements 301A, 301L, focus elements 302A, 302L and anode elements 303A, 303L. The image amplifier tubes are preferably image tubes manufactured by Rauland Company and designated by part No. R-6175. In these image tubes the photocathode is a layer on the inside of an input window having also an X-ray sensitive, light producing input phosphor layer. The anode element is the output phosphor. A coating on the inside of the image tube envelope is used as the focus element 302. The image amplifier tubes 47A, 47L are isolated from ground potential. The coatings on the envelopes of the image tubes which are represented by the focus electrodes 302A, 302L are connected to adjustment taps of focus control potentiometers 305A, 305L respectively. The anode elements 303A, 303L are connected to positive 33 kilovolt supplies. The focus control potentiometers 305A, 305L are connected to positive 680 volt supplies which place the focus electrodes at about 600 volts positive to ground. The photocathodes 301A, 301L are connected to ground point 306 via conductors 307A, 307L and through diodes 308A, 308L having their anodes connected to the ground point 306. The conductors 63A, 62L from the outputs of the high voltage flip-flop circuit 71 are connected to the conductors 307A, 307L at voltage points 309A, 309L between the photocathodes 301A, 301L and the diodes 308A, 308L.

The switching amplifier 70 comprises a double triode tube having two triode sections 318, 319. The plates of the triode sections 318, 319 are connected to the conductors 72, 73 respectively. The control grid of the triode section 318 is connected to the input control conductor 61 through a resistor 320 and its cathode is connected to ground. The triode section 319 has its control grid element connected to a minus 10 volts through a resistor 319 and its cathode element connected directly to the control conductor 61. This arrangement of the triode sections 318, 319 is such that when the voltage level on the control conductor 61 is substantially at zero, the

triode section 318 is turned on and conducts to connect the conductor 72 effectively to ground and the triode section 319 is turned off. When the voltage on the conductor 61 is at a predetermined negative level, then the triode section 318 is turned off and the triode section 319 is turned on and connects the conductor 73 effectively to ground. Connecting either of the conductors 72, 73 to ground provides negative voltage excursions on them which are integrated by capacitors 313, 314 to form negative trigger pulses for operating the high voltage flip-flop 71.

The high voltage flip-flop 71 includes two high voltage power tubes 311, 312, for example, 6293 tubes. The output square wave voltages from the tubes 311, 312 are, for example, 1300 volts, and are sufficiently powerful to maintain the shape of the square waves over several feet of coaxial cable connecting the control circuit 60 to the image amplifier tubes 47A, 47L.

The high voltage tubes 311, 312 are arranged in a conventional flip-flop circuit as shown. When one high voltage tube is on the other high voltage tube is off. The operating condition of the flip-flop 71 is such that when a negative voltage excursion appears on conductor 72 from amplifier 70, the resulting trigger pulse passed by the capacitor 313 turns the tube 312 on and the tube 311 off. When a negative voltage excursion appears on the conductor 73, the resulting negative trigger pulse passed by the capacitor 314 turns the voltage tube 311 on and the voltage tube 312 off.

The plates of the high voltage tubes 311, 312 are connected as the outputs of the flip-flop 71 to the voltage points 309A, 309L, respectively. Each of the voltage points 309A, 309L is at approximately 1300 volts positive when its associated high voltage tube is turned off in the flip-flop circuit 71. When a voltage point is at a positive 1300 volts, the photocathode of the associated image amplifier tube is much more positive than the focus electrode and the image amplifier tube is turned off so that no electrons move from its photocathode to its anode. Positive potentials at the voltage points 309A, 309L also reverse bias the diodes 308A, 308L so that conduction through the diodes is blocked and the photocathodes remain 1300 volts positive relative to the ground point 306. When a high voltage tube is turned on in the flip-flop circuit 71, the associated voltage point 309A or 309L is driven to a negative voltage and forward biases its associated diode 308A or 308L. The forward biased diode clamps its photocathode to ground. The photocathode is then at substantially zero voltage level relative to the focus electrode thereby causing an electron flow to the anode element. In this condition, the image amplifier tube is on and the electronic shutter provided by that image tube is described as open. When one image tube is on, the 33 kilovolts potential between its cathode and anode elements accelerates the moving electrons and thereby intensifies the image on the output phosphor. Acceleration rings or electrodes are also suitably provided for image intensification purposes.

Because the AP and lateral cameras 48A, 48L and the camera clutch trigger circuits 75A, 75L are identical, the operating parts of the AP camera and AP clutch trigger circuit only are shown schematically in FIGURE 5. Each cine camera is a suitable clutch operated camera similar to a movie camera, but not having a shutter. A suitable camera is a clutch operated camera sold under the designation of "Flight Research Single Frame Camera" by Giannini Schietific Corporation. Each camera comprises a motor 320A having a set of two pole windings 321A, a set of four pole windings 322A, a rotor 336A and an output shaft 337A. The windings 321A, 322A are energizable across conductors 323A, 324A connected to a voltage source "e" via contacts 326A, 327A of a frame rate selector switch relay 328A. The relay 328A includes a coil 329A which is energizable from the voltage source "e" by closure of a 60 frames per second selector switch

330A. The selector switch 330A is closed by the selector switch 230 when the selector switch indicator 231 is set to the 60 frame rate terminal *a*. The contacts 326A, 327A in their normally closed position shown are connected to conductors 331A, 332A and connect one of the two pole windings 321A directly across the voltage source "e" and the other two pole winding across the voltage source "e" through a phase splitting capacitor 333A. The two pole windings are energized to cause the rotor 36A and output shaft 337A to rotate at 3600 r.p.m. when voltage source "e" is provided by a main switch (not shown). Closure of the switch 330A energizes the coil 329A to move the contacts 326A, 327A to connect the conductors 334A, 335A to the supply conductor 324A, thereby connecting one of the four pole windings 322A across the voltage source "e" and the other four pole windings across the voltage source "e" through the phase splitting capacitor 333A. The energized four pole windings cause the rotor 336A and the output shaft 337A of the camera to rotate at 1800 r.p.m.

The rotor 336A has its output shaft 337A connected to one part of a clutch 338A. The other part of the clutch 338A is connected to a film transport drive shaft 339A. As the motor shaft 337A rotates, the shaft 339A follows its rotation because the clutch parts are in engagement. The shaft 339A drives a film transport wheel 340A which transports a film 341A. A single frame stop 342A projects from the shaft 339A and is positioned to strike a clutch latch 343A as the shaft 339A rotates.

Engagement of the latch 343A by the stop 342A prevents rotation of the shaft 339A by virtue of slippage in the clutch 338A even though the motor shaft 337A continues rotating. Retraction of the latch 343A by a coil 350A against the bias of a spring (not shown) will permit the film transport shaft 339A to again rotate thereby transporting the film 341A. One rotation of the shaft 339A represents one frame in the film 341A.

Energization of the coil 350A is controlled by the AP clutch trigger circuit 75A, a normally closed contact 352A of the relay 350A, and a normally open contact 353A operated by a control relay coil 354A. The coil 354A is energized to close contact 353A by closure of a second contact 245A' of the foot switch 245A (FIGURE 2) which connects the coil 354A across the voltage source "e." Contact 352A is normally closed and opens to break the energization circuit when the coil 350A is energized. The energization circuit for the clutching coil 350A is completed when a thyatron tube 360A in the camera clutch trigger circuit 75A is biased to a state of conduction. The thyatron tube is normally biased in a cut-off condition by the negative bias on conductor 364A in the circuit shown. A positive voltage excursion appears on the conductor 74A when the triode section 318 turns off. The positive voltage excursion is integrated by capacitor 363A. The resulting trigger pulse biases the thyatron tube 360A to a state of conduction connecting the conductor 63A and the conductor 355A effectively across the rectified voltage source "e."

The energized relay coil 350A retracts the latch 343 thereby allowing the shaft 339A to rotate and transport the film. Movement of the armature of the relay 350A also opens the normally closed contacts 252A thereby breaking the energization circuit for the coil 350A. The latch 343A returns to its latching position under the influence of a bias spring (not shown) so as to engage the stop 342A when it completes one revolution thereby permitting the shaft 339A to transport the film one frame position only. This system thus makes one frame of film available for exposure for each trigger pulse introduced to the clutch trigger circuit 75A via conductor 74A.

Continuous transportation of the film 341A is required for 60 and 30 frame selections. Normally open contacts 357A and 358A are connected across the contact 352A and are closed to by-pass contact 352A to maintain energization of the clutching coil 350A. This causes free rota-

tion of the shaft 339A at either 1800 r.p.m. or 3600 r.p.m. to transport the film at either 30 frames per second or 60 frames per second, respectively. The contact 357A is closed by energization of the coil 329A of the 60 frame rate selection relay 328A. Contact 358A is closed by energization of the relay coil 359A across the voltage source "e" by closure of a switch 361A. The frame rate selection switches 330A, 361A are operated by the selector 231 (FIGURE 3). The switch 330A closes when the selector is positioned to the 60 frame rate terminal *a*. The switch 361A closes when the selector 321 is positioned to either one of the 30 frame rate terminals *b*, *e*.

60 frames per second operation

The X-ray system is set to provide 60 frames per second, biplane operation with half cycle exposure times by moving the indicator 231 to the *a* terminal on the panel 230 (FIGURE 4). The selector switch 236 is moved to the cine position so that contacts 238a-238f engage fixed contacts 235a-235f. Moving the indicator 231 to the *a* terminal closes the 60 frames per second selector switches 330A, 330L in the A-P and lateral cameras (FIGURE 5) and opens the bridge rectifier switch 125 in the A-P energization circuit and opens the bridge circuit selector switch 126 in the lateral X-ray tube energization circuit. The power supplies *e* and E are provided by closing suitable main controls (not shown). The camera motors cause their output shafts 337A, 337L to rotate at 3600 r.p.m. The film transport shafts 339A, 339L remain stationary by reason of the stops 342A, 342L engaging the latches 343A, 343L.

The X-ray exposures are initiated by closing the foot switches 245A, 245L so that the gates 241A, 241L are turned ON and the gates 234A, 234L are turned off. The next trigger pulse on conductors 207, 209 is passed to the first input of the shutter flip-flops 243A, 243L via movable selector switches 231a, 231d, contacts 235a, 235d, 238a, 238d, conductors 240a, 240l, and the gates 241A, 241L which are now turned on.

The start trigger signals provided to the first inputs of the shutter flip-flops 243A, 243L turn the second outputs of these shutters flip-flops on to provide output signals on the conductors 248A, 248L, 250A, 250L to the inputs of the OR circuit 249 and to the first inputs of the exposure time control flip-flops 251A, 251L.

Since the output signals appearing on the conductors 248A, 248L are provided simultaneously to the OR circuit 249, the OR circuit provides one output signal on its output conductor 257 to the input of the single shot multivibrator 258. The single shot multivibrator 258 delays this signal and provides a corresponding delayed signal on its output connected to the conductor 259 and then to the input of normally off gates 263, 264. Gate 263 is now on or open by reason of the start trigger signal being also introduced to its control input via conductors 265, 240A. The signal at the input of the gate 263 is introduced to the second input of the final output flip-flop 262 which increased the voltage level on the conductor 61 from a negative potential to a zero voltage in response thereto. The increase in the voltage level on the conductor 61 turns the triode section 318 on in the amplifier 70 (FIGURE 5). The triode section 318 provides a negative excursion on the conductor 72 to turn the high voltage tube 312 off and the high voltage tube 311 on in the high voltage flip-flop 71. The conducting high voltage tube 311 causes the photocathode of the AP image tube 47A to be connected to ground thereby turning the AP image system on.

The start trigger pulses introduced to the first inputs of the exposure flip-flops 251A, 251L by the conductors 250A, 250L turn the second outputs of the exposure flip-flops 251A on to provide an energization initiation signal on each of the conductors 55A, 55L. The energization initiation signals turn the multivibrators 54A, 54L on which in turn cause the thyatron tubes 40, 41 in each

of the electronic contactors 27A, 27L to connect their respective transformers 28 to the supply source "e." Because the bridge rectifier circuits 35A, 35L in each of the systems have only two of their rectifier tubes turned on, then only half wave rectified voltage is provided to the X-ray tubes 25A, 25L. The AP X-ray tube 25A is energized by the positive half cycles of the source voltage "e" and the lateral X-ray tubes 25L is energized by the negative half cycles of the input source voltage "e." The A-P and lateral X-ray tubes are, therefore, energized in an alternate, biplane relation as long as the first outputs of the exposure flip-flops 251A, 251L remain on and consequently the electronic contactors 27A, 27L remain on.

At the time the foot switches 245A, 245L were closed, a positive half cycle of the incoming line voltage "e" on line 201 resulted in the square wave output pulse on conductors 207, 209. A negative half cycle of the incoming line voltage "e" causes an output square wave pulse from the Schmitt trigger on conductors 206, 208. The latter signal pulse is introduced to the second inputs of the shutter flip-flops 243A, 243L via the conductors 206, 208, contacts 235b, 235e, 238b, 238e and conductors 246A, 246L. The shutter flip-flops 243A, 243L turn on their first outputs and turn off their second outputs so that control signals appear on conductors 247A, 247L and are introduced simultaneously to the input of the OR circuit 249. This control signal is again delayed by the single shot multivibrator 258 and is introduced to the inputs of the gating circuit 263, 264. At this time, the gate 264 is opened by reason of the signal on conductors 266, 246 so that an input signal is introduced to the second input of the final output flip-flop 262. The final output flip-flop 262 decreases the level of the voltage on the conductor 61 to the amplifier 70. This decrease in voltage level turns the triode section 318 off and the triode section 319 on in the amplifier 70. Consequently, the high voltage tube 311 is turned off, the high voltage tube 312 is turned on, the AP image amplifier 47A is turned off and the lateral image amplifier tube 47L is turned on. When the triode section 318 turns off in the amplifier 70, a positive trigger pulse is applied to the control grid of the thyratron tube 360A in the AP camera clutch trigger circuit 75A, to energize the clutching coil 350A, thereby releasing the latch stop 342A. The film transport shaft 339A moves the film 341A through the magnetic clutch 338A. The contact 357A is closed by reason of closure of the switch 330A and energization of the coil 329A so that the clutching coil 350A is sealed in and remains energized and the shaft 339A continues to transport film until either the switch 330A is opened or the motor supply source "e" is turned OFF as when the entire system is shut down.

The gates 234A, 234L are turned off by reason of the control voltage on the conductors 233A, 233L and prevent the passage of an exposure stop signal to the second inputs of the exposure flip-flops 251A, 251L. The second outputs of the exposure flip-flops 251A, 251L therefore remain on to maintain the multivibrators 54A, 54L on and the X-ray tubes 25A, 25L connected for continuous alternate energization in the biplane relation.

The next signal pulse on the conductors 207, 209 passes through the start switches 230a, 230d, the gates 241A, 241L, the shutter flip-flops 243A, 243L, the OR circuit 249 and into the first input of the final output flip-flop 262 via the gate 263. The final output flip-flop 262 increases the voltage level on the conductor 61 to turn the AP image tube system on and the lateral image tube system off. The lateral film transport mechanism is actuated when the internal image tube is turned off to release a corresponding latch stop 342L (not shown) in the lateral clutch trigger circuit 75L which is also held or sealed in its release position by a coil 350L (not shown) until the system is completely shut down.

At this point, the film in both cameras is being transported at the rate of 60 frames per second. The X-ray

tubes are being alternately energized 60 times per second for half cycle exposure periods each. The next succeeding wave signals alternatively provided to the conductors 207, 206 from the outputs of the Schmitt trigger 205 alternately increase and decrease the voltage level on conductor 61. Each increase in voltage turns the A-P image tube on and turns the lateral image tube off. Each decrease in the voltage level on conductor 61 turns the lateral image tube system on and the A-P tube off.

The operation of the electronic contactors 27A, 27L which control energization of the X-ray tubes 25A, 25L must be properly phased to operation of the frame rate and exposure time selector control circuit 58 so that one X-ray tube is energized when its associated image tube is turned on as a shutter and the other image tube is turned off. Coincident phasing of the operation of the shutters to the operation of the electronic contactors is substantially provided by using the same voltage source "e" throughout the two X-ray systems 22, 23. Adjustments in phasing the operation of the selector system 58 to the energization circuits for the X-ray tubes, both of which are supplied by the same voltage source "e" to maintain synchronism is by means of the phase adjusting element 203 in the phase shift circuit 202. The delay adjustment element 260 of the single shot multivibrator 258 adjusts the amount of delay required to delay operation of the image amplifier tubes as shutters relative to the operation of the electronic contactors to compensate for inherent delays in the transformation systems in the X-ray tube energization circuits.

When an exposure is terminated by releasing the foot switches 245A, 245L, the gates 241A, 241L are turned off to prevent any further start trigger signals reaching the first inputs of the shutter flip-flops 243A. However, a signal pulse on conductors 206, 208 from the first output of the Schmitt trigger 205 is still conveyed to the second inputs of the shutter flip-flops 243A, 243L so that a lateral exposure is always the last or final exposure. Releasing the foot switches 245A, 245L turns the gates 234A, 234L on so that the next output signal pulse on the conductor 207, 209 is introduced to the second inputs of the exposure control flip-flops 251A, 251L via the contacts 231c, 231f, 235c, 235f, conductors 252A, 252L. The exposure control flip-flops 251A, 251L then turn off their second outputs and turn on their first outputs so that the electronic contactors are de-energized to open the energization circuits for the X-ray tubes for further energization after the lateral exposure is made.

Positioning the OV-TV cine selector contact 238a, 238f, to engage the OV-TV contact 237a-237f also provides for 60 frames per second, half cycle exposure operation of the AP and lateral X-ray tube systems 22, 23. In addition, the selector switch 236 sets up a television system and/or an optical viewing piece selectively for viewing the output phosphors of the image amplifier tubes 47A, 47L, instead of the cine cameras 48A, 48L.

30 frames per second operation

Moving the indicator 231 to either of the 30 frame rate terminals b, c closes the switches 361A, 361L to energize relays 359A, 359L and close contacts 358A, 358L in the A-P and lateral camera circuits (again, only the AP components are shown in FIGURE 5). The film transport motors are then caused to rotate their output shafts at 1800 r.p.m. which will provide 30 frames per second transportation of the films 341A, 341L when the clutch coils 350A, 350L are energized to release the latch stops 342A, 342L. The closed contacts 358A, 358L will seal in the clutching coils 350A, 350L so that film transportation is continuous once initiated.

Closing the exposure initiating foot switches 245A, 245L permits a start trigger signal on conductor 216 to pass through the start trigger switch 230a to the first input of the shutter flip-flop 243A via the selector contact 231a, contacts 235a, 238a, conductors 240A and the gate 241A.

The same signal on the conductor 216 is also introduced into the lateral portion of the selector circuit 58 by the lateral shutter closed selector switch 230e to the second input of the lateral shutter flip-flop 243L and by the exposure stop selector switch 230f to the second input of the exposure flip-flop 251L. The second output of the A-P shutter flip-flop 243A and the first output of the lateral shutter flip-flop 243L are turned on. The control signals appearing on the conductors 248A and 248L from the flip-flops 243A, 243L are introduced simultaneously to the OR circuit 249 which produces a single signal to the multivibrator 258 which results in a delayed signal being introduced to the inputs of the gate circuits 263, 264. The gate 263 is on since the conductors 265A, 240A are energized and passes the input signal to the first input of the final output flip-flop 262 to increase the voltage level on the control conductor 61. The signal at the second output of the shutter flip-flop 243A is also introduced to the first input of the exposure control flip-flop 251A which turns the electronic contactor 27A on in the A-P circuit. The increase in voltage level on the conductor 61 turns the A-P image tube shutter system on for an A-P exposure.

One cycle later, a signal appears on the conductor 217 from the Schmitt trigger 211 and is introduced by the shutter closed selector switch 230b to the second input of the shutter flip-flop 243A in the A-P system and to the first input of the lateral shutter flip-flop 243L in the lateral system. If the selector contacts 231a-231f are at the b terminals then the exposure stop selector switch 230c introduces the same signal on conductor 217 as a stop signal to the second input of the exposure termination flip-flop 251A to turn off the AP electronic contactor 27A. If the selector switches 231a-231f are positioned at the c terminals, then the exposure stop selector switch 230f introduces a control signal from the conductor 209 as an exposure stop signal to the second input of the exposure flip-flop 251L a half cycle after the start trigger signal from the start trigger signal selector 230a. The shutter closed signal from the selector switch 230b and the start trigger signal from the selector switch 230d cause a single signal to be produced by the OR circuit 249 to the second input of the final output flip-flop 262 through gate 264 since the conductor 266 is energized. This results in a decrease in the voltage level on the conductor 61 to turn the lateral image tube system on and the A-P image tube system off. One cycle later, another output signal appears on the conductor 216 to turn the A-P shutter system on and to turn the lateral shutter system off. If the selector switch 230f is at the terminal b, the same signal causes the A-P X-ray tube to be energized and the lateral X-ray tube to be de-energized. The lateral camera is also sealed in and running, thereby transporting its film continuously at 30 frames per second. As long as the foot switches 245A, 245L are closed the system continues to run with the shutters provided by the image tubes being turned on alternately at the rate of 30 exposures per second each so as to expose each adjacent frame of the films in the cameras. The electronic contactors are opened and closed 30 times a second to provide 30 X-ray exposures per second from their respective X-ray tubes in synchronized relation with the image tubes. Opening the exposure initiating switches 245A, 245L prevents a further start trigger signal being introduced to the shutter flip-flops 243A, 243L and also to the exposure control flip-flops 251A, 251L. The system makes a final lateral exposure and then stops.

15 and 7½ frames per second operation

The operation of the system for the 15 and 7½ frame rate settings is substantially identical to the 30 frame rate setting just described except that the film transport mechanism is not continuously running. In the 15 and 7½ frames per second settings, the contacts 357, 358 remain open and the coils 350A, 350L are de-energized immediately after each energization by contacts 352A, 352L to relatch the film transport shafts 339A, 339L. In the 7½ and 15 frame rate settings, therefore, the shafts 339A, 339L

make one revolution only for each input trigger pulse supplied to each of the clutch trigger circuits 75A, 75L and thereby position a single frame for exposure. In these two frame rate settings, therefore, each time an image tube system is turned off, its film is transported one frame position only and then stops.

If one of the 15 frame rate terminals d or e are selected, then the shutter closed signals introduced to the second inputs of the shutter flip-flops are two cycles behind the start trigger signals introduced to the first inputs of the shutter flip-flops. The exposure termination signals introduced to the second inputs of the exposure flip-flops are then two cycles behind the start trigger signals if terminal d is selected and a half cycle behind if terminal e is selected. In the 7½ frame rate setting, the shutter closed signals are four cycles behind the start trigger signals. The exposure stop or termination signals are four cycles behind the start trigger signals for the terminal f and a half cycle behind if terminal g is selected.

Single frame operation

Single frame exposures are provided by closing the switches 256A, 256L. When switches 256A, 256L are closed, output signals at the number two outputs of the exposure control flip-flops 251A, 251L bias the controlled rectifiers 225A, 225L to conduct and energize the control relays 224A, 224L to open their contacts 223A, 223L. The open contacts 23A, 23L turn off the gates 241A, 241L and prevent the transmission of start trigger signals to the shutter flip-flops 243A, 243L. The contacts 223A, 223L remain held open until the foot switches are released to open. Subsequent reclosure of the foot switches again biases the gates 241A, 241L to pass another starting trigger pulse to each of the shutter flip-flops 243A, 243L. Thus, the gates 241A, 241L are turned on by initial closure of the foot switches 254A, 254L to pass one start trigger pulse each and are turned off by an exposure termination pulse and held off by the locking gates 244A, 244L until the foot switches are released, thereby permitting a single exposure only.

Although the invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. An X-ray system comprising:

- (a) an X-ray tube for providing X-ray to a subject;
- (b) supply means for selectively energizing said X-ray tube, and including an electronic contactor for selectively connecting and disconnecting said X-ray tube and a supply source;
- (c) an image amplifier tube having:
 - (i) input window means receiving an X-ray image from the subject X-rayed,
 - (ii) said input window means including cathode means for emitting electrons in the received image,
 - (iii) output window means for receiving said electrons and providing an output image, and
 - (iv) control means between said cathode means and said output window means;
- (d) bias means for biasing said output window means and said control means to enhance the flow of electrons toward said output window means and for biasing said cathode means relative to said control means so as to prevent the flow of electrons from said cathode means toward said output window means;
- (e) switch means connected to said bias means and to said cathode means for selectively connecting said cathode means to a bias potential that is positive relative to a bias potential on said control means

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to prevent thereby said flow of electrons, and for selectively connecting said cathode means to a potential that is negative relative to said bias potential on said control means thereby to permit said flow of electrons; and

(f) exposure time control means connected to said electronic contactor and to said switch means, said exposure time control means causing said electronic contactor to connect said X-ray tube to said supply source when said switch means connects said cathode means to the relatively negative potential and to disconnect said X-ray tube from said supply source when said switch means connects said cathode means to the relatively positive potential after a preselected exposure period.

2. The system of claim 1 wherein said exposure time control means includes means to initiate a preselected exposure period by causing said switch means to connect said cathode means to said ground reference potential for said predetermined period and by causing said electronic contactor to connect said X-ray tube to said supply source for said preselected period.

3. The system of claim 2 wherein said exposure time control means includes delay means to delay initiation of the operation of said switch means relative to the operation of said electronic contactor.

4. The system of claim 3 including:

(g) a shutterless camera focused in light tight relation on said output means so that a film in the camera is exposed for a period that the electrons flow to the output window means from the cathode means; and,

(h) said camera having film transport means connected to said switch means and transporting an unexposed film portion into the camera's field when the bias of the cathode means relative to the control means is changed to prevent the flow of electrons to said output window means.

5. In an X-ray system having a plurality of X-ray tubes for providing X-rays to a subject from different angles and image amplifier tubes for receiving X-ray images on their input windows and displaying intensified images on their output windows, a control system comprising:

(a) a plurality of X-ray tube energization circuits for energization said X-ray tubes for the duration of energization control signals received at their inputs;

(b) a plurality of image tube shutter circuits connected to said image tubes and normally being turned OFF and maintaining said image tubes in an off-biased condition wherein an image received at its input window is prevented from being intensified and transmitted to its output window for display purposes, each said shutter control circuit when turned ON changing the bias on its respective image tube in response to an ON signal to permit the intensification of a received image and transmission of it to its output window for the duration of said ON signal and thereby turning its image tube ON;

(c) switching means connected to each of said shutter control circuits and assuring that one shutter control circuit is turned OFF when the other shutter control circuit is turned ON; and,

(d) exposure control means connected to said shutter control circuits and to said energization circuits for energizing one X-ray tube when its respective image amplifier tube is ON while maintaining the other X-ray tube de-energized, and for energizing the other X-ray when its respective image amplifier tube is ON while maintaining said one X-ray tube de-energized.

6. The combination of claim 5 wherein said switching means comprises a high voltage flip-flop having first and second outputs, one shutter control circuit is connected to said first output and the other shutter control circuit is connected to said second output.

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7. The system of claim 5 wherein each of said shutter control circuits includes a first circuit means connecting a photocathode of the input window of its associated image amplifier tube to a positive potential to normally maintain said image amplifier tube turned OFF and a second circuit means connecting said photocathode to effectively zero potential when said shutter control circuit is turned ON by said switching means.

8. The system of claim 6 wherein each of said shutter control circuits includes a first circuit means connecting a photocathode of the input window of its associated image amplifier tube to a positive potential to normally maintain said image amplifier tube turned OFF and a second circuit means connecting said photocathode to effectively zero potential when its respective output of the flip-flop is turned ON.

9. The system of claim 5 wherein said exposure control circuit includes exposure time means for selecting the duration of the energization control signals provided to the X-ray tube energization circuits thereby selecting exposure periods.

10. The system of claim 5 wherein said switching circuit turns said shutter control circuits ON alternately in response to successive trigger signals provided to said switching means and said exposure control means includes frame rate selection means for selecting the frequency of trigger signals provided to said switching means and for selecting the frequency of said energization control signals provided to said energization control circuits whereby the frequency of the X-ray exposures may be selected.

11. The system of claim 9 wherein said switching circuit turns said shutter control circuits ON alternately in response to successive trigger signals provided to said switching means and said exposure control means includes frame rate selection means for selecting the frequency of trigger signals provided to said switching means and for selecting the frequency of said energization control signals provided to said energization control circuits whereby the frequency of the X-ray exposures may be selected.

12. The system of claim 11 wherein said exposure control means includes delay means for delaying the trigger signals relative to the energization control signals so as to compensate for delays in the energization circuits so that the energization of the X-ray tubes coincides exactly with turning on the associated image tube.

13. The system of claim 12 including:

(c) a shutterless cine camera for each image tube, said camera being focused in light tight relation on the output window of its image amplifier tubes.

14. The system of claim 13 wherein each of said cameras include film transport means connected to said shutter control means for transporting an unexposed portion of film into an exposure position when its respective image amplifier tube is turned OFF.

15. A biplane system comprising:

(a) AP and lateral X-ray tubes arranged to emit beams of X-rays at different angles to a subject;

(b) AP and lateral energization circuits connected to said AP and lateral X-ray tubes respectively for selectively energizing the X-ray tubes in response to energization initiation signals for the period of said signals;

(c) AP and lateral image amplifier tubes associated with said AP and lateral X-ray tubes respectively, each image amplifier tube having:

(i) an input window disposed to receive X-rays from its associated X-ray tube in the image of the subject X-rayed at the angle X-rayed;

(ii) intensification means for intensifying the image received at the input window;

(iii) an output window for displaying the intensified image; and,

(iv) image transmission control means for selec-

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tively permitting and preventing the transfer and intensification of the image from the input window to the output window;

(d) AP and lateral shutter control means connected to said image transmission control means of the AP and lateral image tubes respectively and normally biasing said control means to prevent the transmission and intensification of any incident X-ray images from the input windows to the output windows;

(e) switching means connected to each of said shutter control means, said switching means having alternate first and second states and switching from one state to the other in response to a trigger input signal, said switching means in said first state causing said AP shutter control means to bias the image transmission control means of its respective AP image tube to permit the intensification and transmission of the image to the output window for the period that said switching means is in said first state, said switching means in said second state causing said lateral shutter control means to bias the image transmission control means of the lateral image tube so as to permit the intensification and transmission of the received image to its output window for the period that said switching means is in said second state, and said switching means preventing intensification and transmission within the AP and lateral image tubes when said switching means is in its second and first states respectively;

(f) exposure control means connected to said switching means and to said AP and lateral X-ray tube energization circuits, said exposure control means providing control trigger signals in successive pairs to said switching means so that said switching means changes to one of said states in response to a first of the paired signals and then to the other of said states in response to a second of the paired signals, and,

(g) said switching means providing successive signals to said X-ray tube energization circuits to cause said

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AP energization circuit to energize said AP X-ray tube when said switching means is in said first state and to cause said lateral energization circuit to energize said lateral X-ray tube when said switching means is in said second state whereby transmission and intensification of images within the AP and lateral image amplifier tubes is prevented when the lateral and AP X-ray tubes are energized respectively.

16. The system of claim 15 wherein said switching means comprises a high voltage flip-flop having first and second outputs, one shutter control means is connected to said first output and the other shutter control means is connected to said second output.

17. The system of claim 16 wherein each of said shutter control means includes a first circuit means connecting a photocathode of the input window of its associated image amplifier tube to a positive potential to normally maintain said image amplifier tube turned OFF and second circuit means connecting said photocathode to effectively zero potential when said shutter control means is turned ON by said switching means.

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U.S. Cl. X.R.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,440,422 Dated April 22, 1969

Inventor(s) Jack Ball and Gunter G. Wilkens

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 2, delete "brightness" substitute -- brightness--

Column 6, line 1, delete "," at end of line.

Column 10, line 32, delete "contractor" substitute -- contactor--

Column 11, line 22, delete "be" substitute -- the --

line 58, delete "63A" substitute -- 62A --

line 72, delete "319" substitute -- 319' --

Column 12, line 67, delete "Schietific" substitute -- Scien-
tific--

Column 13, line 10, delete "36A" substitute -- 336A --

Column 18, line 28, delete "23A, 23L" substitute -- 223A, 223L --

Column 19, line 44 (claim 5) delete "energization" substitute
-- energizing --

Column 19, line 46 (claim 5) after "shutter" insert -- control --

SIGNED AND
SEALED

OCT 21 1969

(SEAL)

Attest:

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