Dec. 2, 1969 | Y. PALTI | 3,482,093

FLUOROSCOPY

Filed Nov. 30, 1966

FIG. 1

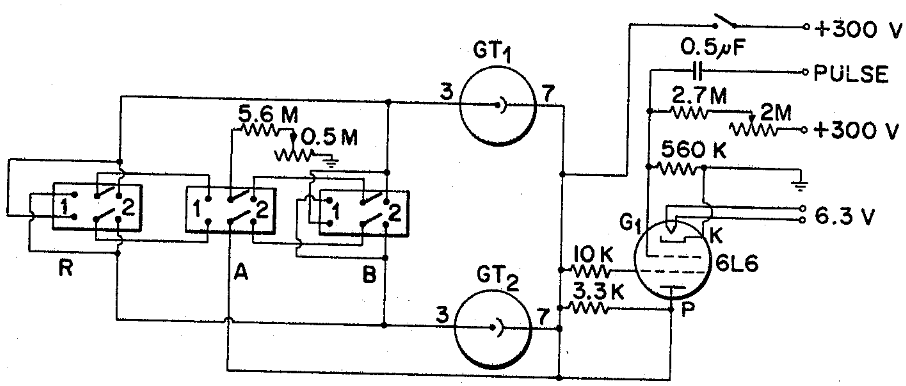


FIG. 2

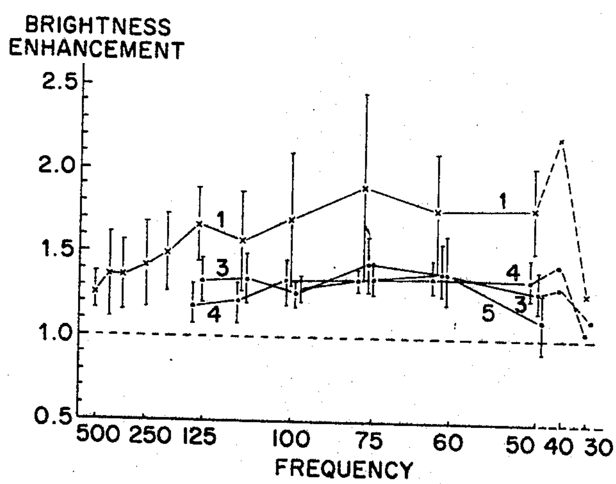
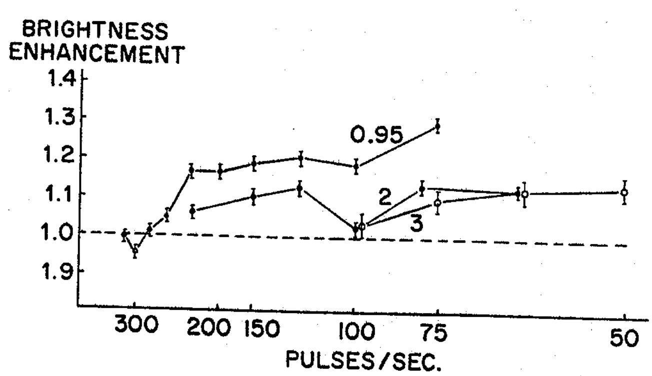


FIG. 3



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FLUOROSCOPY

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U.S. Cl. 250—53 1 Claim

ABSTRACT OF THE DISCLOSURE

The present disclosure relates to improvements in fluoroscopy and, more particularly, a system of fluoroscopy by which the amount of radiation to which the examined and examining personnel are subjected is reduced. Such reduction is accomplished by striking the fluoroscent screen with pulses of radiation, rather than a continuous stream of radiation. This is accomplished by using a moving mechanical screen or shutter or by using an electronic pulse generator in the X-ray machine circuit.

BACKGROUND

Fluoroscopy of humans by means of X-ray is very fequently used in various diagnostic and surgical procedures. Recently the use of this convenient and important examination tool has been drastically curtailed because of the fear of cumulative effects of radiation, which may cause severe damage. As the method of fluoroscopy is of considerable diagnostic value, any method which is adapted to decrease the amount of radiation applied to the examined person is of considerable value.

During the conventional fluoroscopy of still patients some of the radiation applied to the patient reaches the examiner who may be exposed to dangerous cumulative effects. A similar problem arises in the X-ray examination of welded, cast and other articles for the detection of manufacturing flaws. Any method which decreases the required output of an X-ray machine, makes possible the use of such machines which are safer and of simpler and less expensive construction.

In order to decrease the quantity of applied radiation, various optical and electronic devices have been developed. Among these there may be mentioned the use of a fluoroscent screen in conjunction with an image intensifier, adapted to result in an image of adequate brightness with substantially decreased intensity of radiation. Such intensifiers are rather expensive, and devices of equivalent performance, but of substantially decreased cost are widely sought.

Conventioinal X-ray machines make use of continuous radiation (which may be of the frequency of the current used, such as 50 or 60 cycles), and after passing through the tissue the radiation impinges on a fluoroscent screen, where an image is obtained which corresponds roughly to the intensity of the impinging radiation.

SUMMARY

In accordance with the present invention there is provided an X-ray fluoroscope having a source of X-rays and a fluorescent screen in which the source of X-rays is arranged to emit X-rays intermittently at an adjustable repetition frequency in the direction of the screen.

Further in accordance with the invention there is provided a method of examining welded, cast and other articles for the detection of manufacturing flaws by examining them with an X-ray fluoroscope, characterized in that the fluoroscope employed is a fluoroscope as aforesaid.

The source of X-rays may be an X-ray tube provided with a grid or other control electrode (e.g. an electrode arranged to deflect the electron beam away from the target) by which the generation of the X-rays is rendered intermittent, or by supplying the tube's anode with pulsatile potential. For example, a high frequency pulse generator may be placed between the power source and the X-ray tube of the fluoroscope. Alternatively the stream of X-rays may be interrupted with a mechanical shutter. Advantageously the repetition frequency at which the X-rays are emitted in the direction of the screen and the time fraction of the cycle for which the X-rays are emitted in the direction of the screen are both variable. The intensity of the X-rays emitted in the direction of the screen is preferably also variable.

DRAWING

FIG. 1 is a schematic circuit diagram of a pulse generating circuit for providing X-ray pulses in accordance with the present invention; and

FIGS. 2 and 3 are graphical representations of screen brightness based on various pulse frequencies.

DESCRIPTION

It will be noted that when the actual generation of the X-rays is rendered intermittent, all parts of the screen tend to be affected simultaneously by the intermittent effect. However where a mechanical shutter is provided, there will often be a tendency for the different parts of the screen to be affected in sequence; this is especially true where the shutter is a rotary device having parts which are substantially opaque (e.g. formed of lead), and apertures or other parts which are transparent, to the X-rays or having parts of markedly different transparencies to the X-rays. A mechanical shutter in the form of a disc, with a variable speed drive, which has a transversely movable axis of rotation and which is divided into transparent and opaque parts bounded by generally radial, but appropriately non-linear boundaries, may be employed to vary both the repetition frequency and the time fraction of the cycle for which the X-rays are emitted in the direction of the screen.

In place of a mechanical shutter, rotating disc or otherwise, an electronic system may be used. Such a system may merely comprise a variable pulse generator in the X-ray machine circuit. Such a pulse generator may be located immediately before the X-ray tube in the circuit, or, if desired, the entire power input to the X-ray machine may be controlled by such a pulse generating circuit.

Various other alternatives are also possible including mechanical switching devices. For example, power to the X-ray tube or the machine may be controlled with a rotating disc switch having electrically conductive and insulating areas thereon and an electrically conductive element sliding along the surface of such rotating disc.

For convenience of description, reference will be made hereinafter to pulses of the radiation. Actual pulses are obtained only when the radiation from the X-ray tube is cut off or reduced and then returned to its former level in each cycle. They are not obtained with the mechanical devices such as shutters which do not affect all parts of the screen simultaneously but it will be understood that references to pulses are to be taken as including such shutters unless the context otherwise demands.

In using the apparatus the frequency, duration and intensity of the pulses will be adjusted so as to result in a bright image, yet with substantial decreased total quantity of radiation as compared with conventional methods.

The brightness of the fluorescent screen depends on the intensity of the radiation and to a lesser degree on its frequency, the efficiency of most screens being somewhat higher at higher frequencies. The total amount of emitted light depends also on the total duration of irradiation. It would be expected that the use of pulses totalling say half the time of observation would result in an image of about half or slightly more than the intensity of continuous radiation of equal intensity. This would be found to be true if the light emitted by the fluorescent screen were measured with photometric means, but the perception of light-intensity (brightness) by a human observer depends on the intensity of the light and on its distribution in time. If the light is applied in pulses, there is obtained the physiological phenomenon called "sommation," according to which the application of the stimuli results in an effect which is considerably greater than the time average of the individual stimuli. The sommation gives rise to a bigger and longer nervous response per pulse resulting in a perception by the observer of increased intensity and prolonged duration as compared with a continuous stimulus of integrally equal total radiation. The prolongation of perception is usually due to the development of a repetitive response, in this case at some levels beyond the observer's receptors themselves.

There exists a critical fusion frequency (CFF), which varies between about 20–80 pulses per second depending upon the intensity of the light. At this, or at a higher frequency, there is obtained an apparently continuous image. The frequency of pulses used for fluoroscopy according to the present invention is preferably above the CFF, so as to give the observer the impression of a continuous image. It was found experimentally that when the duration of a light pulse is around 1 millisecond and the pulse repetition rate is around 50 pulses/sec. (which is over the CFF for light intensities obtained by fluoroscopic screens) the sensation of brightness is enhanced (see FIG. 2). Such pulses give a sensation of brightness equivalent to the brightness of a continuous source of light, the energy output of which is from 2 to 3 times larger than the integral output of the pulsatile light.

The pulse duration and frequency which give the best brightness enhancement depend on the size and intensity of the light source, on the degree of dark adaptation of the observer and on his degree of fatigue. For this reason the repetition frequency at which the X-rays are emitted in the direction of the screen and the time fraction of the cycle for which the X-rays are emitted in the direction of the screen should preferably both be variable as also should the intensity of the X-rays so that the observer is able to choose the combination of parameters which gives the optimal sensation with the minimal total output of radiation.

Advantageously means are provided to give the observer information on the rate at which X-radiation is being received through the screen. Such means may, for example, be a radiation meter or a badge containing piece of film which is developed after a known period and compared with a standard.

The controls provided should conveniently enable the observer to adjust the pulse duration within the range from 0.3 to 3 milliseconds and preferably less than 1 millisecond. They should also enable the repetition frequency to be adjusted within the range of from 30 to 150 pulses per second, e.g. from 50 to 75 pulses per second in order to get the best results under the referred different conditions. Intensity control should, of course, also be provided. Under some conditions the image might actually be brighter than given by the unpulsed source since the efficiency of the fluoroscopic screen is usually better for intermittent illumination.

FIG. 1 is a schematic diagram of a system which emits constant and pulsatile light. In the drawing:

G.T.—Sylvania type R1131C Glow Tube
Pulse—Square pulse input from Tektronix type 161 pulse generator

A, B—Manually operated switches
R—Relay operated switch

When the cathode (3rd leg) of a Glow Tube is connected to the plate of the penthode GL6, it generates square light pulses. When it is connected to the ground it generates a continuous light, the intensity of which can be controlled by a potentiometer.

With switch A in position **2** and switch B in position **1** GT_1 emits pulses of light while GT_2 continuous light. On turning B to **2**, GT_1 begins to emit continuous light and GT_2 pulsatile light. When A is in position **1** the switch R replaces B in the circuit and it automatically switches from position **1** to **2** every 1 or 2 seconds. Under these conditions each Glow Tube emits alternatively every 1–2 seconds continuous or pulsatile light.

The mean light enhancement achieved by the use of the present invention may be illustrated by employing the Glow Tubes GT_1 and GT_2 of FIG. 1 to illustrate the response of a fluoroscopic screen to continuous and pulsed X-ray beams. However, for actual X-ray tube control, one or both of these glow tubes could be replaced by a X-ray tube in the manner illustrated for the Glow Tubes in FIG. 1 so that the X-ray tube would be pulsed by the variable pulsing circuit.

Light enhancement is the relationship between the total light energy emitted in pulsed illumination unit time and the total light energy emitted in continuous illumination. This may be charted, as illustrated by FIGS. 2 ad 3, by making calculations according to the following equation:

$$\frac{Vc \cdot Pi}{Vp \cdot Pd} = \text{enhancement}$$

where

Vp=the light intensity of one pulse;
Vc=the light intensity of a continuous source;
Pi=the duration of time between the beginning of a pulse and the beginning of the pulse which follows it;
Pd=the duration of the pulse

The graph of FIG. 2 illustrates the mean light enhancement calculated at various pulse frequencies using a circuit similar to that of FIG. 1 including a continuous glow tube source and a pulsed Glow Tube source.

The graph of FIG. 3 illustrates the mean light enhancement calculated at various pulse frequencies using a single light source which alternately produced continuous and pulsed illumination in the manner described in connection with the circuit of FIG. 1. It will be understood that an image intensifier may be used with the apparatus and method of the present invention to give additionally improved results.

What is claimed is:

1. A method for minimizing radiation in a fluoroscope while maintaining brightness perception by achieving brightness enhancement at a frequency above the critical fusion frequency range for a fluoroscopic screen which includes directing an X-ray beam at a fluoroscopic screen and pulsating said beam at a frequency of 30–150 pulses per second but above a critical fusion frequency falling within the range of from 20 to 80 pulses per second for fluoroscopic screens to form square wave pulses having a pulse duration of from 0.3 to 3 milliseconds.

References Cited

UNITED STATES PATENTS

2,617,046	11/1952	Douma et al.	250—102
2,790,085	4/1957	Fransen et al.	250—65
2,905,827	4/1959	Graves	250—65
2,937,277	5/1960	Euler, Jr. et al.	250—65
3,277,302	10/1966	Weighart	250—102

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