

July 16, 1940.

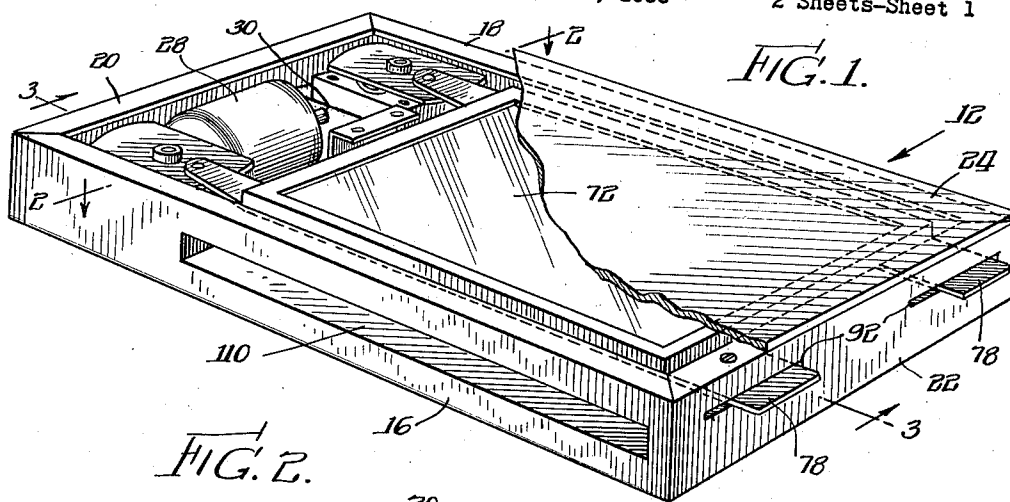
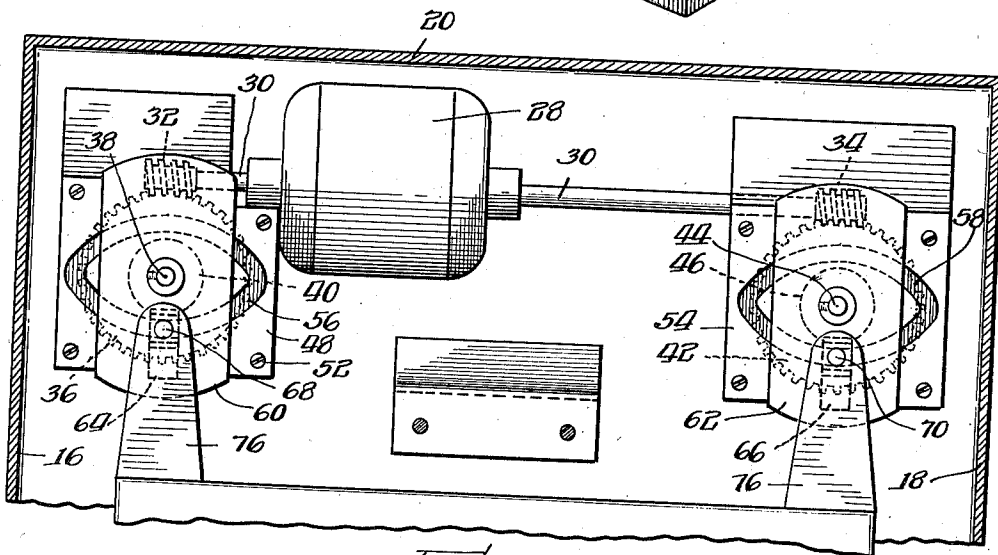
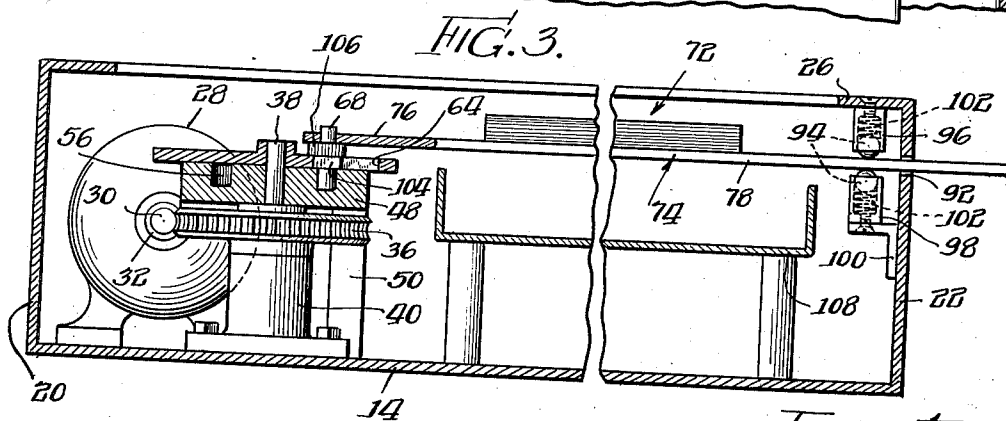
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RADIOGRAPHIC METHOD AND APPARATUS

Filed March 25, 1938

2 Sheets-Sheet 1



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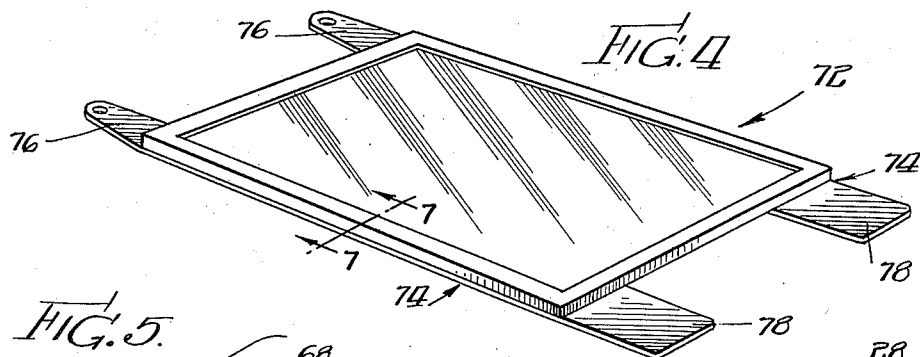
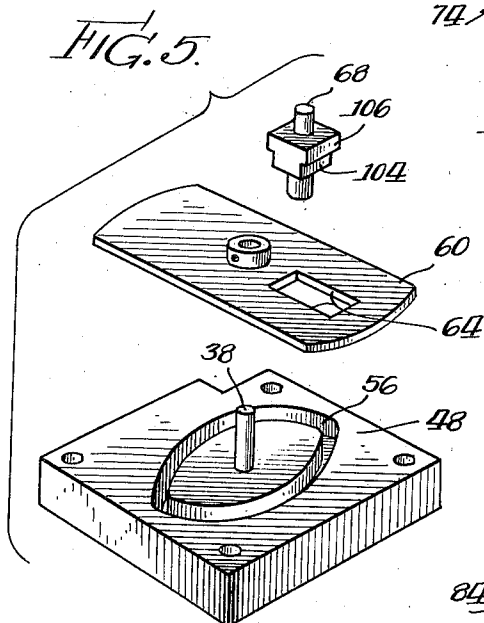
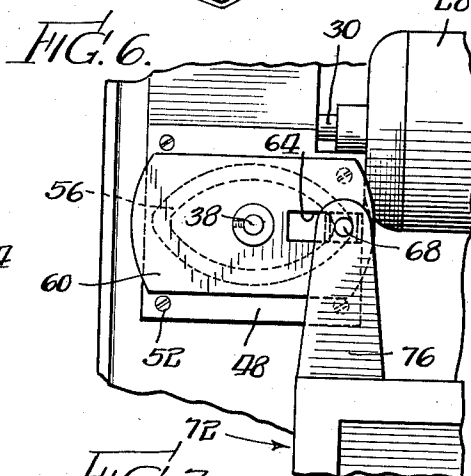
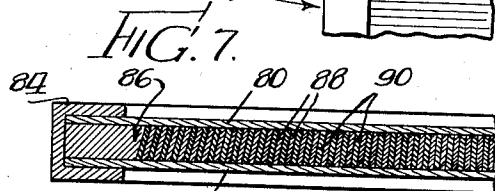
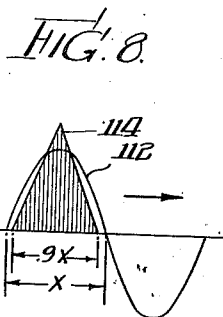
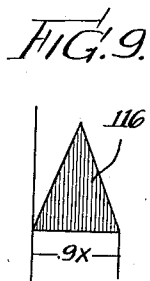
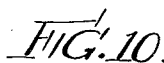
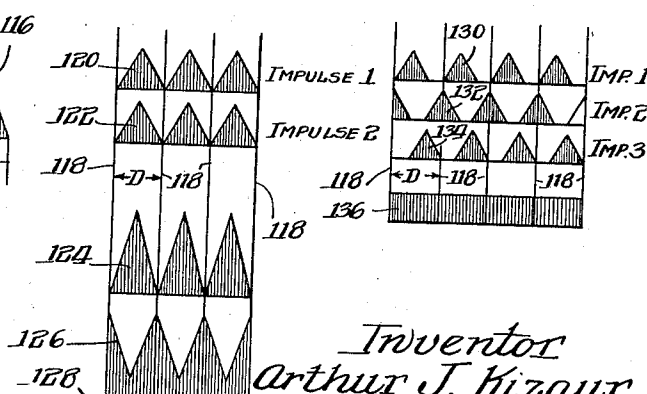
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RADIOGRAPHIC METHOD AND APPARATUS

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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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RADIOGRAPHIC METHOD AND APPARATUS

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Application March 25, 1938, Serial No. 198,022

9 Claims. (Cl. 250—62)

This invention relates to X-ray radiography or photography, and more particularly to a method and apparatus for making X-ray radiographs by means of a diaphragm of the "Bucky" type.

An object of this invention is to provide an X-ray radiographic method and apparatus, by means of which a diaphragm having alternate X-ray opaque and transparent strips may be successfully used during relatively extended exposures without producing shadow lines or density contrasts upon the film or plate.

Another object of the invention is the provision of simple, economical and efficient means for moving a diaphragm in a manner which will produce the most efficient results and make uniform the density loss caused by the X-ray opaque strips of the diaphragm.

Another object of the invention is to provide means for moving a diaphragm in such a manner that the speed component of motion at right angles to the grid strips of the diaphragm is maintained substantially constant and is reduced to zero only for a minimum period or operating interval.

The invention contemplates the provision of means for continuously moving the diaphragm along a closed curvilinear path at a constantly changing speed in such a manner that the speed component of motion at right angles to the grid strip is constant except at the two reversal points.

Another object of applicant's invention is to provide a method and means for taking X-ray radiographs by means of a diaphragm whereby the background film density may be substantially uniform throughout the entire area of the film to eliminate shadow lines or density contrasts heretofore caused by the X-ray opaque strips of the diaphragm.

Other and further objects and advantages will be apparent from the following description when taken in connection with the accompanying drawings wherein:

Fig. 1 is a perspective view of a device constructed in accordance with the invention, certain parts being broken away for purposes of illustration.

Fig. 2 is a fragmentary horizontal section taken substantially along the line 2—2 of Fig. 1.

Fig. 3 is a vertical section taken along the line 3—3 of Fig. 1.

Fig. 4 is a view in perspective of the diaphragm.

Fig. 5 is an exploded view showing in perspective certain operating parts of the device.

Fig. 6 is a fragmentary view of the elements

shown to the left of Fig. 2 but in a different position of operation.

Fig. 7 is a fragmentary vertical section taken along the line 7—7 of Fig. 4.

Figs. 8, 9, 10 and 11 are diagrammatic sketches in explanation of the invention.

As illustrated in Fig. 1, an apparatus constructed in accordance with the invention may comprise a frame 12 having a bottom wall or plate 14, side walls or plates 16 and 18, end walls or plates 20 and 22, and a cover plate 24 secured to the intumed flanges 26 of the side and end walls or plates.

The frame 12 may be mounted upon or attached to a conventional X-ray table or stand (not shown). An electric motor, or other suitable constant speed motive means 28 is mounted on the base plate 14 adjacent the end 20 of the frame 12. The motor shaft 30 projects outwardly from both ends of the motor and carries worm gears 32 and 34 at its opposite ends. The worm gear 32 meshes with a worm wheel 36 secured to a vertical shaft 38 journaled in a bearing bracket 40 secured to the base plate 14 adjacent the side plate 16. The worm gear 34 in like manner meshes with a worm wheel 42 secured to a vertical shaft 44 journaled in a similar bearing bracket 46 secured to the base plate 14 adjacent the side wall 18. The shaft 38 is also journaled in a stationary plate 48 extending above the worm wheel 36 and secured to the base plate 14 by one or more brackets or posts 50 to which the plate may be secured by screws 52. The vertical shaft 44 is similarly journaled in and passes through a plate 54 extending above the worm wheel 42 and similarly secured to the base plate 14.

The plates 48 and 54 are provided with internal, curvilinear cam grooves 56 and 58 of identical shape and dimensions. Crank plates or levers 60 and 62 are secured to the upper ends of the shafts 38 and 44 for rotation therewith and are provided with slots 64 and 66 extending radially with respect to the axes of the shafts for slidably receiving crank pins 68 and 70. The crank pins 68 and 70 extend beneath the crank plates 60 and 62 and into the cam grooves 56 and 58 so that upon rotation of the crank plates the crank pins 68 and 70 move in synchronism along identical paths of movement determined by the shape and dimensions of the cam grooves 56 and 58.

The crank pins 68 and 70 are directly connected to, and control the movements of, a Bucky diaphragm 72 mounted on spaced plates or bars 55

74, each of which extends beyond the ends of the diaphragm to provide a lever arm or lug 76 and a guide portion or projection 78. The lever arms or lugs 76 are pivotally connected to the crank pins 68 and 70.

The diaphragm 72 may be of any conventional structure comprising X-ray transparent top and bottom plates 80 and 82 mounted in a rim frame 84 with a grid 86 interposed between the top and bottom plates 80 and 82. The grid 86 comprises the customary plurality of X-ray opaque strips 88 alternating with X-ray transparent strips 90. The strips 88 and 90, when the diaphragm is mounted in the frame 12, extend substantially at right angles to the side walls 16 and 18 and parallel to the end walls 20 and 22.

The guide portions or projections 78 of the diaphragm supporting plate 74 extend outwardly of the frame 12 through enlarged slits or slots 92 in the end wall 22 and pass between guide rollers or balls 94. The balls 94 provide guide means which cooperate with the operating means to establish the horizontal plane of movement of the diaphragm, these balls 94 being mounted in hollow housings or cylinders 96 and 98 secured to the turned flange 26 of the end plate 22 and to a bracket 100 mounted upon said end plate. Springs 102 are interposed between the balls 94 and the bottoms of the housings, the springs 102 maintaining the balls in guiding engagement with the plates 74 and the balls 94 are spaced apart such a distance that upon removal of the plates 74 the balls will engage one another while still being confined within the housings 96 and 98.

Each of the crank pins 68 and 70 is provided with a rectangular collar or block 104 (Fig. 5) slidably fitting within the slot 64 or 66 of the crank plate 60 or 62 and a rectangular collar or block 106 above the collar 104 for spacing the plates 74 above the crank plate 60 or 62 and in alignment with the balls 94 and the slot 92 in the end plate 22 of the frame 12. A cassette supporting tray or pan 108 is mounted within the frame beneath the diaphragm 72 and extends between the side plates 16 and 18 of the frame, the side plate 16 being provided with a longitudinal slot or opening 110 by which the cassette may be placed and removed from the pan 108.

It will be evident that upon operation of the motor 28, simultaneous rotation of the crank plates 60 and 62 will be effected to cause the crank pins 68 and 70 to move continuously and simultaneously along the cam grooves 56 and 58. The diaphragm 72 will therefore be moved along a curvilinear path in a single plane, the distance of movement of the diaphragm being greatest in the direction at right angles to the grid strips 88. The motor 28 may be of any suitable and constant speed type, but is preferably a synchronous motor energized from the same source of supply voltage as the X-ray tube.

Reference will now be made to Figs. 8 to 11 for a theoretical analysis in explanation of the invention. The sine wave 112 represents the alternating current voltage applied to the X-ray tube. The impulse of X-ray radiation produced by the positive half of the voltage wave 112 is approximated by the triangular shaded area 114 in Fig. 8. The base of the triangle 114 is in actual practice approximately nine-tenths the length "X" of the base of the voltage wave impulse and this is true for kenotron-rectified and half-wave, self-rectified units, but is not strictly true in the case of mechanical rectification.

The film density loss caused by an X-ray opaque strip 88 varies directly with the intensity of the X-ray radiation and therefore is representable by the shaded triangle 116 of Fig. 9, wherein it is shown that the density loss is a minimum when the X-ray radiation is a minimum and a maximum when the X-ray radiation is a maximum.

If the velocity of the grid 86 is such that a strip 88 would travel a distance equivalent to the pitch of the grid during one X-ray impulse, the graphs of the film density loss for all X-ray impulses would coincide exactly and the corresponding density variations on the film would be such that lines or shadows would be clearly apparent. This is represented in Fig. 3 wherein the vertical lines 118 diagrammatically represent the grid strips 88 and the distance D between these lines represents the grid pitch, which is the distance between the X-ray opaque strips 88. If the grid strips move the distance D during one X-ray impulse, the density loss caused by the X-ray opaque strips will vary in accordance with the curves 120 and 122, the curve 120 representing the density loss for the first impulse and the curve 122 representing the density loss for the second impulse. Similar succeeding impulses will cause similar variations in density loss. The curve 120 is a "saw-tooth" curve in which the teeth are triangular in form and of maximum height when the X-ray impulse is a maximum. The curve 122 is identical to the curve 120. The total density loss is the sum of the density loss for each X-ray impulse making up the total X-ray exposure. Since the curves 120 and 122 coincide, the curve 124, representing total density loss, will comprise successive triangles, the maximum height of which is the sum of the maximum heights of the curves 120 and 122.

It will be seen that the density loss varies greatly from a minimum value from the position which a strip 88 occupied at the beginning of the X-ray impulse to a maximum value at a position midway in the movement of the strip and then decreases to a minimum value at the end of the X-ray impulse. The corresponding variation in film density is represented by the curve 126 of Fig. 10, the line 128 being a base line representative of zero film density. It will be seen from the curve 126 that the greatest proportion of X-rays will strike the film along the lines covered by the opaque strips at the instances of beginning and ending of the X-ray impulse. These lines of maximum value will of course be spaced apart a distance equal to the grid pitch D.

The proportion of X-rays striking the film will be a minimum along parallel lines spaced apart a distance equal to the grid pitch and spaced from the lines of maximum exposure value a distance equal to one-half the grid pitch. The density of the film will of course vary between these maximum and minimum exposures. This density variation becomes readily perceivable to the eye in the forms of shadows or lines which distort or destroy the shadow contrasts made by the object being radiographed.

Applicant has found that if the speed of the grid is made such that it moves during each impulse a distance which is equal to a non-reciprocal fraction, preferably two-thirds of the grid pitch, the exposure density will be uniform. A "non-reciprocal fraction," as the terms are used herein, means a fraction which when reduced to its lowest terms, does not have a numerator of one. Since the time period of the impulses is de-

terminated by their frequency, in the case of the continuous or alternating current, the speed of the diaphragm is substantially equal to such non-reciprocal fraction of the grid pitch times the frequency (number of impulses per second) of the energizing impulses.

In Fig. 11, wherein the vertical lines 118 again diagrammatically represent the X-ray opaque strips and the distance D between these lines represents the grid pitch, the shaded triangles 130 represent the density loss variation for one impulse; the shaded triangles 132 represent the density loss variation for a second and succeeding impulse; and the shaded triangles 134 represent the density loss variation for a third impulse. The resultant density loss is represented by the shaded rectangle 136 which is a graphical summation of the density loss triangles 130, 132 and 134.

It will be seen from Fig. 11 that the density loss triangles 130, 132 and 134 will be so spaced in relation to the film surface which underlies the grid that the resultant effect will be the uniform density loss represented by the shaded rectangle 136. Since the density loss is thereby made uniform, the density variation for the proportion of X-rays which strike the film will be maintained constant and no shadows or lines will be produced on the film by the diaphragm 14.

The cam grooves 56 and 58 are so designed that the angular velocity of the shafts 38 and 44 being constant, the tangential velocity of each crank pin, 68 or 70, constantly changes in such a way that its velocity component at right angles to the grid strips is always constant except at the two reversal points. The diaphragm 12 will accordingly be moved continuously along a curvilinear path in such a manner that its component of motion at right angles to the grid strips is always constant except at the opposite ends of the cam groove, when this component at right angles to the grid strips instantaneously reduces to zero and increases to the same constant value in the opposite direction.

It will be apparent from the foregoing description that applicant has provided a simple, economical and efficient method and apparatus for taking X-ray radiographs in which the background is substantially uniform to eliminate shadow lines or density contrasts heretofore caused by the X-ray opaque strips of the diaphragm.

Changes may be made in the form, construction and arrangement of the parts without departing from the spirit of the invention or sacrificing any of its attendant advantages, and the right is hereby reserved to make all such changes as fairly fall within the scope of the following claims.

The invention is hereby claimed as follows:

1. In an X-ray radiographic apparatus, a diaphragm having a grid of alternate X-ray opaque and transparent strips and means for continuously moving said diaphragm along a closed curvilinear path, said means comprising a motor, a cam element, a cam follower element, and means for connecting one of said elements to said motor and the other of said elements to said diaphragm, said cam element having its cam surface so shaped as to cause the diaphragm to move along said curvilinear path with a substantially constant speed component of motion at right angles to the grid strips.

2. In an X-ray radiographic apparatus, a diaphragm having a grid of alternate X-ray opaque

and transparent strips and means for continuously moving said diaphragm along a curvilinear path, said means comprising constant speed motive means, a stationary cam, a lever operated by said motive means, a cam follower connected to said diaphragm and having lost motion connection to said lever for continuously moving said diaphragm along a curvilinear path and at a speed having a substantially constant component of motion at right angles to the grid strips.

3. In an X-ray radiographic apparatus, a source of X-rays, means to support a film sensitive to X-rays in position to be affected by X-rays from said source, a diaphragm having a grid of alternate X-ray opaque and transparent strips, said diaphragm being interposed between said source and film, and means for continuously moving said diaphragm along a curvilinear path with a constant component of motion at right angles to the grid strips, said means including a stationary cam having a cam surface of generally elliptical configuration having its longer axis substantially parallel to the grid strips, a cam follower secured to the diaphragm, and means for causing said cam follower to traverse the generally elliptical surface of the cam.

4. In an X-ray radiographic apparatus a diaphragm having a grid of alternate X-ray opaque and transparent strips and means for continuously moving said diaphragm along a curvilinear path, said means comprising constant speed motive means, a stationary cam having a cam surface of generally elliptical configuration with its longer axis substantially parallel to the grid strips, a crank operated by said motive means, a cam follower connected to said diaphragm and having a lost motion connection to said crank for continuously moving said diaphragm along said curvilinear path at a speed having a substantially constant component of motion at right angles to the grid strips.

5. A method of taking X-ray radiographs which comprises supplying pulsating impulses of electric current to an X-ray tube to energize the same, interposing a diaphragm having a grid of alternate X-ray opaque and transparent strips between said tube and a radiographic film, shifting said diaphragm back and forth between said tube and film at a speed the component of which at right angles to the grid strips is substantially constant and equal to substantially two-thirds of the grid pitch times the time period of the impulses, whereby the same elemental area of the film is covered by an opaque strip at the same instantaneous current value only after energization of the X-ray tube by a number of impulses.

6. In an X-ray radiographic apparatus, a source of X-rays, means to support a film sensitive to X-rays in position to be affected by X-rays from said source, a diaphragm having a grid of alternate X-ray opaque and transparent strips, said diaphragm being interposed between said source and film, means for energizing said source for the emission of X-rays pulsating at a desired frequency and means for continuously moving said diaphragm at a substantially constant velocity in a direction at right angles to the grid strips, which velocity is equal in magnitude to substantially two-thirds of the grid pitch times the frequency of the impulses, whereby the same elemental area of the film is covered by an opaque strip at the same instantaneous current value only after energization of the X-ray tube by a number of impulses.

7. In radiographic apparatus, a source of

X-rays, means to support a film of material sensitive to X-rays in position to be affected by X-rays from said source, a diaphragm having a grid comprising X-ray opaque and X-ray transparent strips alternately disposed in said grid, the pitch distance between opaque strips being substantially uniform throughout the diaphragm, said diaphragm being interposed between said source and the film, means for energizing said source to produce X-ray impulses therefrom at a selected frequency, and means for moving said diaphragm at right angles with respect to the grid strips at a substantially constant velocity such as to translate the grid strips, during the time interval between successive X-ray impulses, through a distance equal to a non-reciprocal fraction of the opaque strip pitch distance.

8. In radiographic apparatus, a source of X-rays, means to support a film of material sensitive to X-rays in position to be affected by X-rays from said source, a diaphragm having a grid comprising X-ray opaque and X-ray transparent strips alternately disposed in said grid, the pitch distance between opaque strips being substantially uniform throughout the diaphragm,

said diaphragm being interposed between said source and the film, means for energizing said source to produce X-ray impulses therefrom at a selected frequency, and means for moving said diaphragm at right angles with respect to the grid strips at a substantially constant velocity such as to translate the grid strips, during the time interval between successive X-ray impulses, through a distance equal to substantially two-thirds of the opaque strip pitch distance.

9. The method of making radiographs which comprises energizing an X-ray source to produce X-rays pulsating at a desired frequency and applying said X-rays on a sensitive film while interposing between said source and said film, a diaphragm comprising X-ray opaque and X-ray transparent strips alternately arranged in said diaphragm and shifting said diaphragm transversely between said source and film at a speed correlated with the frequency of X-ray pulsation so that each opaque strip of said diaphragm is translated, during the time interval between succeeding pulsations, through a distance equal to a non-reciprocal fraction of the pitch distance between successive opaque strips.

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