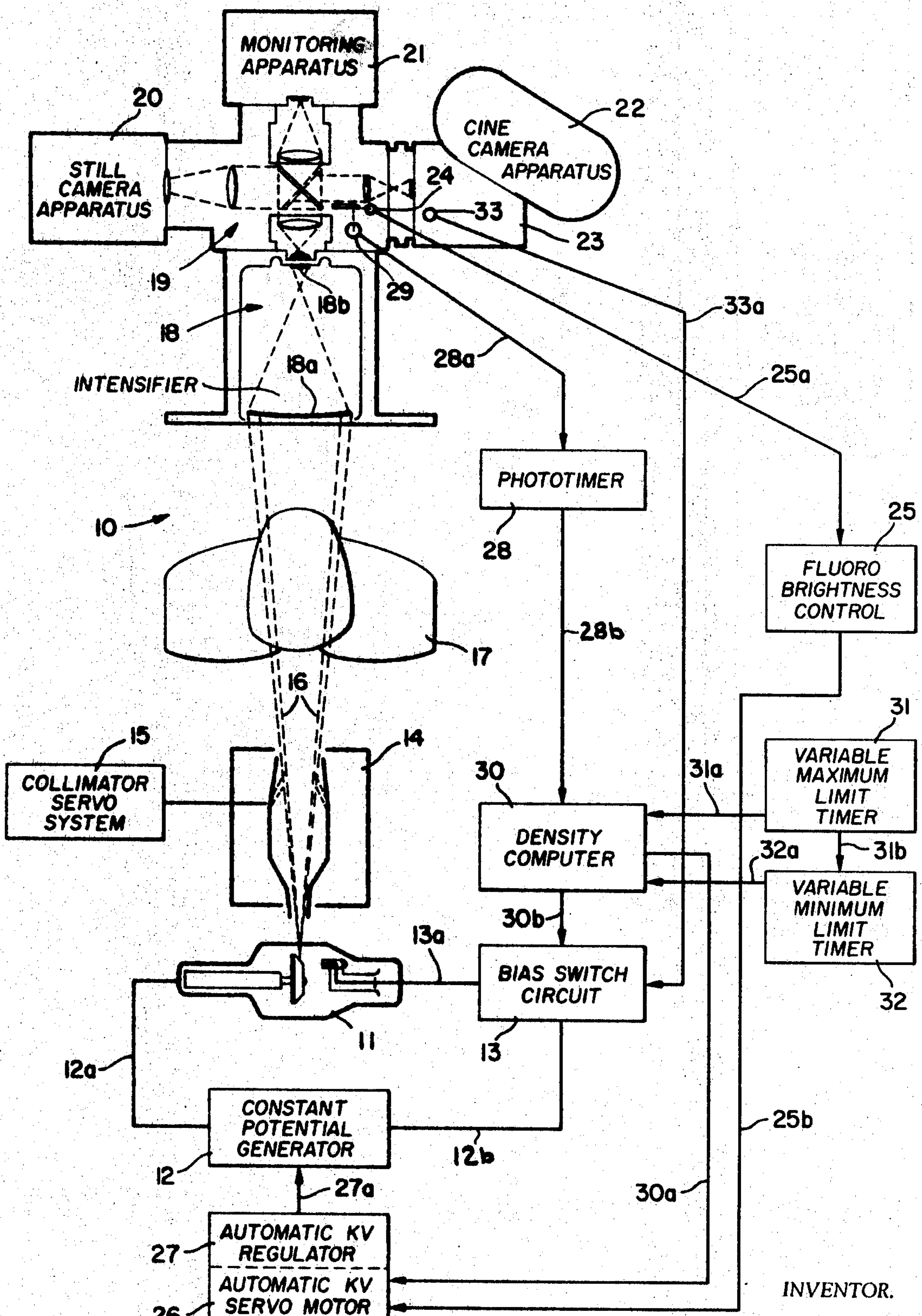
Dec. 8, 1970 J. R. CRAIG 3,546,461

AUTOMATIC CONTROL OF A NONSYNCHRONOUS CINE FLUORORADIOGRAPHIC APPARATUS

Filed Sept. 13, 1968



INVENTOR.
JAMES R. CRAIG
BY
Franklin D. Jankosky
ATTORNEY

United States Patent Office

3,546,461
Patented Dec. 8, 1970

1

3,546,461

AUTOMATIC CONTROL OF A NONSYNCHRONOUS CINE FLUORORADIOGRAPHIC APPARATUS

James R. Craig, Glenview, Ill., assignor to Litton Medical Products, Inc., Des Plaines, Ill., a corporation of Delaware

Filed Sept. 13, 1968, Ser. No. 759,643
Int. Cl. H05g 1/28
U.S. Cl. 250—95 14 Claims

ABSTRACT OF THE DISCLOSURE

A cine fluororadiographic apparatus for providing automatic regulation of the kv. applied across the secondary of the X-ray high voltage transformer. The apparatus is of a nonsynchronous type and is capable of operating at relatively high frame rates. A density computer is utilized to compare outputs from a phototimer, a maximum limit timer, and a minimum limit timer to provide a signal for automatic positioning of the kv. regulator to a desired setting.

FIELD OF THE INVENTION

This invention relates to a cine fluororadiographic apparatus and more particularly to the automatic control of a nonsynchronous cine fluororadiographic apparatus.

DESCRIPTION OF THE PRIOR ART

Pulsing systems to control the precise amount of X-ray radiation per film frame in X-ray cine systems are well known. Two basic systems that have been employed are primary pulsing and secondary pulsing. Primary pulsing systems and secondary pulsing systems control the respective power at the primary and the secondary of the X-ray high voltage transformer, respectively. As is well known, since the primary voltage is an alternating current, the primary pulsing systems are synchronous, i.e., the cameras are operated at 60, 30, 15 and 7½ frames per second. These systems have proven to be quite adequate for cine work on most studies operating in controlled exposure times of 16 milliseconds and beyond; however, when working with extremely fast moving parts of the body, for example, during a study of the heart valves or the cardiovascular system, where the vessels and arteries move very rapidly as the heart pumps blood into them, the utilization of primary pulsing systems, coupled with their inherent relatively slow frame rates, have proven to be inadequate when operating in precisely controlled exposure times in the area of 3 to 5 milliseconds.

In the past, secondary pulsing systems have utilized either a pair of grid-controlled switch tubes, commonly referred to as secondary tetrodes, or a biased-controlled X-ray tube, commonly referred to as a grid-controlled tube, to control the power across the secondary of the X-ray high voltage transformer. Secondary pulsing systems employing the tetrodes have been utilized in cine X-ray systems having a variable pulse time from 2 to approximately 12 milliseconds, being nonsynchronous, indifferent of line frequency, and having a variable speed camera. Secondary pulsing systems employing the biased-controlled X-ray tube have been utilized in cine X-ray systems having a variable pulse time from 2 to approximately 12 milliseconds, being nonsynchronous, and having a variable speed camera. In addition, other secondary pulsing systems also employing the biased-controlled X-ray tube have been utilized in cine X-ray systems having a fixed pulse time usually set at 4 milliseconds, being synchronous, and having cameras with speeds of 60, 30, 15 and 7½ frames per second.

Present cine X-ray systems for automatically controlling the density of X-ray films are of two basic types, one type automatically adjusts milliamperes (hereinafter referred to as ma.) per frame, while the other type automatically adjusts the kilovoltage (hereinafter referred to as kv.) per frame. As is well known in the art, cine X-ray systems require a much greater degree of automatic density control since the density of the body part may be continuously changing, thus necessitating rapid changes in film speed rates and/or intensity that even a skilled technician could not adjust the factors fast enough.

Automatic ma. control has great limitations in that the practical range of varying ma. is not over 2 or 3:1. The minimum and maximum ma. levels are determined by the noise level or scintillation level of the image tube system and the X-ray tube thermal capacity, respectively. Most cine X-ray systems using automatic ma. control provide a center "O" type light meter which must be controlled by a skilled technician who manually adjusts the kilovoltage to maintain the "O" setting. On the other hand, the present automatic kv. control systems require a light sensing device which either reads peak light or integrates light and controls kv. in the primary of the high voltage transformer. These automatic kv. control systems utilize either a thyratron (or SCR) phase control or a motor-driven variable automatic transformer. The automatic kv. control systems are more automatic than the automatic ma. control systems, but the automatic kv. control systems tend to "hunt."

Since the present automatic kv. control systems control the primary of the high voltage transformer, they are not compatible with the nonsynchronous cine system and particularly not with systems having variable pulsed times as there has been no attempt to integrate time and intensity when the time and the frame rate vary as a means to control the kv.

As the use of cine X-ray has increased and medical techniques have been developed to a higher degree of precision for all parts of the body, it has become quite evident that nonsynchronous cine X-ray systems are desirable because of the demand to go beyond 60 frames per second. Furthermore, variable pulse times are desirable since techniques now require extremely short times at higher ma., while other techniques require longer times at lower ma. because of thermal limitations of the X-ray tube.

Accordingly, it is an object of the present invention to provide a novel cine fluororadiographic apparatus which is automatic and does not require a skilled technician.

It is another object of the present invention to provide a novel automatic cine fluororadiographic apparatus of the nonsychronous type operating at relatively high frame rates.

It is a still further object of the present invention to provide a novel automatic cine fluororadiographic apparatus having variable pulsed times.

It is another object of the preesnt invention to provide a novel nonsynchronous automatic cine fluororadiographic apparatus which integrates time and intensity for each cine frame and utilizes this information to automatically adjust the kv.

It is yet another object of the present invention to provide a novel automatic cine fluororadiographic apparatus which acts instantaneously to changes in body part density as well as maintaining film control density over a wide range of body part thickness and body part density.

SUMMARY OF THE INVENTION

In accordance with the objects set forth above, the present invention provides a cine fluororadiographic apparatus comprising a phototimer which integrates time and intensity for each cine frame, a density computer which receives the output of the phototimer along with the respective outputs of a maximum and a minimum timer, the density computer compares the three aforementioned outputs and provides a signal, when necessary, to automatically position the kv. regulator to a desired setting.

BRIEF DESCRIPTION OF THE DRAWING

Additional objects, advantages, and characteristic features of the present invention will become readily apparent from the following detailed description of preferred embodiments of the invention when taken in conjunction with the accompanying drawing which is primarily a block diagram of a cine fluororadiographic apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawing, there is shown a cine fluororadiographic apparatus **10** in accordance with the principles of the present invention. An X-ray tube **11** is shown along with the accompanying actuation circuits, shown in block diagram form, including a constant potential generator **12** and a bias switch circuit **13**. The X-ray tube **11** is the well-known grid-controlled type. Lines **12*a*, 12*b*** and **13*a*** connect these circuits. A servo controlled collimator **14** along with a collimator servo system **15** is utilized to control the size of the X-ray beam **16** that is emitted from the X-ray tube **11**. The aforementioned components are typical of X-ray generating apparatus well known in the art.

The numeral **17** designates the schematic representation of the patient who is undergoing X-ray diagnosis. As the X-ray beam **16** passes through the patient **17** and is picked up by a standard intensifier unit **18**, the image which appears on an input phosphor **18*a*** of the intensifier unit **18** is collimated by means of a combination of electron acceleration and minification so that the image is intensified to a factor of approximately 5,000 and appears on an output phosphor **18*b***. The image is then transferred to a standard lens arrangement which is well known in the cine X-ray art. The image may then be transferred via the lens arrangement to various recording or viewing devices, for example, a still camera apparatus **20**, a monitoring apparatus **21** and cine camera apparatus **22**. The still type camera apparatus **20** may be of a standard type known in the art which is utilized for recording a particular sequence of radiographs for observation at a later time. The monitoring apparatus **21** may include a vidicon for transferring the image to a television monitor or may be viewed directly on a fluoroscopic monitoring screen, neither of the aforementioned apparatus being shown in detail. The cine camera apparatus **22**, of which this invention is primarily concerned, may be a 16 or 35 mm. variable frame rate camera, which along with a control circuit **23** is adapted to provide a movie record of the images appearing on the input phosphor **18*a*** of the intensifier unit **18**.

A fluoro kv. sensor **24**, or standard photodiode, is adapted within the lens arrangement **19** to sense the intensity of the image within the lens arrangement **19**. The signal picked up by the fluoro sensor **24** may be applied to a fluoro brightness control **25** via line **25*a***. The output of the fluoro brightness control **25** may then be applied to an automatic kv. servomotor **26** via line **25*b***. The automatic kv. servomotor **26** is shown as part of a block diagram along with an automatic kv. regulator **27** which is utilized to control the constant potential generator **12**, via line **27*a***, and thus, the kv. potential eventually applied to the X-ray tube **11**. The fluoro brightness control **25** may be manually adjusted to set the kv. to a desired level by a control device not shown.

The automatic adjustment of the kv. may be accomplished through utilization of a phototimer **28**, which is a light integrator, widely utilized in the direct film radiography technology, which integrates time and intensity for each cine frame and may be adjusted to produce a signal when optimum film density is obtained. The phototimer **28** receives signals from a standard photodiode **29**, via line **28*a***, indicative of various intensity levels. When the phototimer **28** receives an intensity signal from the photodiode **29**, and integrates that signal and determines that the predetermined optimum film density level has been established, the phototimer **28** will send a signal to a density computer **30** via line **28*b***.

The density computer **30** is logic circuit which receives two other signals, maximum and minimum exposure signals from a variable maximum limit timer **31** and a variable minimum limit timer **32** via lines **31*a*** and **32*a***, respectively. A line **31*b*** connects the variable maximum limit timer **31** to the variable minimum limit timer **32** to maintain a relationship between the timers, e.g., the minimum exposure time limit will be some set percentage less than the maximum exposure time limit. The variable maximum limit timer **31** and the variable limit minimum timer **32** may be adjusted to provide pulses to the density computer indicative of the maximum and minimum exposure time limits, respectively.

If the phototimer **28** produces a signal within the minimum and maximum exposure time limits, then the density computer **30** will send a signal to the bias switch circuit **13** via line **31*a***, which cuts off the X-ray tube **11**. However, if the phototimer **28** produces a signal before the variable minimum limit timer **32** sends a signal to the density computer **30**, the density computer will produce two output signals upon receiving the phototimer signal, a first output signal to the bias switch circuit **13** to cut off the X-ray tube **11** and a second output signal to the automatic kv. servomotor **26**, via line **30*a***, to adjust the kv. to a lower level. On the other hand, if the phototimer **32** does not produce a signal before the density computer **30** receives a signal from the variable maximum limit timer **31**, the density computer **30** will again produce two output signals, a first output signal to the bias switch circuit **13** to cut off the X-ray tube **11** and a second output signal to the automatic servomotor **26**, via line **30*a***, to adjust the kv. to a higher level. Thus, one output of the density computer **30**, via line **30*a***, may then be utilized to automatically adjust the kv. eventually applied to X-ray tube **11** by means of the automatic kv. servomotor **26** and the automatic kv. regulator **27**, while the other output controls the bias switch circuit **13**.

In the operation of the cine fluororadiographic apparatus **10**, a typical situation would involve a fluoroscopy which precedes any cine film. During the fluoroscopy, the kv. is automatically adjusted by the fluoro brightness control **25**. The kv. is automatically regulated via the fluoro kv. sensor **24** cooperating with a standard reference amplifier, not shown, within the fluoro brightness control **25**, which in turn controls the automatic kv. servomotor **26** and the automatic kv. regulator **27**. The response time of the motor-driven regulator is such that it covers a 60 kv. range in three seconds. This form of automatic density control during fluoroscopy is not new.

The skilled technician has already predetermined the factors to be used during cine filming. For a typical example, he has preset the cine camera **22** to operate at 60 frames per second, has set the variable maximum limit timer **31** to 5 milliseconds, and has selected a value of 200 milliamperes for tube operation. The variable minimum limit timer **32** has been designed and adjusted to send a pulse to the density computer **30** at a time of 60 percent of that of the variable maximum limit timer **31**, which in the present case wold be 3 milliseconds.

When the operator desires cine filming, he actuates an exposure switch, not shown, which accomplishes the following: (1) boosts the X-ray tube filament to a 200 milliampere emission value; (2) automatically directs the image splitting mirror of the lens arrangement **19** so that the output phosphor image is directed into the cine camera **22**; (3) connects certain taps on the X-ray control automatic transformer to compensate for the 200 milliampere tube load; (4) energizes the cine camera motor within the cine camera **22**; (5) energizes all the circuit components of the variable maximum limit timer **31**, the variable minimum limit timer **32**, the phototimer **28**, and the kv. regulating circuitry (**26** and **27**); (6) applies the bias voltage to the cathode of the X-ray tube **11**; and (7) closes the power to the primary of the high voltage transformer, not shown in detail.

When the camera shutter opens, a light chopper switch **33** triggers a positive going pulse in the bias switch circuit **13**, via line **33***a*. This positive going pulse cancels the negative bias and allows X-ray tube **11** to conduct. During the initial frame in a typical examination, the X-ray intensity will be too high due to the kv. being too high. The phototimer **28**, in attempting to cut the exposure time as short as possible, will produce a necessary exposure time shorter than the limit determined by the variable minimum limit timer **32**, that is, shorter than 3 milliseconds. The density computer **30** will recognize this situation and will energize the automatic kv. servomotor **26** to drive the kv. down. After three or four frames, the kv. is lowered to where the X-ray energy is such that the phototimer **28** terminates the exposure after 3 milliseconds. The density computer **30** now recognizes that this is a satisfactory exposure and the automatic kv. servomotor **26** is turned off. As long as the phototimer **28** is timing between 3 and 5 milliseconds, the density computer **30** is dormant as the exposure density will be within the correct limit. On the other hand, if there is a change in the density of a body part which requires the phototimer **28** to attempt to time longer than 5 milliseconds, the density computer **30** will recognize this situation and it will energize the automatic kv. servomotor **26** to raise the kv. Therefore, as long as the phototimer **30** is timing between 3 milliseconds (minimum time) and 5 milliseconds (maximum time) it is unnecessary to trigger the automatic kv. servomotor **26**.

Thus, although the present invention has been shown and described with reference to particular embodiments, for example, a cine fluororadiographic apparatus automatically operating within defined time limits with particular film, nevertheless, various changes and modifications obvious to a person skilled in the art to which this invention pertains, for example, time limits of 1 to 3 milliseconds and 90 mm. film, are deemed to lie within the spirit, scope, and contemplation of the invention as set forth in the appended claims.

What is claimed is:

1. A cine fluororadiographic apparatus comprising:
- an X-ray means for generating an X-ray beam;
- voltage regulating means connected to said X-ray means for regulating the kv. applied to said X-ray means;
- intensifier means receptive to said X-ray beam for producing X-ray images;
- light integrator means for determining the film density established by said X-ray images during each respective cine frame;
- timers means for providing minimum and maximum time limits;
- logic means connected to said light integrator means and said timer means for providing first output signals to cut off the operating bias to said X-ray means and second and third output signals to control said voltage regulator means; and
- cine means for recording said X-ray images.

2. A cine fluororadiographic apparatus as recited in claim **1** wherein said X-ray means comprises a grid-controlled X-ray tube, a bias switch circuit for controlling the ma. provided said X-ray tube, a constant potential generator, and collimator means.

3. A cine fluororadiographic apparatus as recited in claim **2** wherein said voltage regulating means comprises an automatic kv. regulator and an automatic kv. servomotor.

4. A cine fluororadiographic apparatus as recited in claim **3** wherein light integrator means comprises light detecting means for receiving the intensity of said X-ray images during each respective cine frame and a light integrator having a predetermined optimum film density recognizing level.

5. A cine fluororadiographic appartus as recited in claim **4** wherein said light integrator means provides an output signal indicative of said optimum film density recognizing level having been established.

6. A cine fluororadiographic apparatus as recited in claim **5** wherein said timer means comprises a first timer which provides a minimum time limit signal and a second timer which provides a maximum time limit signal.

7. A cine fluororadiographic apparatus as recited in claim **6**:
- wherein logic means is adapted for receiving said light integrator means output signal, and is further adapted for receiving said minimum time limit signal and said maximum time limit signal from said first timer and said second timer, respectively;
- wherein said logic means is adapted for providing a first output signal to cut off said operating bias to said X-ray means if said light integrator output signal arrives at said logic means between the period that said first timer output signal and said second timer output signal arrive at said logic means;
- wherein said logic means is adapted for providing said first output signal to cut off said operating bias to said X-ray means and said second output signal to said voltage regulating means for lowering the kv. applied to said X-ray means if said light integrator output signal arrives at said logic means prior to the time that said first timer output signal is due to arrive at said logic means; and
- wherein said logic means is adapted for providing said first output signal to cut off said operating bias to said X-ray means and a third output signal to said voltage regulating means for raising the kv. applied to said X-ray means if said second timer output signal arrives at said logic means prior to the time that said light integrator output signal arrives at said logic means.

8. A cine fluororadiographic apparatus as recited in claim **7** wherein said cine means comprises a cine camera and a control circuit including a light chopper switch means for providing a trigger to allow said grid-controlled X-ray tube to conduct.

9. A cine fluororadiographic apparatus as recited in claim **8** wherein said cine camera is a 16 mm. variable frame rate camera.

10. A cine fluororadiographic apparatus as recited in claim **8** wherein said cine camera is a 35 mm. variable frame rate camera.

11. A cine fluororadiographic apparatus as recited in claim **8** wherein cine camera is a 90 mm. variable frame rate camera.

12. A cine fluororadiographic apparatus as recited in claim 1 wherein said timer means is adjustable for providing said minimum time limit at a fixed percentage of said maximum time limit.

13. A cine fluororadiographic apparatus as recited in claim 6 wherein said minimum time limit signal and said maximum time limit signal are provided 3 and 5 milliseconds, respectively, after the exposure of a cine frame.

14. A cine fluororadiographic apparatus as recited in claim 1 wherein said logic means includes a density computer having a first input from said light integrator and a second and third input from said timer means, said density computer further having a first output to said voltage regulating means and a second output to said voltage regulating means.

References Cited

UNITED STATES PATENTS

2,972,681	2/1961	Lusby, et al.	250—65
3,109,093	10/1963	Arrison et al.	250—65
3,424,901	1/1969	Kok	250—65X

ARCHIE R. BORCHELT, Primary Examiner

U.S. Cl. X.R.

250—65, 77