March 29, 1949. J. DE MENT 2,465,676

X-RAY STROBOSCOPE

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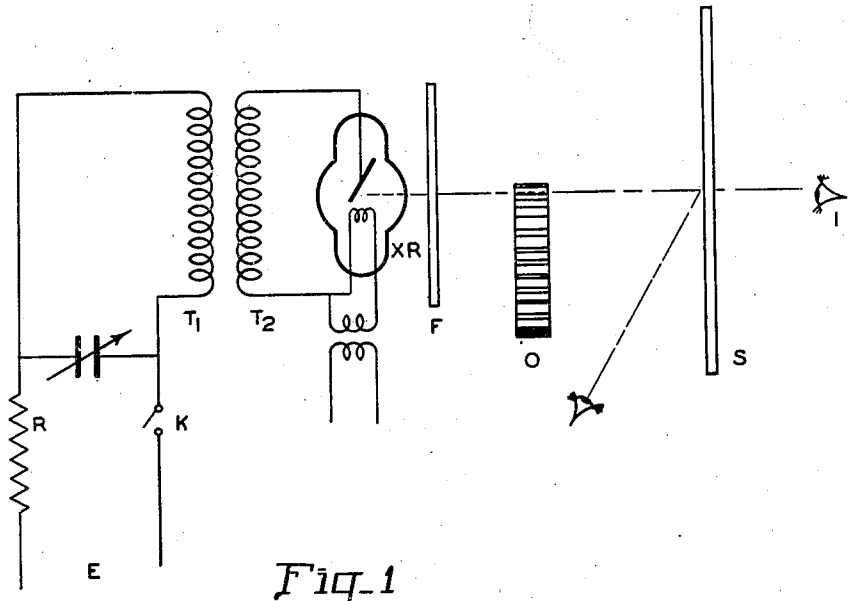


Fig. 1

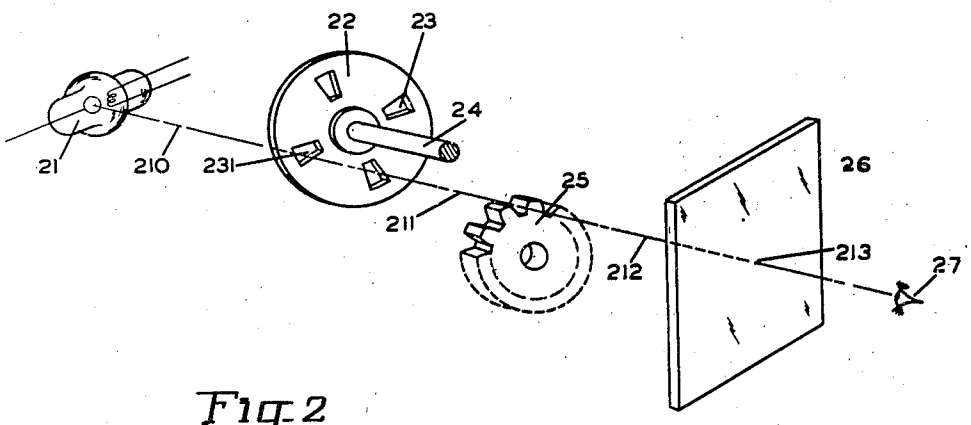


Fig. 2

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X-RAY STROBOSCOPE

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2 Claims. (Cl. 250—61)

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The present invention relates to method and apparatus by which X-ray fluoroscopic and/or radiographic observation of moving objects is achieved.

It is among the objects of the present invention to make available for medical roentgenology an X-ray apparatus that permits inspection of the interior of the human body. The present invention is directed to fluoroscopic and radiographic study of moving parts within the human or other animal body, e. g., the heart in motion.

The present invention has as an object for industrial roentgenology the accomplishment of X-ray fluoroscopic and/or radiographic inspection of the interior structure of a machine during actual operation. Thus, the present invention, may be applied to such industrial work as the study of a steam engine or gasoline combustion engine while these engines are in operation.

Among the objects of the present invention is to make available X-ray stroboscopic photography for the arts, sciences, and industries. Thus, in ballistics work, X-ray stroboscopic means permit roentgenography of a high velocity projectile as it leaves the muzzle of a gun, or the instantaneous X-ray stroboroentgenography of a projectile at the instant of impact with its target, enabling appraisal of the interior structure and condition of fragments and shrapnel derived from the projectile at its burst.

The present method of X-ray fluoroscopy and radiography permits examination of the interior of an object while immobile, and at times, while the same object is in motion, though this latter aspect of the art has always been in need of improvement. For example, the radiography of moving objects may at times be accomplished by brief exposures involving high speed photographic media and single large bursts of X-ray energy. But the means and apparatus for this work are not available to all who wish to use them.

Therefore, an object of the present invention is to permit at low cost, and without expensive or complicated equipment, X-ray fluoroscopic examination and/or roentgenography of a body in motion.

Another object of the present invention, an outgrowth of the abovedescribed limitation in the present art, is to permit an actual inspection of the interior of a moving body while it is actually in motion. During operation a machine, for example, may exhibit structural defects and internal changes that cannot be detected by either inspection of the object in a motionless state or the object radiographed in a single exposure with an ultrasensitive photographic medium.

Briefly, the present invention comprises a heretofore undiscovered and novel departure from the conventional art. It essentially depends upon variably intermittent X-ray beams and their synchronization with the motion of the moving object under study. Thus when, in the present invention, the frequency of interruption of the X-ray beam corresponds to the frequency or periodicity of motion in the body, that body appears to be motionless. As this synchronism is attained, the motion of the body appears to lessen.

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Moreover, if a burst of X-ray energy is synchronized so as to impinge upon a rapidly moving object at the same instant as that object is exposed to the image-recording nature of a photographic medium, and this synchronization of impingement with a given phase in the periodicity of movement of the mobile object is likewise attuned or synchronized with a photographic image-reproducing medium, then that image-reproducing medium will subsequently, after repetitious exposure of the moving body during a given phase in the periodic or oscillatory phase of its movement, photographically reproduce that body radiographically in only that phase of its motion.

These and similar effects are known to the present art as the stroboscopic effect, and the definition of stroboscopic light, stroboscopic photography, and stroboscopic inspection are essentially the same for purposes of the present invention, save by the employment of X-ray, instead of the usually neon-generated light, results can be achieved that fall well outside of the scope of action of the visible light stroboscope.

In the accompanying drawings of my X-ray stroboscope, two of the simpler designs of the same invention are illustrated.

In the drawings:

Fig. 1 is the form of my invention that employs a relaxation oscillator as an interruption means; and

Fig. 2 is of the same invention, except that it employs a mechanical interrupter.

Further describing the apparatus diagrammatically indicated in the drawing. In Fig. 1, E is the source of electromotive force, K a switch, R a resistance, C a variable condenser, T_1 and T_2 the primary and secondary windings of a high tension transformer, and XR an X-ray tube. The X-ray tube XR shown in Fig. 1 is a self-rectifying Coolidge tube giving half-wave rectification, which does not limit the values of the present X-ray stroboscope. A "gas" tube may also be employed in a similar circuit instead of the Coolidge tube for securing variably pulsating X-ray beams over a wide range of frequencies. The moving object, say a gear under inspection, is designated as O, with S a luminescent screen observable by the eye at either 1 or 2.

In Fig. 2, the same invention employs mechanical interrupting rotating disk apparatus. The numerals 21 refer to the X-ray tube, which may be either the so-called "gas" tube or the hot-filament or Coolidge tube, 210 to the beam of X-ray

issuing continuously from tube 21, 22 to an X-ray opaque rotatable disk, 23 to apertures therein, and 24 to a moving motor shaft causing said disk 22 to rotate. The numerals 231 further refer to an aperture within the trajectory of the X-ray beam 210, and the numeral 211 indicates the variably interrupted or discontinuous beam of X-rays produced by movement of disk 22 and the seriatim passage of beam 210 through apertures 23.

Furthermore ,the numerals in Fig. 2 show a moving object under X-ray stroboscopic examination, herein schematically represented by a moving gear 25, the X-ray stroboscopic image of which is designated by 212, the latter of which impinges upon 213 of the luminescent screen 26 so as to be perceived as visible light by the eye 26.

In Figs. 1 and 2, the letter S and the numeral 26 respectively indicate luminescent screens, of a nature hereinafter disclosed, but these may be supplanted by photographic film or plate and/or the intensifying screens well known to the art of radiography.

The X-ray stroboscope relies upon the means well known to the art for stroboscopy, insofar as the production of variably periodic or intermittent light pulses and their synchronization or other relationship to the moving object or periodic motion under visual or photographic X-ray inspection may be concerned, and therefore does not purport to claim such mechanical and electrical means and methods as are well known to the art. Whereas the present invention relies upon certain of the existing principles of the current art of stroboscopy, it nevertheless extends optics principles and means for interpretation into fresh fields as will be explained.

The means for the production of intermittent light pulses for stroboscopy may roughly be divided into two kinds: (*a*) electrical or electronic and (*b*) mechanical.

The mechanical means are exemplified by a rotating X-ray opaque disk, say of a dense metal like lead, over the X-ray energy source. This disk or shutter is provided with one or more slots or apertures through which the X-rays may pass. The X-ray opaque disk rotates or otherwise moves in such a fashion so as to permit different rates of speed, according to the application. This may conveniently be accomplished by means of a rheostat or resistor in the electrical line supplying the motor which causes the rotation or movement of the disk or shutter.

A simple example of an electric oscillator is that known to the art as a relaxation oscillator. In its most rudimentary form, the relaxation oscillator consists of a condenser connected in parallel with the source of E. M. F. energizing the light-emitting unit, and a resistance in series. Both condenser and resistance are preferably of the variable kind.

In operation, a switch or key is employed to close the circuit. The condenser becomes charged until the potential difference between the plates reaches the sparking potential, after which the discharge takes place. As the condenser voltage drops, the discharge eventually ceases, then begins to build up with a rise in plate potential, and the process is again repeated.

If the time of discharge is small compared with the time required for recharging the condenser, the periodic time of oscillation is given by:

$$T=CR \log (E-V_b)/(E-V_c)$$

in which T is the periodic time, E is the applied E. M. F., and V_c and V_b are the sparking and extinction potentials respectively of the unit in the circuit drawing the E. M. F.

A range of oscillations varying between radio frequency and two discharges per minute can be preferentially obtained in this way, which probably embraces the frequency extremes in most motion study.

On the basis of this simple relaxation oscillator circuit, many refinements and amplifications have been constructed. These are well known to the art. Thus, stroboscopic X-rays or variably intermittent X-ray beams can be secured with circuits employing a Thyratron tube. Sundry mechanical and electromechanical means are also well known to the art, and representative means include vibrating hammer, solenoid, rotary contact breakers, and others. These in general may be employed in variably oscillating the E. M. F. supplying the high tension equipment for an X-ray apparatus with a self-rectifying X-ray tube.

In the present invention, the X-ray stroboscope, irrespective of the nature of the X-ray tube, whether it be the so-called gas-type tube or the hot-filament Coolidge tube, the high tension is pulsed. The reason for this in the case of the gas or ion tube is evident. In the case of the hot-filament tube, the filament is left continuously "on" or incandescing, since with high frequencies it would not be possible to turn electron emission off and on instantaneously, and coincidently in view of the fact that the filament obeys the radiation laws regarding hot bodies.

While it is not necessary to employ D. C. or rectified high tension E. M. F. to energize the X-ray tube, I point out that D. C. E. M. F. which has been previously rectified into half or quarter wave forms is a preferred embodiment of my invention. In such a case, the oscillation must proceed along lines different than smooth or waveless D. C. high tension. This is to say that calculations of frequency for comparatively smooth D. C. high tension will be different than stroboscopic X-ray energy secured in the oscillation of half-wave D. C.

With the X-ray stroboscope, as with all forms of X-ray apparatus, it is necessary to take proper precautions in shielding from scattered radiation, and means must be taken to eliminate both visible light and in certain instances soft components. These means entail the use of various metal filters, and are well known to the art, e. g., aluminum or copper.

The means for appreciating the results of my X-ray stroboscope can roughly be divided into two kinds: (*a*) luminescent, which includes both fluorescent and phosphorescent and (*b*) photographic.

The (*a*) luminescent means may fluoresce or glow only as long as the luminescent material is excited by X-ray energy, permitting a rapid transition of images upon that device currently known to the art as a fluoroscopic screen. Or, it may glow after the invisible image-carrying X-ray beam has ceased to excite it, permitting subsequent observation or observation at frequencies different than those of synchronization, e. g., at frequencies of isochronization. Moreover, the luminescent or fluoroscopic means may be defined as (*a*) opaque, or viewable from the same side as impingement of the X-ray beam and (*b*) translucent, or viewable from the side opposite impingement of the X-ray beam, and coincidently

transparent to the luminescence emitted in the screen itself.

It is not possible in the present application to describe all such screen materials and designs as may be useful in my X-ray stroboscope, nor do I limit myself to a given choice of fluoroscopic or phosphorescent screen design, construction and composition. I mention in particular the screens used for fluoroscopy in the present art as being satisfactory for these purposes, including zinc sulfide phosphor, barium platinocyanide, alkaline earth tungstates, and others that are available in a wide range of luminescent characteristics, depending upon the composition and mode of preparation that may possess fluorescence and/or phosphorescence.

The (*a*) luminescent media may be supplanted by either non-moving or moving photographic plate or film, at a rate depending upon the special application of my X-ray stroboscope. These materials are likewise well known to the art, and are often employed in conjunction with what are known to the art as intensifying screens for radiography.

I claim:

1. A stroboscopic X-ray apparatus comprising a source of X-ray energy, relaxation oscillator means effective on each half-cycle to cause pulsation of the said X-rays at the source thereof, means for selectively varying the pulsation rate, means for collimating the pulsating X-rays and directing them against an object to be stroboscopically examined, and luminescent means responsive to said pulsating X-rays, after said X-rays have struck an object under stroboscopic examination thereby, said luminescent means transforming said X-rays into visible light.

2. A stroboscopic X-ray apparatus comprising a source of X-ray energy, relaxation oscillator means effective on each half-cycle to cause pulsation of the said X-rays at the source thereof, means for selectively varying the pulsation rate, means for collimating the pulsating X-rays and directing them against an object to be stroboscopically examined, and photographic recording means responsive to said pulsating X-rays, after X-rays have penetrated an object under stroboscopic examination thereby, said photographic recording means transforming said X-rays into a photographic image.

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