Jan. 31, 1956

A. G. BILLIN

2,733,352

RECIPROCATING BUCKY ACTUATOR

Filed Feb. 20, 1952

3 Sheets-Sheet 1

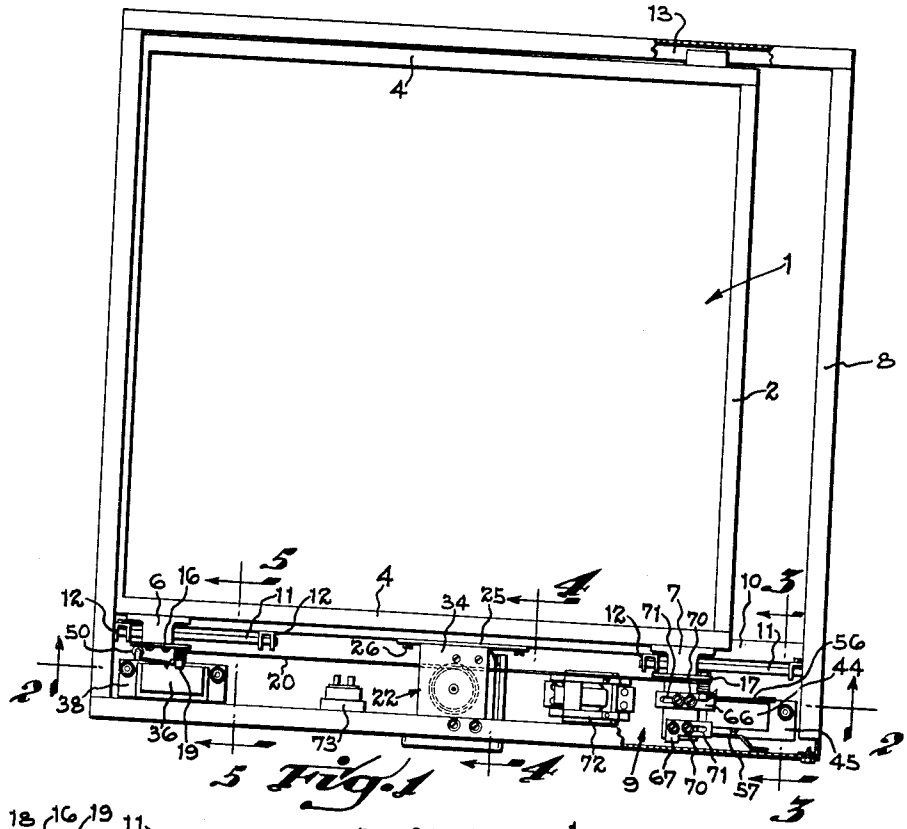


Fig. 1

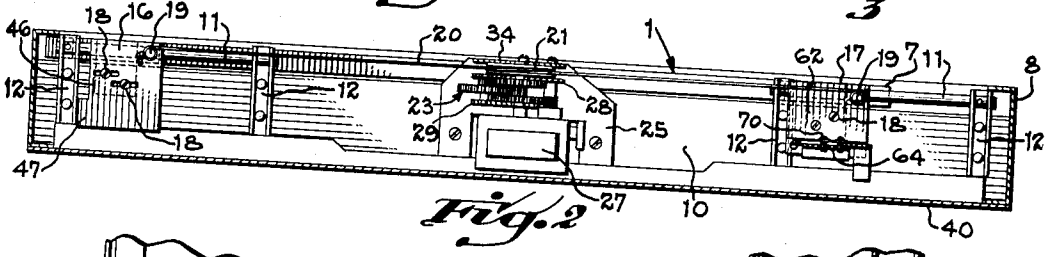


Fig. 2

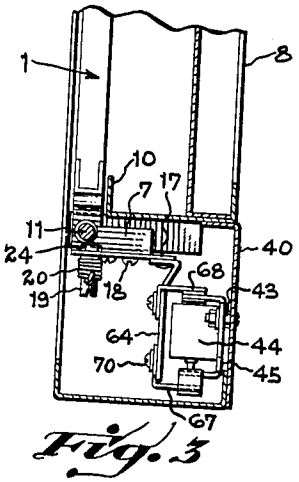


Fig. 3

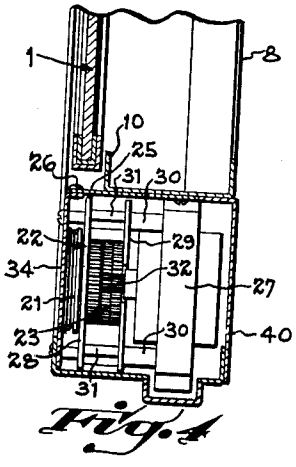


Fig. 4

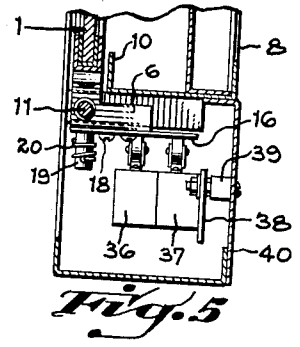


Fig. 5

INVENTOR.
Arthur G. Billin.
BY
Wood, Herron & Evans.
ATTORNEYS.

Jan. 31, 1956

A. G. BILLIN

2,733,352

RECIPROCATING BUCKY ACTUATOR

Filed Feb. 20, 1952

3 Sheets-Sheet 2

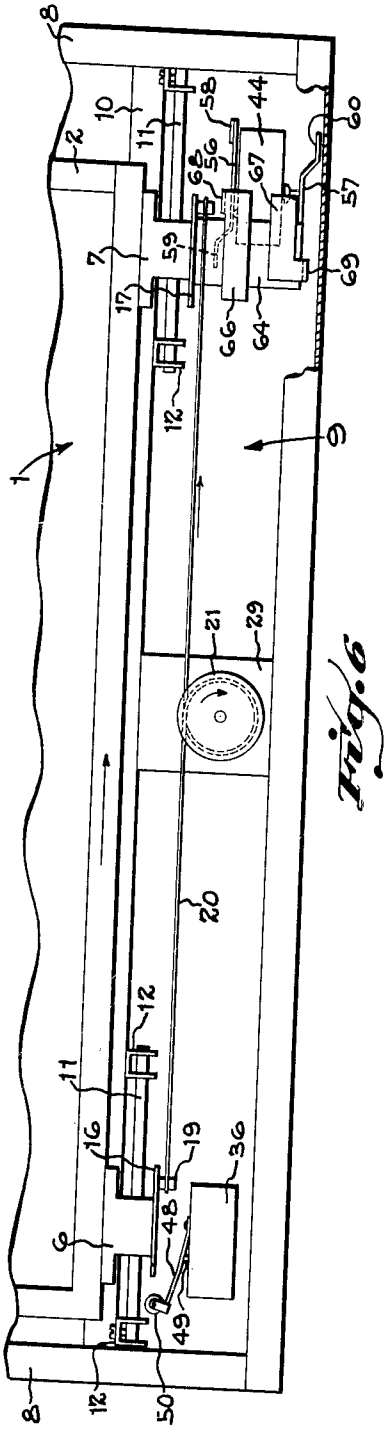


Fig. 6

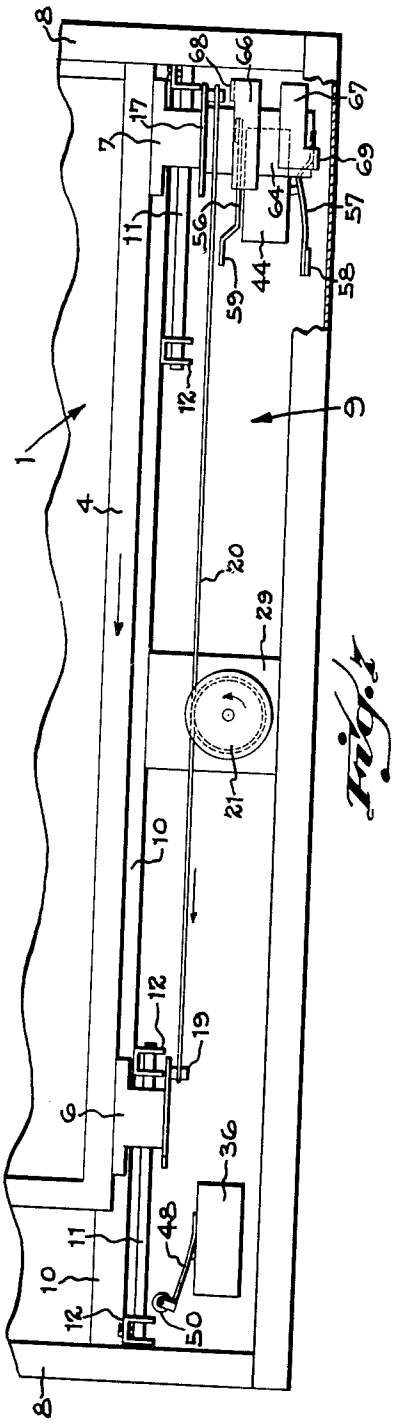


Fig. 7

INVENTOR.
BY Arthur G. Billin.
Wood, Herron & Evans.
ATTORNEYS.

Jan. 31, 1956

A. G. BILLIN

2,733,352

RECIPROCATING BUCKY ACTUATOR

Filed Feb. 20, 1952

3 Sheets-Sheet 3

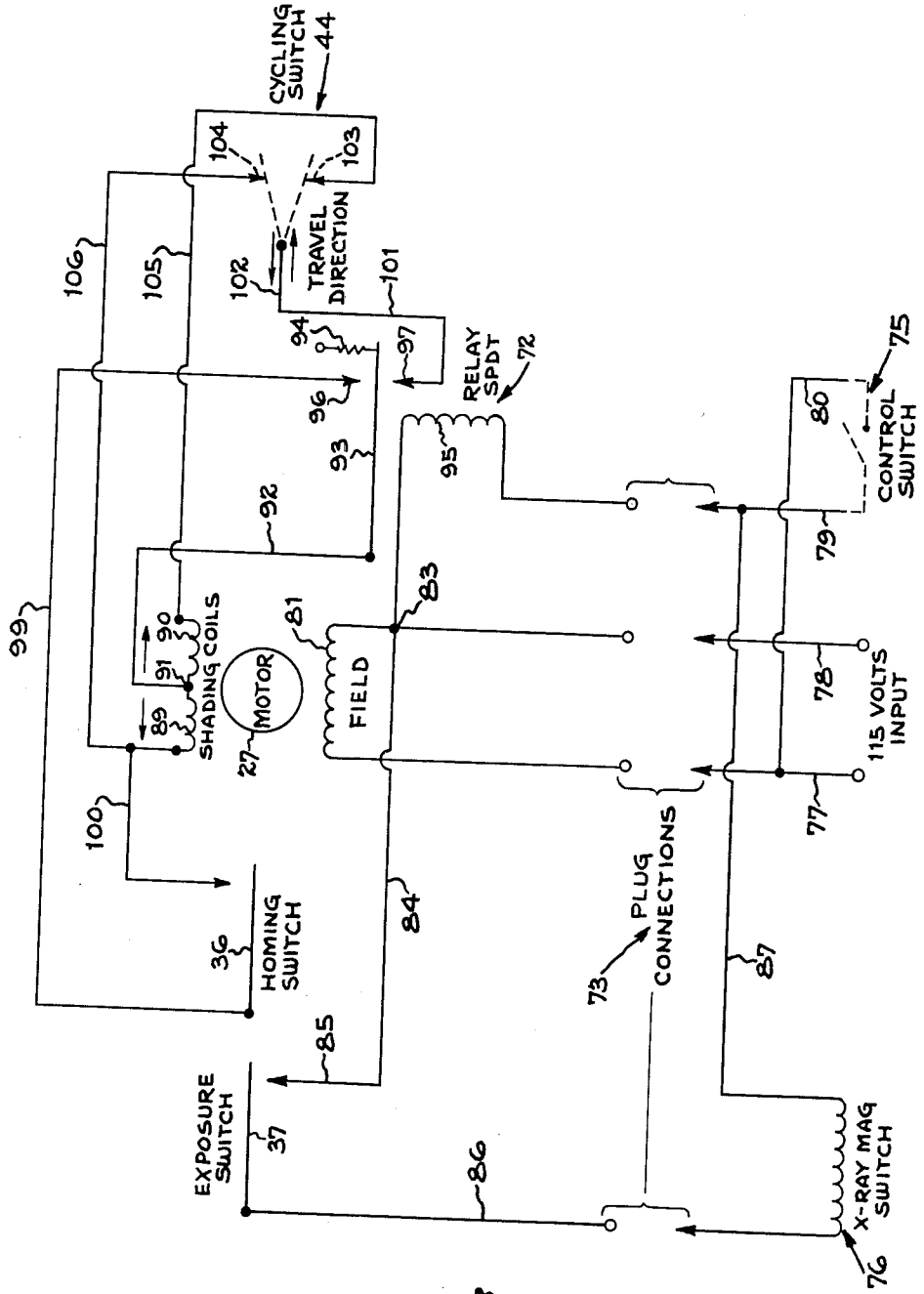



Fig. 8

INVENTOR.
Arthur G. Billin.

BY Word, Herron & Evans.
ATTORNEYS.

United States Patent Office

2,733,352

Patented Jan. 31, 1956



2,733,352

# RECIPROCATING BUCKY ACTUATOR

Arthur G. Billin, Cincinnati, Ohio, assignor to The Liebel-Flarshiem Company, Cincinnati, Ohio, a corporation of Ohio

Application February 20, 1952, Serial No. 272,658

9 Claims. (Cl. 250—62)

This invention relates to apparatus for producing X-ray photographs. It is directed particularly to an improved mechanism for actuating a Bucky diaphragm of the type conventionally employed to screen secondary radiations from a photographic film or plate in X-ray photography.

In a co-pending United States patent application, Serial No. 71,074, now Patent No. 2,591,536, there is disclosed a mechanism in which a Bucky diaphragm is actuated at different rates of speed in opposite directions during an X-ray exposure, whereby undesirable shadows of a Bucky diaphragm upon the X-ray photograph may be avoided. The objective of the present invention has been to produce a mechanism for operating Bucky diaphragms at the same, or substantially the same, rates of speed in opposite directions while still preventing diaphragm shadow lines from the X-ray photograph. The present invention, therefore, differs in operating principle from that disclosed in the co-pending application. However, in order to fully understand the nature of the present invention and the benefits which it provides, a brief review of roentgenology technique employing Bucky diaphragms is helpful.

A conventional diaphragm, termed a Bucky diaphragm in respect to the name of its inventor, consists of a plurality of thin strips of material, such as lead, which are opaque to X-rays and which are arranged, on edge, in spaced relationship to one another. The diaphragm is interposed between the subject to be X-rayed and the photographic film or plate. Primary radiations generated at the X-ray tube pass through the subject and through the spaces between the opaque strips of the diaphragm to impinge upon the photographic film or plate, the slits of the diaphragm through which the X-rays may pass being angulated to coincide with the diverging stream of X-rays generated at the tube. However, in passing through a subject, some X-rays are scattered or deflected, thereby producing so-called secondary radiations which would blur the image on the photographic plate if they were unobstructed. It is the function of the Bucky diaphragm to screen such secondary radiations from the photographic medium. This result is accomplished because the grid or diaphragm permits the direct radiations to pass through its slits but it excludes radiations which approach it along paths outside of the angles of acceptance delineated by its slits.

The opaque strips of a Bucky diaphragm would cast their shadows upon the film if the diaphragm were stationary during the X-ray exposure, and, upon development of the film, the shadow areas would appear as undesirable strips of density contrasting with that of other areas of film. Therefore, the photograph would be difficult for the analyst to read. To avoid this result, one conventional practice is to move the diaphragm over the surface of the photographic medium during an exposure period. A Bucky actuator is employed for this purpose, which conventionally has consisted essentially of a motor mechanism, usually a spring, to force the diaphragm in one direction, and a governor which controls the speed



of movement at the desired rate. The grid of such an apparatus, commonly termed a Potter-Bucky diaphragm, makes one pass over the film during the exposure.

Since various subjects being X-rayed require different exposure periods because of their density, thickness, or X-ray opacity, the usual Bucky mechanism is selectively controllable as to rate of movement in one direction to meet the time conditions of exposure. Thus, the X-ray technician, by his judgment or previous experience, sets the actuator to cause passage of the diaphragm over the film in a period of time which is slightly longer than the exposure period he believes will be proper for the subject to be photographed. Thus, mechanisms presently available are usually adjustable to accommodate a range of exposure, this range being adequate to accommodate X-ray examination of a common variety of subjects. If the exposure is to be longer than any of the periods of time within this range, then the total exposure period may be divided into two or more partial exposure periods, and after each partial exposure, the diaphragm actuator will re-cock and release for the second or succeeding partial exposures. However, such procedure obviously is inconvenient and uncertain.

A difficult problem is encountered in all X-ray photography utilizing a Bucky diaphragm because of the pulsating nature of the X-ray emanations generated by the tube of the machine. Since such tubes are operated upon alternating current, usually 60 cycle, it is apparent that if an X-ray pulsation happens to occur, as it frequently does, just when the X-ray opaque strips of the diaphragm reach the same relative position that other opaque strips of the diaphragm occupied during preceding pulsations, then the strips, though actually in movement, will cast shadows just as though they were stationary, and the resultant photograph will be imperfect. Such a condition is known in the art as synchronism, and will be referred to in this specification and the claims hereof by that name.

A non-synchronous condition is one in which the timing or Bucky actuation is such that coincidence of grid positions and X-ray pulsations will not occur repeatedly to such extent that discernable or undesirably contrasting shadows or grid lines will appear upon the resultant photograph. Bucky actuators presently available usually are constructed to embody special provisions by which they may not inadvertently be set to travel at speed rates where objectionable synchronous conditions will occur. However, the problem of avoiding synchronism becomes much more acute when the apparatus is to be constructed to accommodate a wider, longer range of exposure periods.

The principal objective of this invention has been to provide a Bucky actuator adapted to serve both short exposures, e. g. 1/10 second, and exposures of a prolonged nature, for example 15 to 20 seconds or more, or, in fact, exposures which may be for as long a period of time as may be required by the subject undergoing photographic examination. A further principal objective of the invention has been to provide a mechanism which is substantially free of any latent tendencies toward objectionable synchronous conditions through its movement either during long or short exposure periods.

The apparatus of the present invention is useful in conventional photographic technique wherein the operator, by his choice, or from charts and data, arbitrarily selects the time for which a subject is to be exposed and sets his apparatus accordingly. In addition, however, the invention is particularly useful in X-ray photographic techniques more recently perfected, by which exposure is governed automatically to the correct time through excitation of a photocell. In roentgenography employing photoelectric timing, a fluorescent screen is utilized which emits light in proportion to the X-rays impinging upon it after they have passed through the photographic

medium. A photocell, focused upon this screen, generates a current in proportion to the light emitted from the screen, and such current is employed in the charging of a condenser in a control circuit. When the charge upon the condenser reaches a critical value, which is adjusted in respect to the known sensitivity of the photographic medium, the control circuit is energized to terminate the exposure. The arrangement, therefore, constitutes an automatic exposure meter which eliminates the need for the operator to exercise his independent skill or judgment.

It will be apparent that a conventional single-pass Bucky diaphragm is very difficult, if not impossible, to use successfully in photographing a variety of subjects with phototimed X-ray equipment, since the operator has no means of determining the rate or duration of movement of the diaphragm necessary to accommodate an unknown, but automatically terminated, exposure governed by the phototimer.

To accommodate the longer exposure periods, several mechanisms have been proposed for reciprocating the diaphragm back and forth over the film while the X-ray tube is energized. However, the results obtained with such apparatus have generally been quite unsatisfactory because of the incidence of synchronism and because of the inherent tendency for imperfect pictures to be produced when exposure happens to be started at a moment of reversal of the direction of movement of the diaphragm. A diaphragm is quite heavy, embodying as it does a substantial number of lead strips plus a frame in which the diaphragm is supported. By virtue of such weight, momentum and inertial forces are involved which must be overcome in first bringing the diaphragm to rest at the end of a stroke in one direction and in then causing the diaphragm to reach intended speed in the opposite direction. The rates of deceleration and acceleration of the devices proposed in the past have been so slow that undesirable conditions of synchronism occur during the reversal periods when the diaphragm is moving at less than intended speed, or so fast that undesirable vibration is established.

The present invention embodies a Bucky actuating mechanism which is of utmost simplicity and which is relatively inexpensive to construct, yet which provides singularly desirable results in the elimination of synchronous conditions. The apparatus of the present invention is actuable either for short or long exposure periods and operates the Bucky diaphragm reciprocably during an exposure period at substantially uniform rates of speed in opposite directions, but provides rates of deceleration and acceleration of the diaphragm, such that undesirable shadow effects are substantially prevented from occurring during reversal periods.

Reduced to its simplest terms, the diaphragm actuator of the present invention consists of a reversible drive motor, control devices which govern the direction of power movement of the drive motor, and which, in turn, are governed by the diaphragm when it reaches the respective ends of its strokes in opposite directions, and a simple string connection through which the power of the drive motor is imparted to the diaphragm for reciprocating it. The power motor drives the diaphragm through the string connection at a rate which may be the same, or substantially the same, in one direction as in the other, but the limited resiliency of the string, plus prompt reversibility of the motor, enables sufficiently high acceleration and deceleration to be obtained in the reversal periods to eliminate undesirable mechanical and photographic results which would otherwise be obtained by an inelastic or positive connection type of drive.

The actual rate of movement imparted to the diaphragm is non-synchronous with respect to the X-ray frequency; that is, the rate of movement of the Bucky does not bear an integer or simple sub-multiple relation to the frequency of pulsations of the X-ray tube, or otherwise coincidence in the positions of the grid strips might lead to incidence of shadows during passage of the diaphragm in either direction. Also, it is desirable that the rate at which the diaphragm is movable be great enough to cause a sufficient number of opaque strips of the diaphragm to pass a given point on the subject or film and thereby provide proper screening of secondary radiations from the film.



A further feature of the present invention resides in apparatus capable of returning the diaphragm to a predetermined starting position at the end of an exposure period, no matter where the diaphragm happens to be at the moment exposure is terminated. By means of this feature of the invention, the position from which the diaphragm will start to move in the next successive utilization of the apparatus is established and variations or undesirable results which might otherwise occur through variations in the starting position are eliminated. This feature is particularly important when a short exposure is to be made.

The invention also contemplates a mechanism in which the Bucky will assume movement at a desired speed before X-ray exposure can commence, thereby eliminating the incidence of shadows on the film through inadequate Bucky movement at the very start of an exposure.

From the foregoing principles upon which the present invention is predicated, and the following detailed description of the drawings in which a preferred embodiment of the invention is disclosed, those skilled in the art will readily understand the modifications to which the invention is susceptible.

In the drawings:

Figure 1 is a plan view of a diaphragm actuating mechanism of the present invention.

Figure 2 is a sectional elevation taken on the line 2—2 of Figure 1.

Figure 3 is a sectional elevation taken on the line 3—3 of Figure 1.

Figure 4 is a sectional elevation taken on the line 4—4 of Figure 1.

Figure 5 is a sectional elevation taken on the line 5—5 of Figure 1.

Figures 6 and 7 are simplified, somewhat diagrammatic views, showing actuation of reversal switches by the diaphragm in respective phases of its movement, and

Figure 8 is a circuit diagram illustrating a control circuit through which reversal of movement is accomplished in conjunction with return of the diaphragm to starting position at the end of an exposure.

The diaphragm with which the actuator mechanism of the present invention is attached to be used may be of any suitable type, and is indicated generally in the drawings at 1. The diaphragm is equipped with a peripheral frame 2, and a longitudinal edge 4 of the frame is provided with spaced guide blocks 6 and 7 through which the diaphragm movably is mounted. The diaphragm 1 is contained within an overall frame or housing 8, which is made up, for example, of plates or channel irons of suitable configuration, all joined together by bolts or welding.

The overall frame 8, as will be noted from Figure 1, is both longer and wider than the screen diaphragm 1, the additional length providing a field of movement of the diaphragm, and the additional width providing space, indicated generally at 9, within which components of the actuating and control mechanism are housed. The area 9 is delineated from the remainder of the overall frame 8 by a dividing wall 10, the top of which is spaced from the bottom of the diaphragm 1.

Guide blocks 6 and 7 are bored longitudinally to receive guide rods 11 which are supported rigidly upon pairs of brackets 12, 12 extending upwardly from the face of the dividing wall 10. The rods 11, therefore, slidably support the diaphragm along one longitudinal edge thereof. Similar guide rods may be provided to sustain the

opposite edge, or it merely may be slidably supported on a ledge 13 extending from the back wall of frame 8.

The outer faces of slide blocks 6 and 7 respectively carry plate members 16 and 17 which are fastened thereto by means of screws 18. In the construction illustrated, each of plates 16 and 17 has an attachment post 19, 19 extending from it, and a string drive member 20 has its opposite ends wrapped around or otherwise suitably fastened to the posts 19. The portion of the string 20 residing intermediate the post 19 passes once or twice around a drive sheave 21 which is in driven connection with power motor mechanism indicated generally at 22, equipped with a speed reduction gear train indicated generally at 23. Thus, string drive member 20 is in frictional engagement with the drive sheave 21 or anchored to it, so that when the drive sheave is actuated by means of the motor mechanism through the gearing 23, the sheave pulls upon the string at one side thereof and pays out string at the other, thereby moving the diaphragm according to the direction of rotation of the drive sheave.

In the preferred construction, the string 20 is attached to each post 19 by wrapping it around the post once or twice and then passing its free end through a transverse bore therein, after which the string is knotted. To adjust the tension or tautness of the string, one or both of the posts may be rotatably mounted, after which the posts may then be locked in place by means of suitable lock nuts, as at 24 (Figure 3).

The "string" of drive member 20 is preferably in the form of a fibrous cord having sufficient pliability to pass around the drive sheave 21, and sufficient strength to withstand the forces to which it is subjected in causing the diaphragm to reciprocate. Braided cord fabricated of nylon fiber is very suitable, in that it provides good frictional engagement with the drive sheave so as to avoid slippage, and in that it also provides a slight amount of stretch or give when called upon to overcome the inertia or momentum of the mass of the diaphragm. In place of a cord which is made of textile fiber, cord or cable made of metal or glass may be used, although unyielding, absolutely positive interconnection between the drive sheave and diaphragm is generally undesirable in so far as it unduly strains the motor mechanism during reversal, and tends to cause vibration of the apparatus.

The power motor mechanism 22 occupies a position in the housing area 9 which is preferably about midway of the length of the overall frame 8, and is supported stationarily upon a plate 25 which, in turn, is fastened to the dividing wall 10 by means of screws 26.

In the preferred construction, the power motor mechanism 22 is a unit assembly comprising an electric motor 27 which supports spaced plates 28 and 29 by means of posts 30 and 31 extending from the motor casing. The speed reduction gear train 23 is journalled in the spaced plates 28 and 29 and may be of any suitable design. It is driven from the motor 27 by means of a pinion 32 which is mounted on the motor shaft. The gear train, in turn, is in driving connection with the sheave 21 which is journalled in and arranged above plate 29 and beneath a cover plate 34 which extends across the top of the power motor unit assembly 22.

Electric motor 27 of the apparatus is of the reversible type, embodying a field winding and shading coils through the respective short circuiting of which the direction of motor rotation is controlled. Also, the motor is of the type which is capable of reversing its direction of rotation promptly in order to avoid undesirable time lag. Since motors of this general type are conventional, the details of the construction of the motor are not disclosed herein. For the purposes of the present invention, it is sufficient to note that the reversible electric motor drives the gear train, and the gear train, in turn, drives the sheave 21 around which the string 20 is wound for frictional engagement therewith.

The speed reduction provided by the gearing 23 is appropriate, in relation to the diameter of the drive sheave 21 to cause linear movement of the string, and attendant linear movement of the diaphragm 1, at a rate which is non-synchronous with respect to the pulsations of the X-ray tube with which the apparatus is to be employed. For example, by way of illustration but not by way of limitation, motor 27 may operate at 2500 R. P. M., the diameter of the drive sheave may be approximately 1¾ inches, and the ratio of the gear train may be approximately 125 to one. In such event, the motor when energized will cause the diaphragm to move at a rate of approximately 1¾ inches per second, at which rate it is adapted to provide non-synchronous conditions in the operation of a 60 cycle X-ray tube utilizing a Bucky diaphragm having 50 grid strips per inch.

At one end of the stroke of diaphragm 1, a homing switch and an exposure switch are installed in the housing area 9. In the apparatus illustrated in the drawings, these switches are at the left hand side of Figure 1, and are designated 36 and 37 respectively. These switches are mounted one on top of the other, and are carried upon a table 38 which is supported by posts 39, the latter extending upwardly into the housing area 9 from bottom wall 40 thereof.

At the opposite end of the stroke of the diaphragm 1, a cycling switch 44 is located. This switch is also positioned in the housing area 9 and resides on a table 45 which is supported from the bottom wall 40 by means of posts 43. The homing switch 36, the exposure switch 37, and the cycling switch 44 are actuated in response to movement of the diaphragm by actuators which are mounted on the diaphragm so as to be movable with it. Thus, when the diaphragm reaches a point in its cycle of movement at which a switch is to be operated, the actuator engages the switch and operates it.

In the construction illustrated, switches 36 and 37 are acted upon by upper and lower edgewise portions 46 and 47 of plate 16 which is fastened to the face of left end guide block 6. It is to be noted that the fastening screws, 18, pass through slots in the plate 16, thereby permitting the plate to be adjusted longitudinally of the diaphragm so that the desired timing of the actuation of these switches in relation to diaphragm position may be accomplished. Switches 36 and 37 are both of the normally closed type, i. e., they must be held in open positions and when released they close. Each switch is provided with a yieldable operating arm 48 which bears against a plunger 49 by means of which the switch is opened. The arms 48 carry rollers 50 which are disposed in the path of movement of the leading edges 46 and 47 of plate 16, the leading edges being the left hand edges of the plate 16, as shown in Figure 1. Therefore, when the diaphragm is moving to the left, the edges of plate 16 engage the rollers 50 so as to depress the switch arms 48 and thereby actuate the buttons 49 of the switches. It is to be noted that the edgewise portion 47 of plate 16 is offset from the edgewise portion 46 of the same plate. This offset causes the exposure switch 37 to be operated slightly in advance of the homing switch 36 when the diaphragm moves to the left, and to be released slightly after the homing switch when the diaphragm is moved to the right. The purposes of the sequential operation of switches 36 and 37 which are obtained in this manner are explained in connection with the later description of the operation of the apparatus.

Cycling switch 44, which is located at the other end of the equipment, is of the single pole, double throw, snap action microtype, and has no neutral position. For operation, it is equipped with two levers 56 and 57 which are best seen in Figure 6. Both levers are yieldable and bear respectively upon the operating buttons of the switch unit. Lever 56, which throws switch 44 as the diaphragm reaches the left hand end of its stroke, is fastened to a post 58 from which it extends along switch 44 and terminates in an offset portion 59. Lever 57 is mounted simi-

larly on a post (not shown) at the opposite end of switch 44 and at the opposite side thereof from post 58. Lever 57 extends along the switch and terminates in an offset portion 60 which is actuated when the diaphragm reaches the right hand end of its stroke.

The levers 56 and 57 are served by an actuator assembly 62 which is supported on plate 17, the latter being fastened to the face of guide block 7 as previously described. Actuator assembly 62 includes a shelf portion 64 extending over and above switch 44, and finger members 66 and 67 are mounted on the shelf, the finger members respectively providing fingers 68 and 69 which are positioned for engagement with the offset portions 59 and 60 of the respective levers 56 and 57. The finger members 66 and 67 are fastened to the shelf 64 by means of screws 70 which pass through appropriate slots 71, thereby permitting the relative positions of the finger members to be adjusted for timing purposes.

When diaphragm 1, in moving to the right, reaches the end of its intended stroke, the depending finger 69 engages the offset portion 60 of actuating lever 57, the switch 44 is thrown, and this promptly causes reversal of motor 27, as described at a subsequent point in the specification. Similarly, when the diaphragm, after moving to the left, reaches the end of its stroke in that direction, the finger 68 engages the offset portion 59 of lever 56, throwing the switch 44, and thereby again reversing the direction of motor rotation. Since the switch 44 is of the snap action type, it remains in any position in which it may be set until it is next actuated to the opposite position.

A relay 72, which is employed in the preferred electrical circuit of the apparatus, may be positioned in the housing area 9 and, to facilitate power connections to the entire apparatus, a plug receptacle 73 may also be mounted in the front wall of the overall frame 8. To avoid confusion in the illustration of the mechanical parts, the wiring connections are not illustrated in Figures 1–7, though it will be noted that the housing area 9 provides ample space for wiring without interference thereof with the movable parts of the apparatus.

*Electric circuit*

An X-ray machine is provided with a primary control switch which, for present purposes, is indicated generally at 75. This control switch may be operated either manually or by a mechanical timer or by photoelectric timing means. In addition, an X-ray tube is usually powered through a magnetic switch or other suitable contactor, which is indicated generally at 76. For the purpose of illustrating the operation of the present apparatus, these elements are shown in the circuit diagram of Figure 8. Operating voltage is supplied through leads 77 and 78, while the leads from the control switch 75 are designated 79 and 80. All of these connections may be made through a plug (indicated diagrammatically), which is engageable with the plug receptacle 73 of the apparatus.

Input voltage leads 77 and 78 are connected directly to the field winding 81 of the motor 27, while lead 79 from the control switch 75 is taken to one terminal of relay 72, which is a single pole, double throw relay. The opposite terminal of the relay 72 is in connection with input lead 78, as at 83, and is also in connection, through lead 84, with one of the contacts 85 of the exposure switch 37. One terminal of the magnetic switch 76 of the X-ray apparatus is in connection through lead 86 with the other of the contacts of the exposure switch 37, and the opposite terminal of the magnetic switch is in connection with input lead 79 of the control switch 75 through lead 87.

Thus, the field winding 81 of motor 27 is connected directly across input terminals 77 and 78, while switches 75 and 37 are in a series circuit extending from input terminal 78 through junction 83 to switch 37 through lead 84, and from lead 86 of switch 37 through magnetic switch 76 to lead 87 which passes to lead 79 for control switch 75, the latter being connected to input terminal 77 through lead 80. Relay 72 is connected across junction 83 and lead 79, and therefore, is in parallel with switch 37 and coil 76 in series.



As previously noted, the motor 27 of the power unit 22 embodies shading coils which are magnetically coupled with the field winding 81 and which govern the direction of motor rotation. These shading coils are designated 89 and 90, the common connection between them being designated 91. When the circuits to both coils are open, the motor 27 is idle, but when either coil is short circuited, the motor will run. The coils are so wound or arranged that short circuiting of one will cause the motor to run in a direction of rotation which is opposite the direction of rotation prevailing when the other coil is short circuited. The electric circuit is arranged to cause short circuiting of these coils through actuation of cycling switch 44. For this purpose, the common terminal 91 of the shading coils 89 and 90 is in connection through a lead 92 to the movable armature 93 of relay 72. The movable armature is biased in one direction, for instance by means of spring 94, but when the relay winding 95 is energized, the armature 93 of the relay is attracted sufficiently to overcome the bias of the spring 94. Thereby, the armature 93 alternately serves the two contacts 96 and 97 of the relay.

Contact 96 of the relay is in connection with the movable contact of homing switch 36 through a lead 99. The other contact of the homing switch is connected as at 100 to the end of the shading coil 89 opposite the common connection 91 thereof. The other contact 97 of the relay 72 is in connection through lead 101 to movable contact arm 102 of cycling switch 44. This cycling switch, as previously noted, is of the double throw type, having two stationary contacts 103 and 104, with which the contactor arm 102 alternately makes engagement. Contact 103 is connected through lead 105 to the end of shading coil 90 which is opposite the common terminal 91, while contact 104 of the cycling switch is connected through lead 106 to the junction at which lead 100 from the homing switch 36 joins the shading coil 89.

*Description of operation*

When the diaphragm is at rest, preceding usage of the apparatus, exposure switch 37, and homing switch 36 are open, and the contact 93 of the relay 72 is in engagement with contact 96 thereof under the influence of spring 94. For purposes of the description, it is assumed that the contactor arm 102 of cycling switch 44 is in "down" position, in engagement with contact 103 thereof. The circuit of shading coil 89 is open at the cycling switch 44, and the circuit of shading coil 90 is open at relay 72. The field of motor 27 is energized through the leads 77 and 78, and the apparatus is ready for operation.

As soon as control switch 75 is closed, either manually, mechanically, or electrically, relay 72 is energized causing contactor 93 thereof to make engagement with contact 97 against the bias of spring 94. This operation causes shading coil 90 to be short circuited, the circuit extending from the mid connection 91 through lead 92 to armature 93 of relay 72, and through lead 101 and contacts 102 and 103 of the cycling switch 44, thence back to the shading coil 90 through lead 105. Short circuiting of the shading coil 90 causes the motor to operate the diaphragm to the right, for example as shown by the arrow adjacent shading coil 90 in the drawing.

Shortly after the diaphragm starts to move, the arms 48, 48, respectively controlling homing switch 36 and exposure switch 37, are released, and these switches close. Closure of the exposure switch completes a circuit to the magnetic switch 76 of the X-ray tube through leads 86, 84, and 87, and control switch 75, thereby energizing the X-ray tube only after the diaphragm is in motion. Closure of homing switch 36 conditions the circuit so

that it subsequently may be governed by the homing switch.

Once placed in motion, the diaphragm continues moving to the right until it reaches the right hand end of its stroke. At this time, finger **69** of the actuator assembly **62** comes into engagement with the offset portion **60** of the lever **57**, thereby throwing cycling switch **44** to its other position. This, in effect, causes contact arm **102** of cycling switch **44** as shown in Figure 8, to break engagement with contact **103** and make engagement with contact **104**. Since the relay **72** is energized, contact **93** thereof is in engagement with contact **97**. Therefore, the circuit to shading coil **90** is opened at the cycling switch and the circuit to shading coil **89** is closed through lead **92**, contacts **93** and **97** of relay **72**, contacts **102** and **104** of the cycling switch, and lead **106**.

The motor **27** now promptly rotates in an opposite direction which is effective to move the diaphragm to the left. Such movement continues until the diaphragm reaches the left hand end of its stroke. Finger **68** of the actuator assembly **62** is so positioned that it comes into engagement with the offset portion **59** of lever **56** at the end of the intended movement to the left, thereby throwing the cycling switch **44** in opposite direction. This operation is timed to occur before the edges **46** and **47** of plate **16** reach the actuators of the cycling and homing switches. Therefore, the direction of motor rotation is again reversed and the Bucky diaphragm is driven to the right. Such reciprocating movements occur through these switching connections so long as the control switch **75** is closed; hence, there is no limit on the time period during which the diaphragm may be oscillated back and forth.

The control switch **75**, of course, may be opened at any time, independently of the position which the diaphragm happens to occupy at that given moment. The opening of switch **75** nominally occurs at the end of an exposure period, at which time the diaphragm may be at point in its field of movement travelling either to the right or left as the case may be. The apparatus is so arranged that the diaphragm, whatever its position, will move to home or starting position which, for purposes of illustration, is shown to be at the left in Figure 1. Also, homing movement of the diaphragm, after exposure is terminated, is effective to reset the homing and exposure switches and thereby condition them for proper operation of the apparatus in the next usage.

To illustrate the operation of the homing feature of the invention, it may first be assumed that the diaphragm is being moved to the right when the control switch **75** is opened. In this circumstance, cycling switch **44** will be in the "down" position, i. e., contact **102** thereof will be in engagement with contact **103**. When the control switch **75** is opened, the relay **72** is immediately de-energized and the circuit to magnetic switch **76** is opened, thereby terminating the exposure. Contact **93** of relay **72** assumes engagement with contact **96** thereof, short circuiting shading coil **89** through lead **99** to the closed homing switch **36**, and simultaneously opening the circuit to cycling switch **44** so that it loses control over the circuit. The direction of motor rotation, therefore, is reversed and the diaphragm immediately starts to move to the left. The diaphragm, in moving to the left, will now pass the reversal point. Diaphragm movement will also continue past the actuation point of exposure switch **37** and until the homing switch **36** is actuated to open position. When this occurs, the short circuit on the shading coil **89** is opened and the motor ceases to operate, allowing the diaphragm to come to rest.

When the diaphragm is moving to the left, the cycling switch **44** will be in the "up" position, with contactor **102** in engagement with contact **104**, to provide the short circuit for shading coil **89**. If the control switch **75** is now opened, relay **72** is de-energized and contactor **93** moves into engagement with contact **96**, which re-establishes or maintains short circuit of shading coil **89** through lead **99** and homing switch **36**. Here again, the separation of contact **97** from **93** of relay **72** inactivates the cycling switch **44**. Thus, the diaphragm will continue moving to the left, past the reversal point of the cycling switch **44**, which has lost control over the circuit. The movement to the left continues until the homing switch is actuated to open the circuit of the shading coil **89**. However, the diaphragm, in moving past switch **44**, actuates it so that it will dictate movement to the right when the apparatus is next used.

From this description, it is seen that the homing switch is inactive so long as the cycling switch has control of the circuit, and that the relay **72** which is responsive to the main switch **75** dictates whether the cycling switch or homing switch will govern motor operation. Therefore, whenever switch **75** is opened, the diaphragm moves to home position no matter where the diaphragm happens to be when the control switch **75** is opened.

The interconnection of the exposure switch **37** in circuit with control switch **75** and magnetic contactor **76** insures movement of the diaphragm before the X-ray tube can be energized, and thereby precludes the possibility of inadvertently starting an exposure at a moment when the Bucky is at rest or is at a reversal point. However, it is to be understood that the exposure switch is not essential to the reciprocation and homing control features of the circuit and may be omitted if desired. When the exposure switch is included, it is appropriate for an exposure allowance to be made of the time required to move the Bucky from rest position to the position in which the exposure switch is actuated. This allowance provision may be built directly into the timer, or may be ignored entirely in long exposures.

Having described my invention, I claim:

1. A diaphragm assembly for screening secondary X-ray radiations from a photographic film comprising, a frame, a screen diaphragm slidably mounted in said frame, a reversible electric motor mounted in said frame, a drive sheave, speed reduction gear means interconnecting the said drive sheave with said electric motor, a string member in driven engagement with said drive sheave and in driving engagement with said screen member for effecting linear movement thereof in back and forth directions in said frame as determined by the direction of operation of said electric motor, and a control circuit including said electric motor and switch members responsive to the movement of said diaphragm for reversing the direction of operation of said motor at predetermined points in the movement of said screen member, the said string member having limited elasticity effective to absorb the momentum of said screen member in consequence of reversal of direction of its movement.

2. A diaphragm assembly for screening secondary X-ray radiations from a photographic film comprising, a frame, a screen diaphragm slidably mounted in said frame, a reversible electric motor mounted in said frame, a drive sheave, speed reduction gear means interconnecting the said drive sheave with said electric motor, a string member in driven engagement with said drive sheave and in driving engagement with said screen diaphragm for effecting linear movement thereof in back and forth directions in said frame as determined by the direction of operation of said electric motor, a control circuit including said electric motor and switch members responsive to the movement of said diaphragm for reversing the direction of operation of said motor at predetermined points in the movement of said screen diaphragm, the said string member having limited elasticity for absorbing the momentum force of said diaphram in consequence of reversal of its direction of movement, and means for automatically returning the diaphragm to a predetermined starting position after cyclic reciprocating operations thereof are terminated.

3. A diaphragm mechanism including a reversible elec-

tric motor and a diaphragm driven thereby in opposite directions, a reciprocation control circuit including switch means for energizing the motor to cause it alternately to operate in opposite directions, and a homing circuit including said electric motor and a homing switch which is responsive to movement of said diaphragm for completing a circuit to said motor following reciprocating operations thereof and effective thereafter to cause continued motor operation sufficient to drive the said diaphragm to a predetermined position.

4. Mechanism for reciprocating a Bucky grid continuously during an X-ray exposure, comprising a base having means for slidably mounting a Bucky grid therein, a reversible electric power unit mounted in said base, a string drive member connecting the said power unit to said Bucky grid for imparting movements in opposite directions to said grid from said power unit, reversing switch means in electrical connection with said power unit, an actuator for said switch means secured to said grid, whereby reversal in the direction of movement of said electrical power means is effected at predetermined points in the movement of said grid, the said string being of limited elasticity for absorbing the momentum of the moving Bucky grid, means for initiating and terminating reciprocating movement of said power unit, and homing switch means for controlling movement of the said grid to a predetermined position after its reciprocating movements are terminated, whereby movement of the grid in a next successive usage of the mechanism commences from a predetermined point.

5. Mechanism for reciprocating a Bucky grid continuously during an X-ray exposure, comprising a base having means for slidably mounting a Bucky grid therein, a reversible electric power unit mounted in said base, a string drive member connecting the said power unit to said Bucky grid for imparting motor movements in opposite directions to said grid from said power unit, reversing switch means in electrical connection with said power unit, an actuator for said switch means secured to said grid, whereby reversal in the direction of movement of said electrical power means is effected at predetermined points in the movement of said grid, the said string being of limited elasticity for absorbing the momentum of the moving Bucky grid, means for initiating and terminating reciprocating movement of said power unit, and homing switch means independent of said reversing switch means.

6. Mechanism for reciprocating a Bucky grid continuously during an X-ray exposure, comprising a base having means for slidably mounting a Bucky grid therein, a reversible electric power unit mounted in said base, a taut, slightly stretchable string connecting the said power unit to said Bucky grid for imparting movement to said grid in opposite directions from said power unit, reversing switch means in electrical connection with said power unit, an actuator for said switch means secured to said grid whereby reversal in the direction of movement of said electrical power means is effected at predetermined points in the movement of said grid, means for initiating and terminating reciprocating movements of said grid from said power unit through said string, and a homing circuit including said motor and a homing switch which is independent of said reversing switch means for maintaining motor operation after termination of reciprocating movements of said grid until the said grid reaches a predetermined home position.

7. In an X-ray machine, the combination of a Bucky grid, means for reciprocating said grid including a reversible electric motor, a reciprocation control circuit including switch means for energizing the motor to cause it alternately to operate in opposite directions, a homing swith in parallel control connection with said reciprocation control circuit, a control switch for initiating and terminating motor operation, means actuable in response to the condition of said control switch for alternately placing said homing switch and said control circuit in operative control relationship with said reversible motor.

8. In an X-ray machine, the combination of a Bucky grid, means for reciprocating said grid including a reversible electric motor, said electric motor having two shading coils, a reciprocation control circuit including switch means for alternately short circuiting one or the other of said shading coils to cause the motor alternately to operate in opposite directions, a homing circuit for short circuiting one of said shading coils to cause said motor to drive said Bucky to a predetermined position after its reciprocating movements are terminated, said homing circuit including a homing switch operable upon Bucky movement to condition the homing circuit for control of the motor, a control switch for initiating and terminating motor operation, relay means actuable in response to the condition of said control switch for rendering said reciprocation control circuit ineffective for control of said mtor and placing said homing circuit in effective circuit relationship with said shading coil upon opening of said control switch.

9. Mechanism for reciprocating a Bucky grid continuously during an X-ray exposure, comprising a base having means for slidably mounting a Bucky grid therein, a reversible electric power unit mounted in said base, means including a string drive connecting the said power unit to said Bucky grid for imparting movements in opposite directions to said grid from said power unit, reversing switch means in electrical connection with said power unit, an actuator for said switch means secured to said grid, whereby reversal in the direction of movement of said electrical power means is effected at predetermined points in the movement of said grid, said string drive means being of limited elasticity for absorbing the momentum of the moving Bucky grid, means for initiating and terminating reciprocating movement of said power unit, and means for effecting movement of the said grid to a predetermined position after its reciprocating movements are terminated, whereby movement of the grid in a next successive usage of the mechanism commences from a predetermined point.

References Cited in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 2,123,182 | Drake | July 12, 1938 |
| 2,203,689 | MacDonald | June 11, 1940 |
| 2,205,209 | Kunz et al. | June 18, 1940 |
| 2,334,447 | Shaw | Nov. 16, 1943 |
| 2,504,864 | Morgan et al. | Apr. 18, 1950 |
| 2,583,213 | Graves | Jan. 22, 1952 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 305,322 | Great Britain | Feb. 7, 1929 |
| 495,215 | Great Britain | Nov. 19, 1938 |