

[54] X-RAY APPARATUS FOR DISPLAYING IN SLOW MOTION TISSUES WHICH MOVE WITH THE RHYTHM OF THE HEART

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Related U.S. Application Data

[63] Continuation of Ser. No. 281,117, Aug. 16, 1972, abandoned, which is a continuation of Ser. No. 93,089, Nov. 27, 1970, abandoned.

Foreign Application Priority Data

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[58] Field of Search..... 250/322, 401, 402

[56] References Cited

UNITED STATES PATENTS

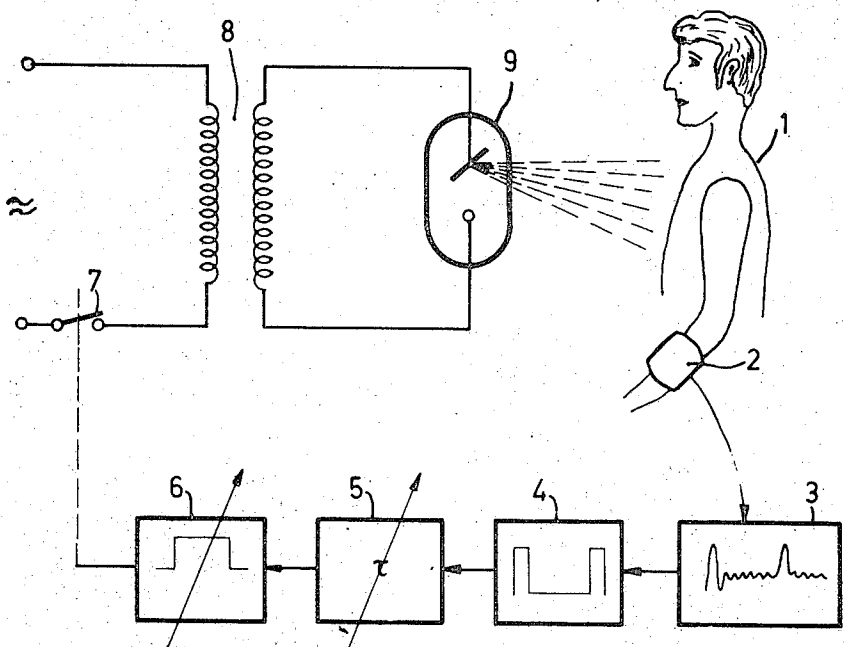
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[57] ABSTRACT

A method of X-ray examination of objects that move in rhythm with the heart wherein the image information is switched on and off in synchronism with the heart action. In a preferred embodiment, the high voltage supply of the X-ray tube is switched on and off at the heart frequency and is on for a period that is short compared with the duration of one heart action.

2 Claims, 2 Drawing Figures



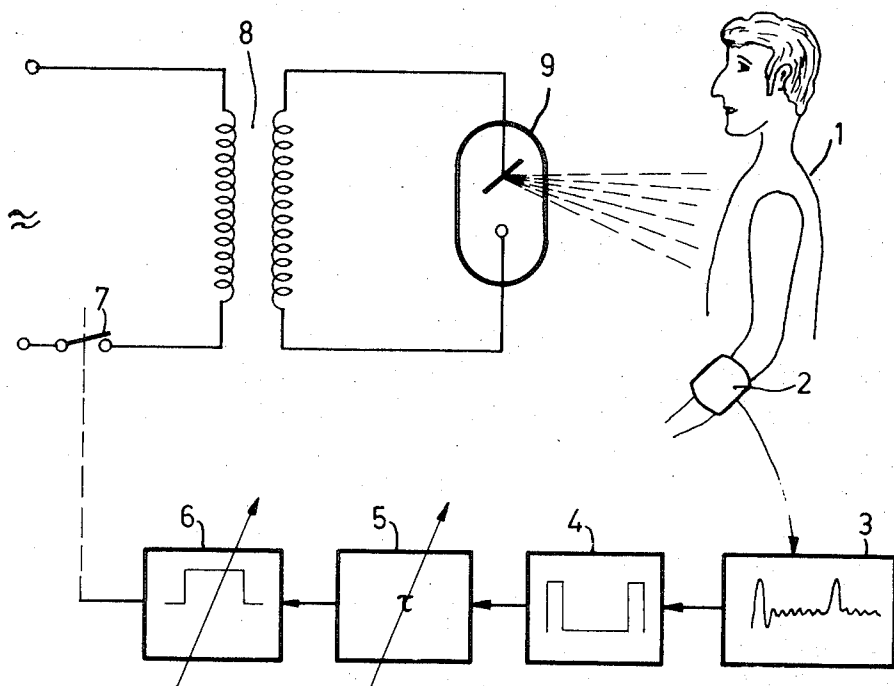


Fig. 1

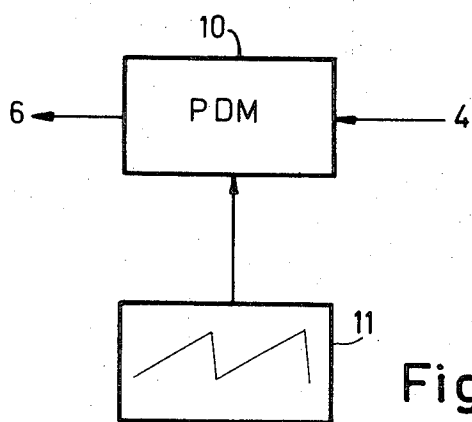


Fig. 2

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X-RAY APPARATUS FOR DISPLAYING IN SLOW MOTION TISSUES WHICH MOVE WITH THE RHYTHM OF THE HEART

This is a continuation of application Ser. No. 281,117, filed Aug. 16, 1972, now abandoned, which application was a continuation of application Ser. No. 93,089, filed Nov. 27, 1970, now abandoned.

This invention relates to a method of X-ray examination of objects that are moved in rhythm with the heart. When examining such objects, for example, the tissue surrounding the heart (in thorax radiographs) or when examining the blood vessels, blurring due to movements is caused both in radiographs and in X-ray screening. The lack of sharpness due to movements in X-ray screening is determined by the inertia of the image transmission system, particularly of the X-ray image intensifier and of the television camera tube, so that only a blurred representation of rapidly moved objects can be obtained.

The lack of sharpness due to movements in radiographs may be minimized by using the shortest possible exposure times, but this approach is limited by the power of the X-ray apparatus. The lack of sharpness in X-ray screening has hitherto been unavoidable.

An object of the invention is to develop a method which avoids unsharpness due to movements in X-ray examination of organs moved in the rhythm of the heart. According to the invention this is achieved by switching the image information on and off at least approximately in rhythm with the heart. In one embodiment of the invention the image information is switched on and off by switching X-rays on and off. As an alternative, the image information could be switched on and off by arranging a rotating diaphragm in front of the film or by darkening the image intensifier and/or the television camera tube in screening. However, this possibility is inconvenient in as much as the X-ray dosage received by the patient is considerably increased as compared with a normal radiograph or screening.

Further details and advantages of the invention will be described more fully with reference to an embodiment shown in the drawing, in which:

FIG. 1 shows an arrangement for carrying out the method embodying the invention in which the switching on and off of the X-rays is accurately synchronized with the rhythm of the heart, and

FIG. 2 shows an arrangement for carrying out said method in which the synchronisation with the rhythm of the heart is not completely accurate.

FIG. 1 shows a patient 1 whose cardio-action voltages are picked up by means of cuff electrodes (the drawing only shows the cuff) and applied to an electrocardiographic apparatus 3. The cardial stresses produce, in a pulse shaper 4, a pulse sequence the periodicity of which corresponds with the periodicity of the cardial action. This pulse sequence is delayed by a delay member 5 by an adjustable time interval and applied to a further pulse shaper 6, which simultaneously amplifies the pulses and which supplies at its output pulses whose duration is adjustable. The pulses supplied by the pulse shaper 6 actuate — during their period — a switch 7 which is included in the primary circuit of the high-voltage transformer 8 of the X-ray tube 9. Thus the X-ray tube 9 supplies X-ray pulses the duration of which corresponds with the duration of the

pulses supplied by the pulse shaper 6 and the frequency of which corresponds with the frequency of the heart. Therefore the radiation also penetrates the patient 1 in phase with the cardial action so that a sharp image is obtained provided that the duration of the pulses is chosen to be short as compared with the duration of a heart action (for example, 20 msec to 1 sec). The radiograph or the screening image become sharper when the pulse duration is shorter. This involves, it is true, a reduction of the radiation power of each X-ray pulse, but this decrease in power can be compensated for to a given extent by an increase in the heating current of the X-ray tube — the heating current supply is not shown for the sake of clarity — particularly in X-ray screening.

It should be noted that in X-ray technology switches controlled in the heart phase are known (for example, for heart-phase controlled stereoscopic graphs). However, in this case, only a single X-ray pulse per radiograph is supplied in a given phase of the heart action. In contrast, in the present method a plurality of X-ray pulses are supplied in a single radiograph and especially in X-ray screening always in the same position of the object, which pulses are summated on the film. In X-ray screening the dosage may be reduced by storing the image in appropriate stores (for example, magnetic recording or the like) until the next-following X-ray pulse.

The position of the X-ray pulses relative to a given phase of the heart action, for example, the so-called R-peak in the electro-cariogram, may be adjusted at will by means of the adjustable delay member 5. If this adjustment is continuously changed during screening, the examined object may be observed during the separate phases of the heart action.

In some practical cases it also is desired to examine, in X-ray screening, the course of the movements, be it not with the actual rate. As in the case of a stroboscope this may be achieved in that the X-ray tube is driven at a pulse frequency slightly differing from the heart frequency.

For this purpose the adjustable delay member 5 has only to be replaced by the circuitry shown in FIG. 2. The pulses supplied by the pulse shaper 4 are applied to a known type of pulse duration modulator 10 which produces pulses whose duration depends upon the instantaneous value of a sawtooth voltage applied to its second input and supplied by the sawtooth generator 11. If the rear flanks of these pulses are utilized for controlling the pulse follower 6, a sequence of pulses is obtained after the pulse follower 6, the phase position of which sequence relative to the heart action voltage depends upon the instantaneous value of the sawtooth voltage. By suitably proportioning the pulse duration modulator and the sawtooth generator it can be ensured that the phase shift during each leading edge of the sawtooth voltage lies between a very short value and the duration of one heart action. The course of the movement is then extended in time in the ratio between the heart frequency and the sawtooth frequency. Therefore the frequency of the sawtooth voltage has to be low as compared with the frequency of the heart action voltage. It is more efficient to use a sawtooth generator of adjustable frequency so that the expansion in time may be varied at will. The switch 7 may effectively be formed by a thyristor which makes it possible to use the shortest possible switching-on periods.

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What is claimed is:

1. An X-ray apparatus comprising an X-ray tube, a source of high voltage for the X-ray tube, a switch coupling said tube and voltage source for switching the tube voltage on and off at substantially a rate which is slightly different from the heart frequency of a person under examination, first means responsive to the heart frequency of the person for deriving a first sequence of pulses with a repetition rate equal to the heart frequency, second means for deriving from said first sequence of pulses a second sequence of pulses of adjustable duration for controlling said switch, a delay member with a continuously variable delay being coupled between said first and second means, and control means connected to said delay member to vary the

delay in a predetermined manner whereby the portion of the person being examined is displayed moving in slow motion for critical examination of the portion in motion.

2. An apparatus as claimed in claim 1 wherein said delay member and said control means connected to said delay member comprise a pulse duration modulator, and a sawtooth voltage generator coupled to and controlling said pulse duration modulator so that it supplies pulses whose duration depends upon the instantaneous value of the amplitude of a sawtooth voltage supplied thereto, the trailing edge of the produced pulses being utilized for controlling the switch.

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