Oct. 17, 1950 E. F. MORAN ET AL 2,526,390

PHOTOFLUOROGRAPH

Filed May 16, 1944 2 Sheets-Sheet 1

Fig. 1.

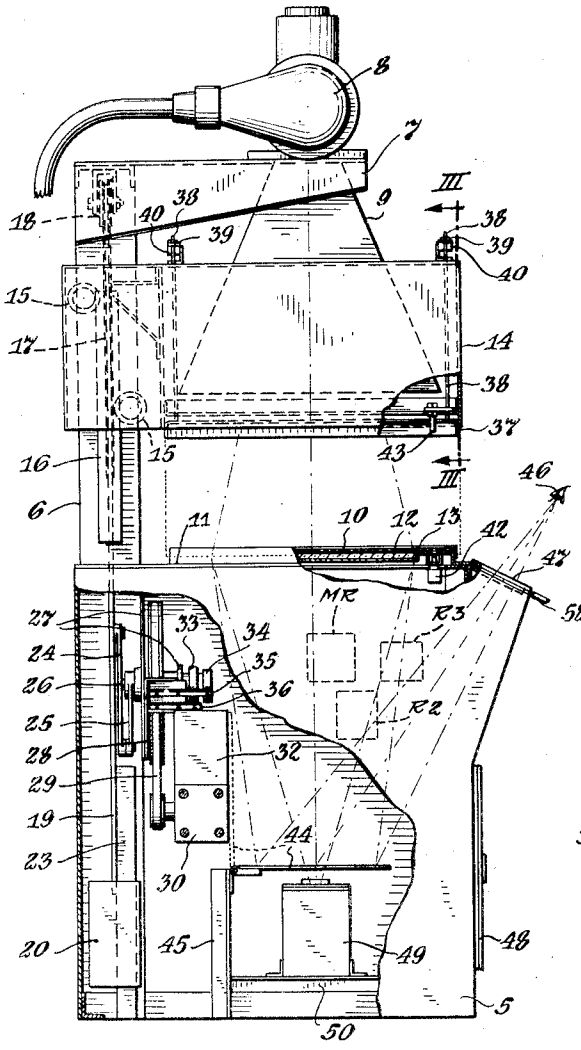
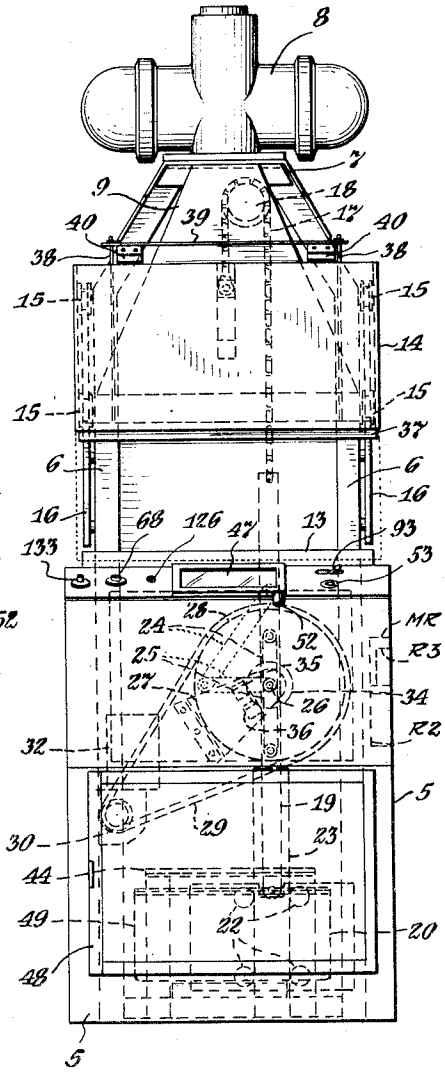


Fig. 2.



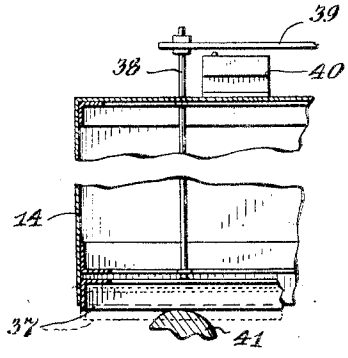


Fig. 3.

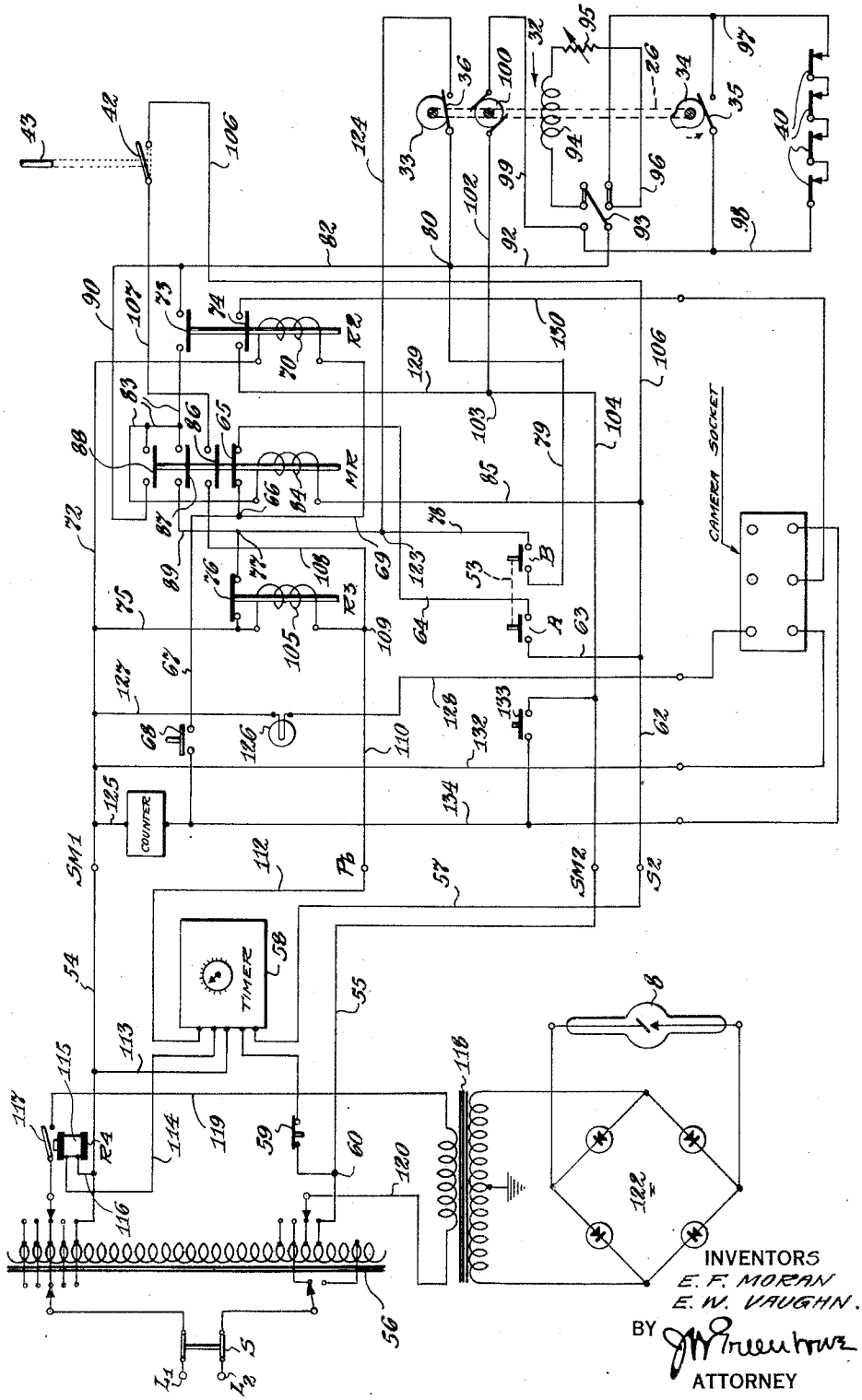
INVENTORS
E. F. MORAN
E. W. VAUGHN.
BY
ATTORNEY

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Fig. 4.



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PHOTOFLUOROGRAPH

Edward F. Moran, Baltimore, and Everett W. Vaughn, Ridgewood, Md., assignors to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application May 16, 1944, Serial No. 535,790

5 Claims. (Cl. 250—65)

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The present invention relates to X-ray apparatus and especially to an industrial photofluorograph of the type now used quite extensively in industrial factories for the inspection of products.

Although the utilization of X-ray has long been known to medical science, it is only within the last few years that they have been extensively employed in the industrial field, particularly for inspection purposes such as metal castings and the like. Inasmuch as the average mechanic who operates the X-ray apparatus is not a trained technician, as is the roentgenologist, it is imperative that industrial X-ray apparatus be fool-proof and harmless in its operation, while at the same time efficient. Otherwise the operator would be subjected to the hazards of stray radiation and perhaps other injury while operating the apparatus.

It is accordingly an object of the present invention to provide an X-ray apparatus especially applicable to industrial uses and wherein the operator is fully shielded from stray X-radiations.

Another object of the present invention is the provision of an industrial photofluoroscopic X-ray apparatus which is automatically energized only when the operator is completely shielded from stray X-radiation.

Another object of the present invention is the provision of an industrial photofluoroscopic X-ray apparatus in which the possibility of injury resulting to the operator during operation of the apparatus is entirely eliminated by the provision of certain automatic safety features.

Still further objects of the present invention will become obvious to those skilled in the art by reference to the accompanying drawings wherein;

Figure 1 is a side elevational view partly in section and with parts thereof broken away of an industrial photofluoroscopic X-ray apparatus constructed in accordance with the present invention;

Figure 2 is a front elevational view of the X-ray apparatus of Figure 1;

Figure 3 is a sectional view taken on the line III—III of Figure 1; and

Figure 4 is a schematic diagram of the electrical control circuits for the apparatus of Figure 1.

Referring now to the drawings in detail, the photofluoroscopic apparatus shown in Figure 1 comprises a light-tight chamber 5 adapted to rest upon the floor, and extending upwardly from such chamber is a frame-work 6 provided at its extremity with a platform 7 which supports an X-ray tube 8 on its upper side and a ray-proof

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cone 9 depending therefrom. The top of the chamber 5, which forms substantially a table top or support 11 for the work to be inspected, such as metal castings and the like, is provided with a raised portion formed by a fluorescent screen 10 backed by lead glass 12 and an X-ray protective sheet of "Bakelite" or the like 13.

Above the chamber top is a rectangular lead-lined hood 14 of slightly larger dimensions than the raised portion of the chamber top so that the hood when lowered surrounds the raised top portion of the chamber. For the purpose of raising and lowering the hood 14, it is provided with rollers 15, which run on tracks 16 longitudinally secured to the sides of the frame-work 6. A link-chain or cable 17 is secured to the hood, and, after passing over a pulley 18 carried by the top of the frame-work 6, the opposite end of the chain is connected to a push-rod 19.

In order to form a balanced unit, the lower end of this push-rod 19 is pivotally connected to a counter-weight 20 provided with rollers 22 movable longitudinally of a guide-post 23. A crank-arm 24, which may, if desired, be formed of two parts with a slot and bolt connection for adjustment purposes, is pivotally connected at one end to the push-rod 19 while its other end is pivotally connected to a second crank arm 25 suitably secured to a shaft 26 journalled in a plate bracket 27. Also keyed or otherwise secured to the shaft 26 is a pulley 28 driven by a belt or the like 29 from a reduction gearing 30 connected to an electric motor 32.

The shaft 26 has secured thereto a pair of cams 33 and 34 adapted to engage a pair of switches 35 and 36 for a purpose hereinafter described more in detail. Depending from the bottom of the hood 14 is an open frame 37 which in the lower-most position of the hood snugly fits the raised portion of the chamber top and is in turn surrounded by the larger section of the hood 14. As shown, this frame 37 is supported by a plurality of rods 38 each pair of which are secured at their upper ends to a cross-bar 39, each of the latter normally resting upon a pair of microswitches 40. This accordingly forms a safety feature so that in the event a foreign object 41 (Fig. 3), such as the work to be inspected or the hand of the operator, is contacted by the hood 14 during its travel, the light-weight frame 37 is slightly raised carrying with it the cross-bar 39, thus disengaging the latter from one or more of the microswitches 40 and interrupting the circuit to the electric motor 32, as hereinafter explained. Likewise, a switch 42 is

affixed to the top of the chamber 5, which is engaged by a detent 43 carried by the hood 14 to interrupt the motor circuit upon complete descent of the hood to its lower limit of travel with attendant energization of the X-ray tube.

When the hood 14 is at rest in its lowermost position and the X-ray tube 8 is energized, an image will be cast on the fluorescent screen 10. To enable the operator to observe such image, a mirror 44 is pivotally connected to an upright 45 within the chamber 5. In its fluoroscopic position, this mirror 44 is disposed in a horizontal position and thus transverse to the axis of the X-ray beam so that the eye 46 of the operator can see the image reflected by the mirror by looking into a window 47 provided in the chamber 5. In the event it is desired to take a photofluorograph of the work being inspected, the operator merely slides open a door 48 provided in the chamber 5 and raises the hinged mirror 44 to a vertical position and thus out of the field of light from the fluorescent screen 10, as shown by the dotted lines in Figure 1. This uncovers a camera 49 supported by a platform 50 within the chamber 5 with the lens of the camera aligning with the fluorescent screen 10. Since the camera 49 is of the continuous film type, it is automatically operated under the control of the operator to take as many pictures as desired. Prior to operation of the camera 49, the operator closes the window 47 by sliding a shutter or curtain thereacross simply by movement of a handle 52 to thus exclude extraneous light from striking the camera film.

When the operator desires to inspect material, he places the same upon the raised portion of the chamber top so that it will be within the field of radiation from the X-ray tube 8. He then presses the push button 53 on the front of chamber 5. By reference now more particularly to Figure 4, it will be noted that depression of this push-button closes an energizing circuit from a 110 volt source of supply. This source is represented by terminals SM1 and SM2, which are connected by conductors 54 and 55, respectively, to taps of an auto-transformer 56, the latter of which is connected by a switch S to the customary commercial source of supply L1, L2 so that the desired voltage can be obtained at the terminals SM1, SM2. It will also be noted from Figure 4 that an additional terminal S2 is provided, which under normal conditions is at the same potential as terminal SM2, since a conductor 57 connects the terminal S2 through a timer 58 and a normally closed main control switch 59 to the conductor 55 at a junction 60.

Since the push-button 53 is a double-pole switch, depression thereof will cause its contacts A to close a circuit extending from terminal S2 through conductors 62 and 63, contacts A, and a conductor 64 to the normally closed contacts 65 of a main relay MR. From such contacts 65 the circuit extends to a junction 66 where it divides, one branch extending by a conductor 67 to the normally open contacts of a switch 68, for a purpose hereinafter explained. The other branch extends from the junction 66 through a conductor 69 to the winding 70 of a relay R2 and thence back to terminal SM1 constituting the opposite side of the supply source, by means of a conductor 72.

Relay R2 is accordingly energized with accompanying closure of its contacts 73 and 74. Upon operation of relay R2, a circuit is then

closed which extends from SM1 (through a junction with conductor 72) through a conductor 75, normally closed contacts 76 of a relay R3 to a junction 77, thence by a conductor 78 to the now closed contact B of push-button 53, through a conductor 79 to a junction 80, then by a conductor 82 through the now closed contacts 73 of relay R2, conductor 83 to the winding 84 of relay MR, back by a conductor 85 to a conductor 62 and constituting an extension of terminal S2. Completion of this latter circuit accordingly energizes relay MR resulting in opening of its contacts 65 and closure of a set of contacts 86, 87 and 88. The operation of relays R2 and MR follow in sequence as described upon depression of the push-button 53, which, of course, is only a momentary operation by the operator since it is almost immediately released.

Opening of the contacts 65 of relay MR interrupts the energizing circuit for the winding 70 of relay R2, with attendant opening of its contacts 73 and 74. However, opening of the contacts 73, which initially completed the energizing circuit to the winding 84 of relay MR, does not cause de-energization of the latter at this time since a self-holding circuit is completed to the winding 84 by closure of contacts 87. This self-holding circuit extends from the junction 77 (thus by-passing open contacts B of push-button 53 and open contacts 73 of relay R2) through a conductor 89, closed contacts 87 to conductor 83 and thence through relay winding 84 and conductor 85 back to terminal S2 in the same manner as previously described. Closure of contacts 88 of relay MR completes a parallel circuit extending from conductor 83 (the latter being the same potential as SM1 by virtue of the closure of contacts 87) through contacts 88 and a conductor 90 which joins conductor 82, and then from junction 80 by a conductor 92 through an emergency reversing switch 93, the field winding 94 of electric motor 32, variable resistance 95, a conductor 96 to a terminal of reversing switch 93, then through a conductor 97 to the microswitches 40 in series relation, conductor 98 to another terminal of reversing switch 93, from the latter through a conductor 99 to the armature 100 of electric motor 32, and from the latter by means of a conductor 102 to a junction 103 and conductor 104 to the opposite side of the supply source represented by terminal SM2.

Inasmuch as the hood 14 was in its uppermost position, energization of the motor 32 causes rotation of the shaft 26, which, together with the crank arms 24 and 25, raises the push-rod 19, thereby causing descent of the hood 14. If during such descent a foreign object strikes the frame 37 lifting the push-rods 38, one or more of the microswitches 40 will be opened, thus interrupting the motor circuit just described. Moreover, the emergency reversing switch 93 is then operated to reverse the electric motor 32 and cause the hood 14 to again raise to allow removal of the foreign object since movement of the switch to reversing position by-passes the microswitches 40, one or more of which are opened by the foreign object.

Assuming, however, the safety microswitches 40 are not opened, the motor continues to operate and the hood 14 descends until the detent 43 engages the switch 42 on the top of the chamber 5. Closure of this switch 42 energizes the winding 105 of relay R3 through a circuit extending from terminal S2 (by a junction with conductor 62),

thence by a conductor 106 to contacts of switch 42, through a conductor 107 to contacts 86 of relay MR, a conductor 108 to a junction 109, then to the winding 105 of relay R3, and thence through the latter winding back to terminal SM1 by means of the conductors 75 and 72. Energization of relay R3 opens contacts 76 and de-energizes winding 84 of relay MR, thus interrupting the previously traced circuit to motor 32 stopping the latter and retaining hood 14 in its lowest position where it completely shields the work to be inspected by confining the X-rays to the field of the raised top of chamber 5 preventing stray radiation from striking the operator.

At the same time that switch 42 closes the circuit to winding 105 of relay R3 to stop electric motor 32, as just explained, such switch also completes a momentary circuit to the timer 58, which circuit extends from the junction 109 by a conductor 110 to a terminal Pb, then by a conductor 112 to the timer 58. Although the internal connections of the timer are not shown in detail, it is sufficient to say this momentary circuit energizes a relay or the like within the timer, the remainder of the circuit being completed to the opposite terminal of the supply source SM1 through a conductor 113. Immediately upon momentary energization of this timer relay circuit, a sustaining circuit is closed by such relay to maintain the contacts of relay R3 open. This sustaining circuit extends from the junction 60 (constituting one side of the supply source SM2) through normally closed switch 59 and timer 58, thence through conductor 112, terminal Pb, conductor 110, junction 109 to relay winding 105 and back to terminal SM1 through conductors 75 and 72. Accordingly relay R3 remains energized and its contacts 76 are maintained open.

Upon energization of the timer relay (not shown), the timer 58 begins to operate and immediately closes a circuit to a further relay R4 extending from junction 60, switch 59 and timer 58, through a conductor 114 to winding 115 of relay R4, and thence back to the opposite side of the supply source SM1 by means of a conductor 116. Operation of relay R4 causes closure of its contacts 117, the latter of which closes a circuit to the primary winding of a high voltage transformer 118. Such circuit extends from a tap on the autotransformer 56 through a conductor 119 to the primary winding of the transformer 118 and back by a conductor 120 to another tap on the autotransformer 56, thus supplying the appropriate voltage. Since the high voltage secondary winding of the transformer 118 is connected through a rectifying bridge arrangement 122 to the X-ray tube 8, the latter is energized for the period for which the timer 58 was preset.

After expiration of the time period set by the timer 58, the circuit to the relay R4 is interrupted, thus de-energizing the X-ray tube 8. At the same time the timer relay (not shown) also interrupts the sustaining circuit for the winding 105 of relay R3, thus de-energizing the latter and causing return of its contacts 76 to their normally closed position. Closure of the latter again automatically energizes the motor 32 through a circuit now extending from a junction 123 with conductor 78 (now carrying the same potential as terminal SM1 due to closure of contacts 76) through a conductor 124 to switch 36. When the hood 14 is in its uppermost position, this switch 36 is in its open position as shown in Fig. 4. However, as soon as the shaft 26 starts to rotate to

move the hood downward, it also rotates the cam 33 carried by the shaft resulting in closure of switch 36 as soon as the hood has initially moved. Hence switch 36 is now closed as the hood is assumed to be in its complete downward position. Thus the above mentioned partially traced circuit is completed from closed switch 36 to junction 80, conductor 92, emergency reversing switch 93 field winding 94 and resistance 95, conductor 96, again the terminal of emergency reversing switch 93, conductor 97, and switch 35, which is now closed by cam 34 in the downward position of the hood 14, thus short-circuiting the safety microswitches 40, conductor 98, emergency reversing switch terminal, conductor 99 to motor armature 100, and thence by conductor 102, junction 103 and conductor 104 to terminal SM2 constituting the opposite side of the supply source.

The electric motor 32 is thus re-energized and due to the arrangement of the connecting rods 24 and 25, the hood 14 is moved in an upward direction until the cam 33 rotates to open the switch 36, thus interrupting the motor circuit and stopping the hood 14 at its uppermost position where it is ready for recycling upon the disposition of additional work to be inspected on the raised portion of the chamber top.

The operation of the apparatus thus described enables a fluoroscopic examination to be made by the operator looking through the chamber window 47 and observing the image reflected on the mirror 44 from the fluorescent screen 10. Should the operator desire to take a radiograph, he merely closes the window 47 by drawing the shade 52 to exclude extraneous light and raises the mirror 44 to a vertical position. At the same time the switch 68 is closed, which may be done manually or such switch may be so disposed as to be automatically closed by movement of the mirror 44 to the vertical position or by movement of the X-ray tube filament control in changing the cathode heating current from its fluoroscopic setting to its radiographic setting.

This having been done, the operator again depresses the push-button 53 with the apparatus operating in the identical manner as previously described but with certain additional operations occurring. For example, when the coil 70 of relay R2 is energized by the circuit previously described, the "Counter" will also be energized because one side of the supply source is supplied thereto by switch 68 (the conductor 67 being at the same potential as S2 by closure of the circuit for the coil 70 of relay R2), while the opposite side of this "Counter" is connected by a conductor 125 to the opposite side of the supply source represented by SM1. This "Counter" is for the purpose of indicating the number of exposed frames of the continuous film camera 49.

At the same time that the counter operates, a signal lamp 126 flashes to indicate advancement of the film within the camera 49, such circuit extending from conductor 72 (constituting an extension of terminal SM1) through a conductor 127 to the lamp 126, and thence through a conductor 128 to the "camera socket." The remainder of the circuit has not been shown, but it should suffice to say that movement of the film in advancing from one frame to another closes a switch which completes the circuit to the opposite side of the supply source SM2, substantially in the manner as shown in the copending application of Chester B. Land, Serial No. 516,220, filed December 30, 1943, now Patent No. 2,433,129.

Also upon energization of relay R2, its contacts 74 close a circuit to the camera motor (not shown). This latter circuit extends from the junction 103 (constituting an extension of terminal SM2) by a conductor 129, through relay contacts 74 and a conductor 130, to the "camera socket" and thus to camera motor and then back to terminal SM1 by a conductor 132.

The camera film will thus advance one frame and position an unexposed film immediately in back of the camera lens at the same time flashing the signal light 126 and causing the "Counter" to register. The hood 14 descends in the manner previously described and upon reaching its lowermost position, energizes the X-ray tube 8 with a resulting radiographic exposure, after which the hood again returns to its uppermost position, the entire cycle of operation being identical to that occurring during a fluoroscopic examination as previously described.

A push-button 133 is provided, which upon depression completes a circuit to the "Counter" by means of a conductor 134 and the conductor 125, and at the same time completes a circuit to the camera motor by means of a conductor 135 and the conductor 132. The purpose of this push-button 133 is to enable advancement of the film to a desired frame during loading of the camera without the necessity of operating the remainder of the apparatus. It should also be noted that although most of the various elements as shown in Fig. 4 are carried by the apparatus of Figs. 1 and 2, the autotransformer 56, together with the rectifier bridge 122 and high voltage transformer 118, are housed within a separate casing positioned adjacent the chamber 5.

From the foregoing it will become obvious to those skilled in the art that a photofluorographic apparatus is herein provided which is particularly adaptable to industrial applications of inspecting work such as metal castings and the like. Moreover, such apparatus automatically operates in response to initiation by the operator to take either a radiographic exposure of the work to be inspected or the making of a fluoroscopic examination, as selected by the operator. The apparatus is also entirely safe in its operation due to the provision of safe-guards which protect the operator from bodily injury by automatically stopping operation should the operator inadvertently come in contact with moving parts thereof, and the operator is adequately shielded from all possible radiation from the X-ray tube during its energization.

Although one specific embodiment of the present invention has been shown and described, it is to be understood that other modifications thereof may be made without departing from the spirit and scope of the appended claims.

We claim:

1. A photofluoroscopic apparatus comprising a work support, an X-ray tube disposed in spaced relation to said work support, a member having a sensitized surface disposed on the underside of the upper end of said work support for registering an image of objects carried by said work support when subjected to a beam of X-rays from said X-ray tube, an X-ray impervious hood normally spaced from said work support, means automatically operable in response to initiation by an operator to cause movement of said hood into contact with said work support to confine the beam of X-rays from said tube to a definite area of said work support and to prevent stray radiations from striking the operator during operation of said X-ray tube, means surrounding said hood and automatically operable to render said first mentioned means inoperative with a cessation of movement of said hood when any side of the latter contacts foreign object, means operable to condition said first mentioned means to cause movement of said hood only in an opposite direction following operation of said last mentioned means, means carried by said work support and automatically operable in response to contact of said hood with said work support to cause energization of said X-ray tube, and a continuous film camera enclosed by said work support for the making of a photograph of the image cast on the sensitized surface of said member upon energization of said X-ray tube.

2. A photofluoroscopic apparatus comprising a work support, an X-ray tube disposed in spaced relation to said work support, a member having a sensitized surface disposed on the underside of the upper end of said work support for registering an image of objects carried by said work support when subjected to a beam of X-rays from said X-ray tube, an X-ray impervious hood normally spaced from said work support, means automatically operable in response to initiation by an operator to cause movement of said hood into contact with said work support to confine the beam of X-rays from said tube to a definite area of said work support and to prevent stray radiations from striking the operator during operation of said X-ray tube, means surrounding said hood and automatically operable to render said first mentioned means inoperative with a cessation of movement of said hood when any side of the latter contacts a foreign object, means operable to condition said first mentioned means to cause movement of said hood only in an opposite direction following operation of said last mentioned means, means carried by said work support and automatically operable in response to contact of said hood with said work support to cause energization of said X-ray tube, means automatically operable upon deenergization of said X-ray tube to return said hood to its normally spaced position relative to said work support, and a continuous film camera enclosed by said work support for the making of a photograph of the image cast on the sensitized surface of said member upon energization of said X-ray tube.

3. A photofluoroscopic apparatus comprising a work support, an X-ray tube disposed in spaced relation to said work support, a member having a sensitized surface disposed on the underside of the upper end of said work support for registering an image of objects carried by said work support when subjected to a beam of X-rays from said X-ray tube, an X-ray impervious hood normally spaced from said work support and adapted to be moved into juxtaposition therewith and into a position surrounding the beam of X-rays from said tube to confine the latter to a definite area of said work support and to prevent stray radiations from striking the operator, electrical means operable in response to initiation by an operator to cause movement of said hood into juxtaposition with said work support, safety means surrounding said hood and operable by contact of any side of said hood with a foreign object during its movement to render said electrical means inoperative and to prevent further movement of said hood, means operable to condition said electrical means to cause movement of said hood only in an opposite direction following operation of said safety means, means carried

by said work support and operable upon movement of said hood into contact with said work support to cause said electrical means to become inoperative and to stop further movement of said hood, means simultaneously operable upon stoppage of said hood in contact with said work support to cause energization of said X-ray tube, a continuous film camera enclosed by said work support for the making of a photograph of the image cast on the sensitized surface of said member upon energization of said X-ray tube, and electrical means operable upon deenergization of said X-ray tube to cause operation of said first mentioned electrical means with attendant return of said hood into its normally spaced position relative to said work support.

4. A photo-fluoroscopic apparatus comprising a work support, an X-ray tube disposed in spaced relation to said work support, a member having a sensitized surface disposed on the underside of the upper end of said work support for registering an image of objects carried by said work support when subjected to a beam of X-rays from said X-ray tube, an X-ray impervious hood normally spaced from said work support and adapted to be moved into juxtaposition therewith and into a position surrounding the beam of X-rays from said tube to confine the latter to a definite area of said work support and to prevent stray radiations from striking an operator, a driving arrangement including an electrical motor for moving said hood into juxtaposition with said work support, an electrical circuit initially closable by the operator to cause energization of said electric motor with attendant movement of said hood into juxtaposition with said work support, a safety switch carried by said hood and operable upon contact of any side of said hood with a foreign object during its movement to cause the interruption of the energizing circuit for said electrical motor and stoppage of said hood, means operable to condition said electrical circuit to cause energization of said electric motor for movement of said hood only in an opposite direction following operation of said safety switch, an X-ray tube energizing circuit, a switch carried by said work support and operable upon movement of said hood into juxtaposition with said work support to cause interruption of the energizing circuit for said electric motor and for causing closure of said X-ray tube energizing circuit, a continuous film camera enclosed by said work support for the making of a photograph of the image cast on the sensitized surface of said member upon energization of the X-ray tube, and a circuit automatically closable upon interruption of the X-ray tube energizing circuit to cause reenergization of said electric motor and operation of said driving arrangement with return of said hood to its normally spaced position relative to said work support.

5. A photofluoroscopic apparatus comprising a work support, an X-ray tube disposed in spaced relation to said work support, an X-ray impervious hood normally spaced from said work support and adapted to be moved into juxtaposition therewith and into a position surrounding a beam of X-rays from said tube to confine the latter to a definite area of said work support and to prevent stray radiations from striking an operator, a driving arrangement including an electrical motor for moving said hood into juxtaposition with said work support, an electrical circuit initially closable by the operator to cause energization of said electric motor with attendant movement of said hood into juxtaposition with said work support, an X-ray tube energizing circuit, a switch carried by said work support and operable upon movement of said hood into juxtaposition with said work support to cause interruption of the energizing circuit for said electric motor and for causing closure of said X-ray tube energizing circuit, a fluorescent screen associated with said work support for the making of a fluoroscopic examination at the will of an operator and observable by the operator exteriorly of said work support for registering an image of the work carried by said work support upon energization of said X-ray tube, a continuous film camera associated with said work support for photographing the image of the work carried by said work support upon energization of said X-ray tube and at the will of the operator in lieu of the making of a fluoroscopic examination, a second electrical circuit automatically closable upon interruption of the X-ray tube energizing circuit to cause reenergization of said electric motor and operation of said driving arrangement with return of said hood to its normally spaced position relative to said work support.

EDWARD F. MORAN.
EVERETT W. VAUGHN.

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