

Dec. 12, 1933.

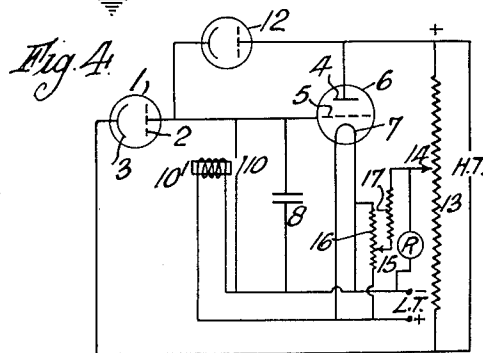
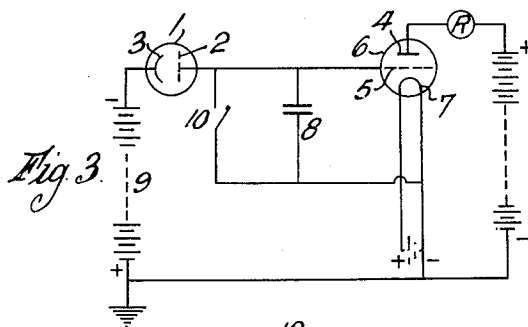
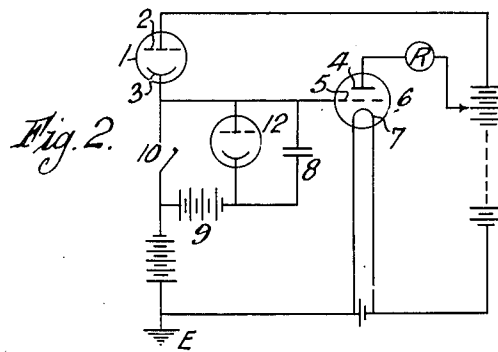
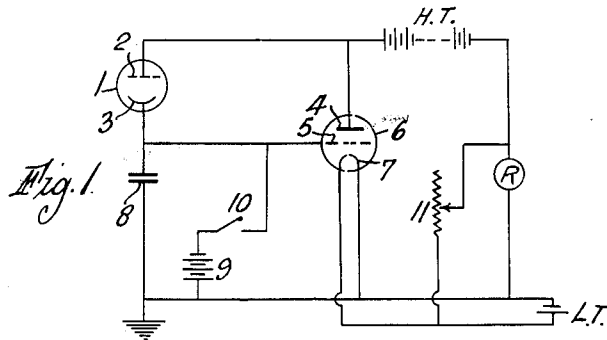
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1,939,243

PHOTOGRAPHIC PRINTING APPARATUS

Filed Jan. 23, 1931

7 Sheets-Sheet 1



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PHOTOGRAPHIC PRINTING APPARATUS

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7 Sheets-Sheet 2

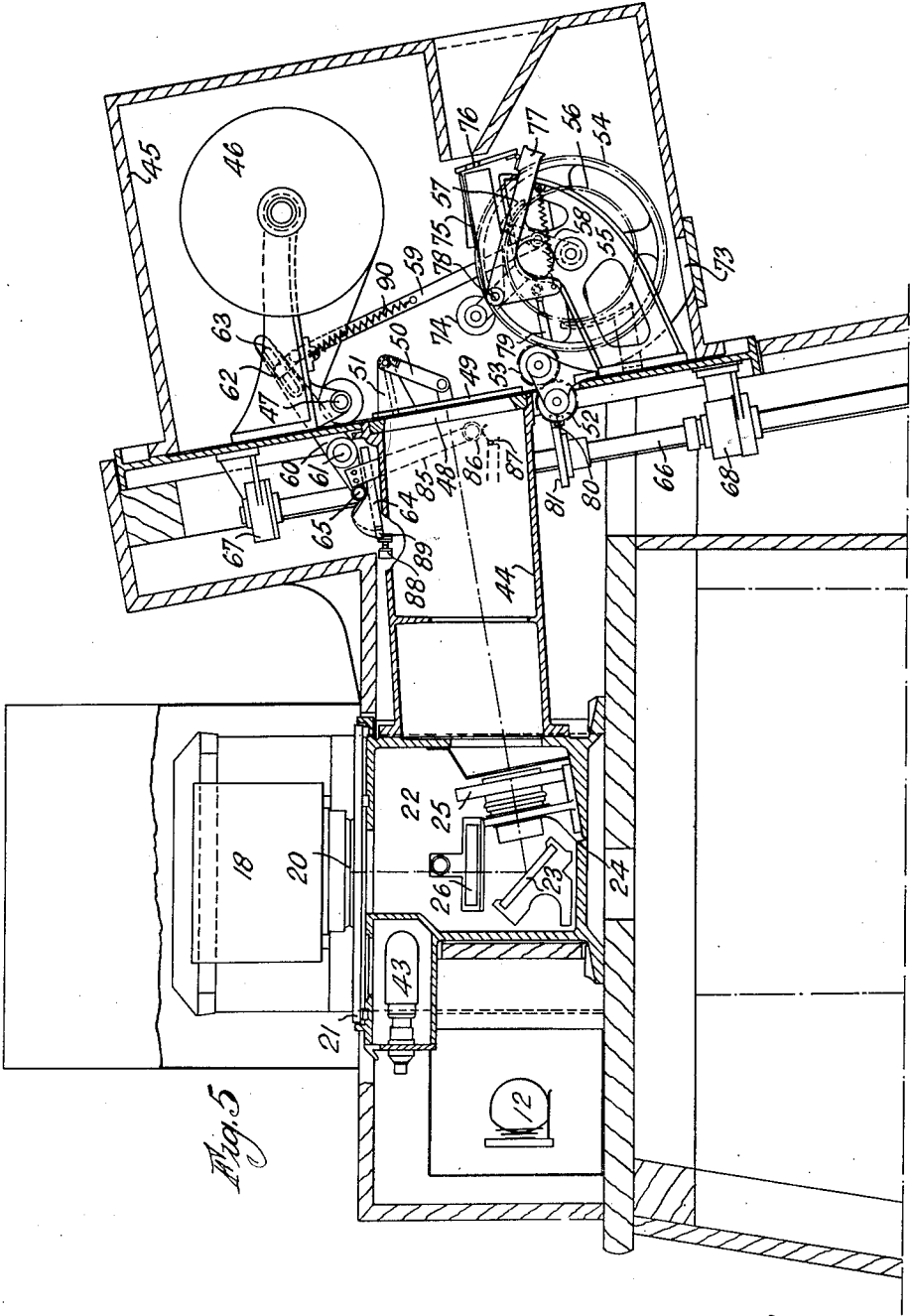


Fig. 5

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7 Sheets-Sheet 3

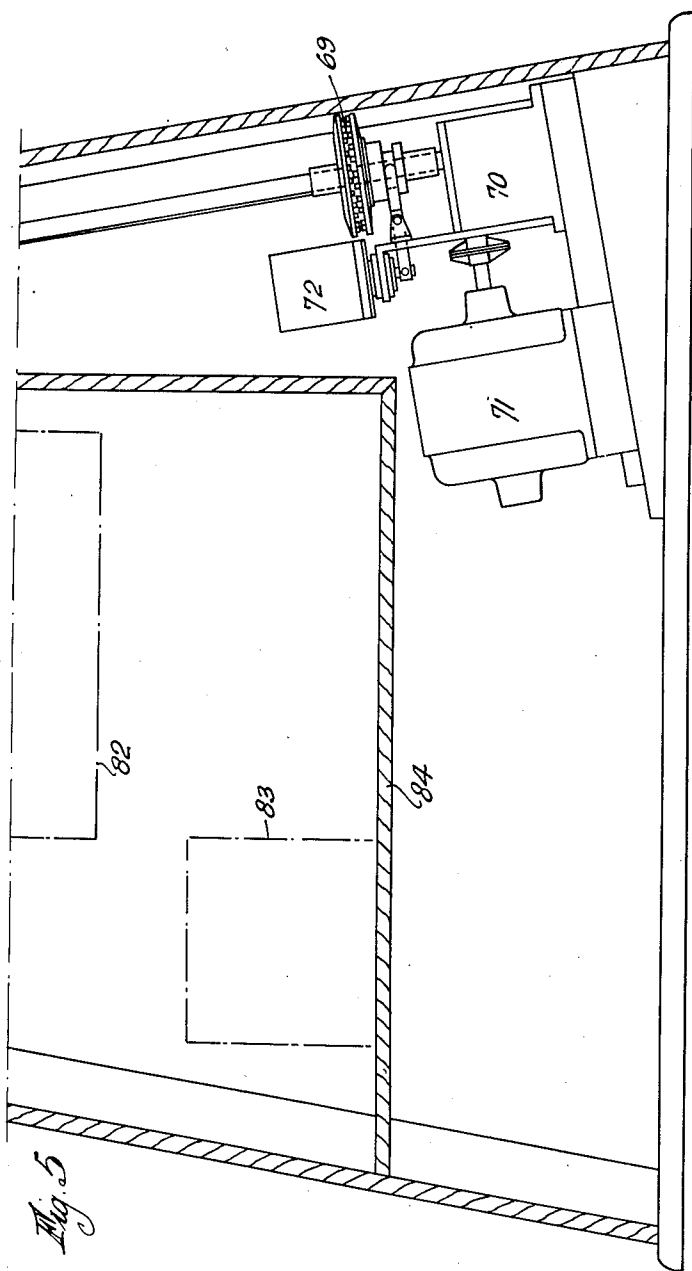


Fig. 5

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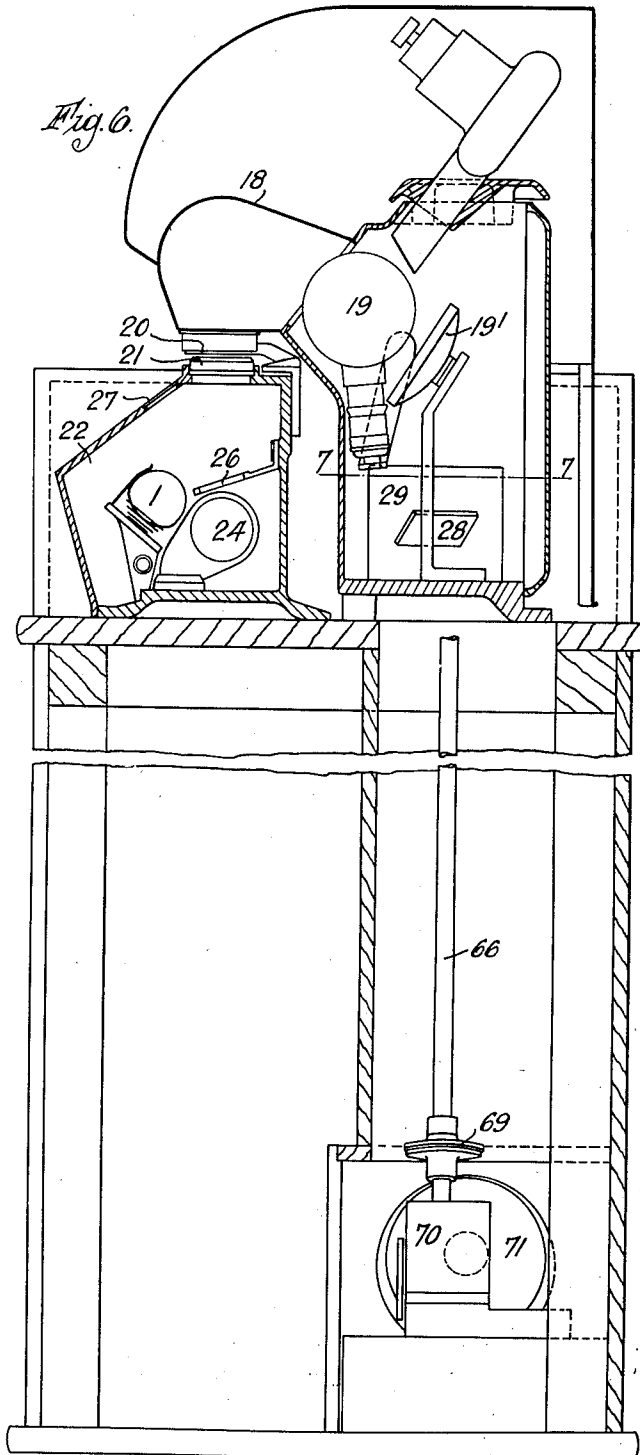
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7 Sheets-Sheet 4



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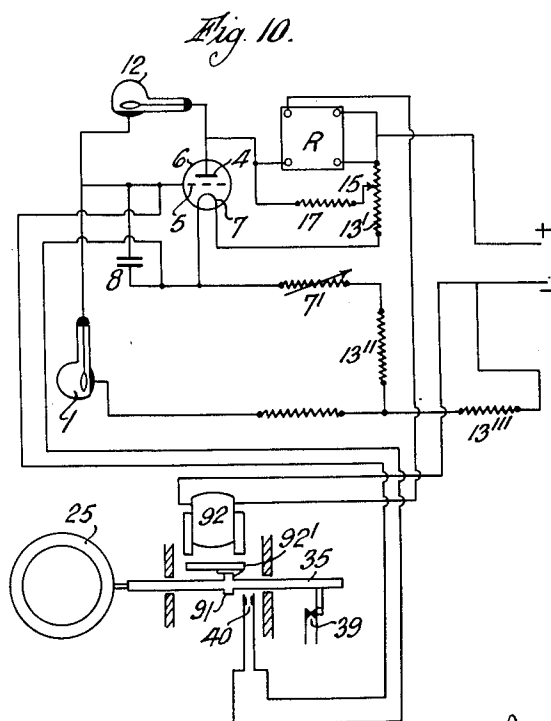
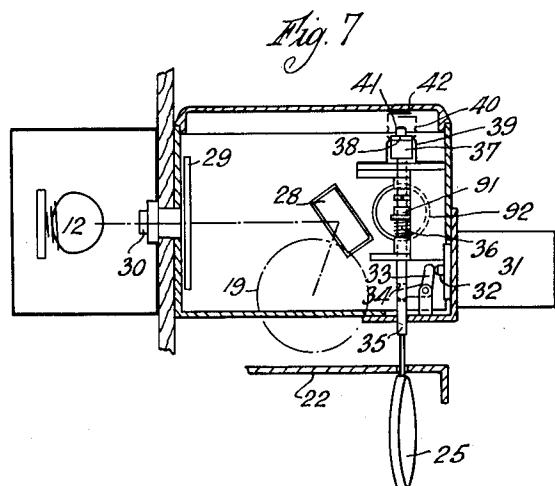
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PHOTOGRAPHIC PRINTING APPARATUS

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7 Sheets-Sheet 5



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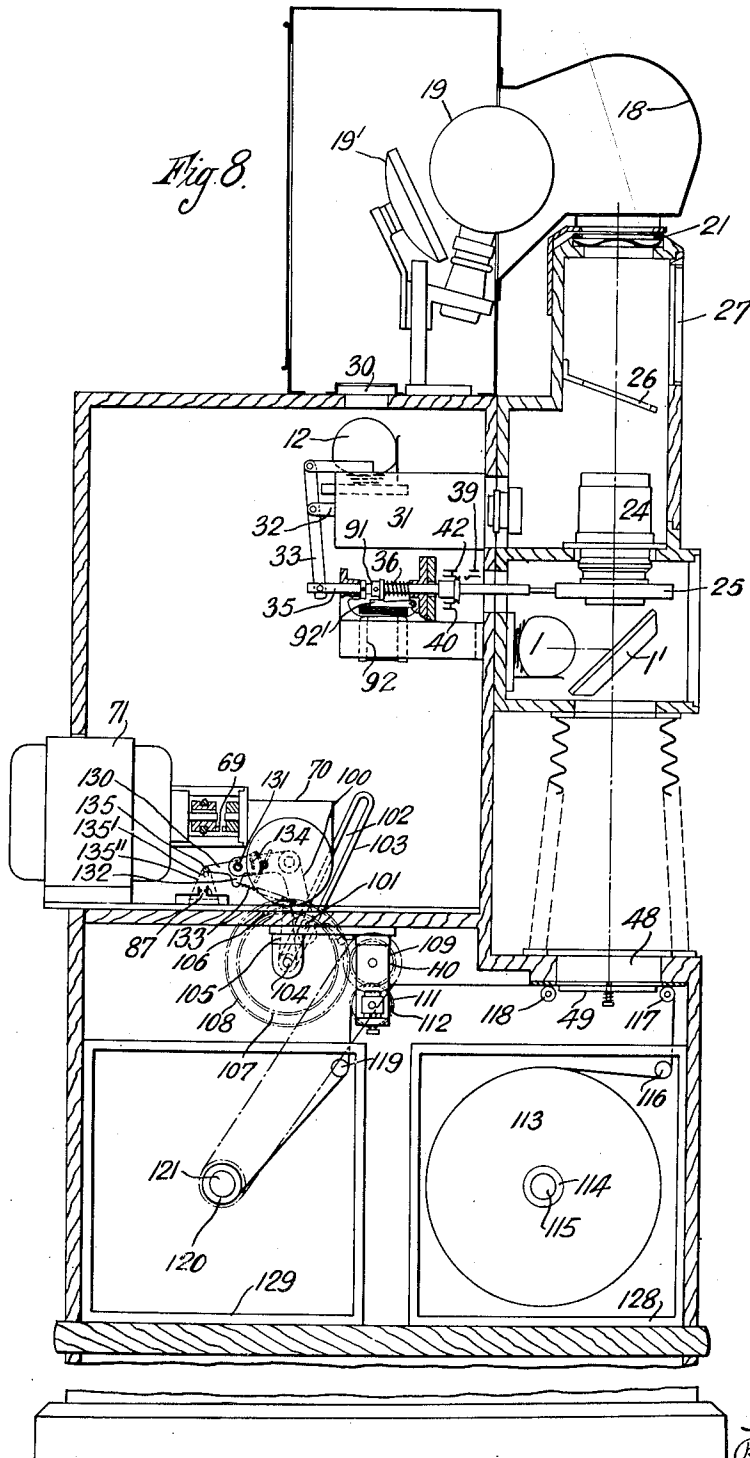
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7 Sheets-Sheet 6



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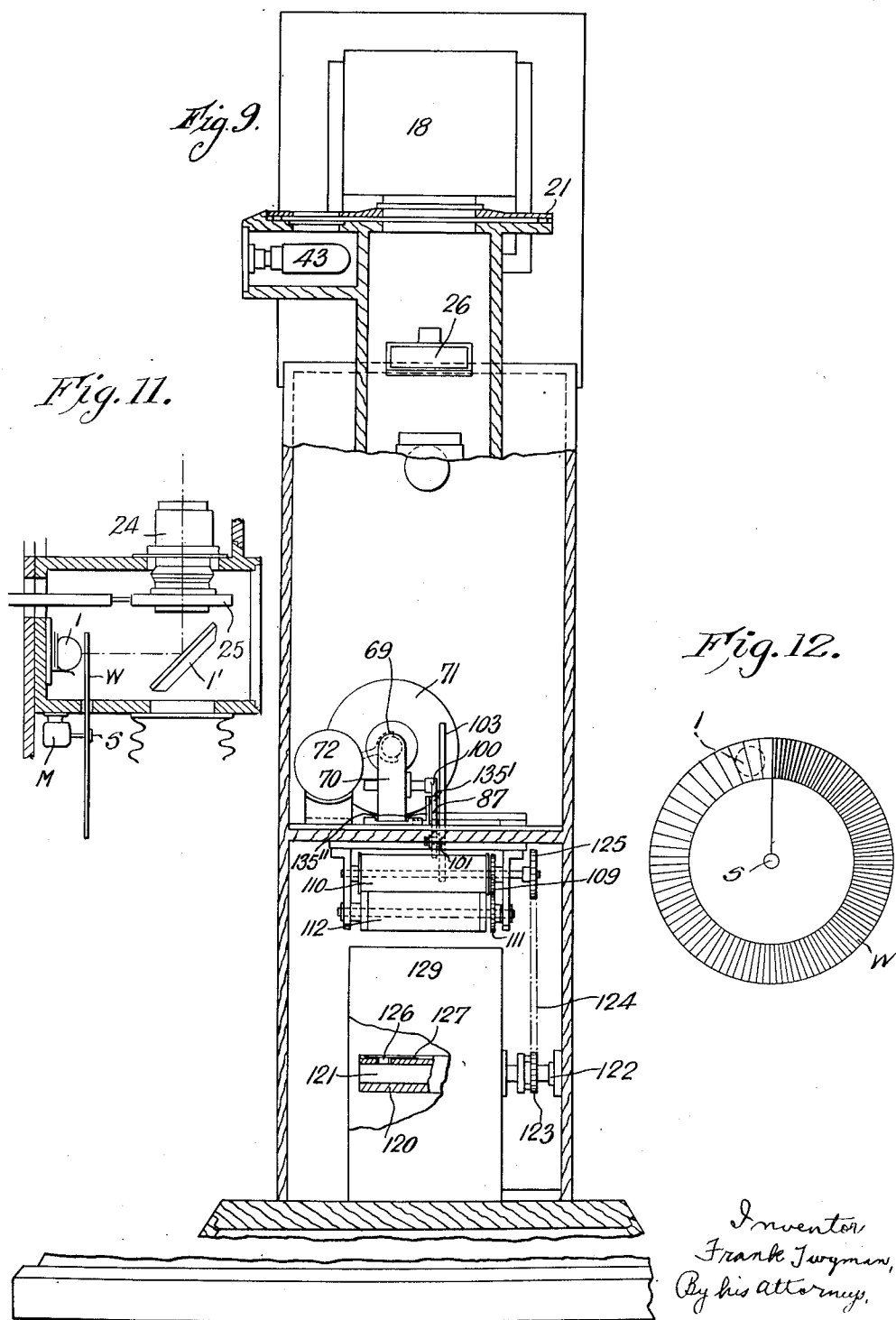
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PHOTOGRAPHIC PRINTING APPARATUS

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7 Sheets-Sheet 7



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UNITED STATES PATENT OFFICE

1,939,243

PHOTOGRAPHIC PRINTING APPARATUS

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mesne assignments, to Eastman Kodak Com-
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Application January 23, 1931, Serial No. 510,821,
and in Great Britain January 25, 1930

37 Claims. (Cl. 88—24)

The present invention relates to photographic printing or enlarging apparatus, and more particularly to automatic means for ensuring a quantum of light (i. e. product or integrated product of intensity of illumination and time of exposure) falling on the printing surface which is either substantially constant or which departs from the constant according to a predetermined rule, the object being to ensure uniform printing.

According to the invention the automatic control of exposure in photographic printing or enlarging is effected by integrating means, physically responsive to quantum of light energy, which, at the desired moment, operate to terminate the exposure.

The integrating means preferably comprises a light sensitive device (e. g. a photo-electric cell), exposed to the influence of light transmitted through the negative, an electric storage device whose charge is adapted to be varied by current under control of the light sensitive device, and an electrical relay adapted to be operated to terminate the printing exposure when the electric storage device is charged to a certain point.

In an embodiment of the invention, a photo-electric cell, which may conveniently be of the potassium-gas-filled type, is placed in circuit with a condenser and with a source of electrical energy of definite potential. The current through the photo-electric cell is then directly proportional to the illumination so that the sensitivity may be expressed in terms of microamperes per lumen, or, alternatively, as microcoulombe per lumen second. The charge of the condenser therefore is varied by the photo-electric current by a voltage which is a measure of the quantity of light that falls on the cell.

By arranging for the condenser to operate an electrical relay when its voltage reaches a certain point, and by causing the relay when operated to terminate the printing exposure, for example, by cutting off the light, the extent of exposure appropriate to the density of the negative is automatically obtained.

The invention is illustrated in the accompanying drawings, in which Figures 1 to 4 are diagrams showing various circuit arrangements employing a photo-electric cell for the integration of a quantum of light in conjunction with a relay device for determining the time of exposure; Figure 5 is a sectional elevation of one form of automatic printing apparatus; Figure 6 is a transverse section of Figure 5; Figure 7 is a

part sectional plan through the line 7—7 of Figure 6; Figure 8 is a sectional elevation of a preferred form of apparatus primarily adapted for use on direct current mains, or alternatively, on suitably rectified alternating current; Figure 9 is a transverse section of Figure 8; Figure 10 is a circuit diagram of the preferred form of apparatus shown in Figures 8 and 9; Figure 11 is a fragmentary section of the apparatus of Figure 8, showing a light modifying device in front of the measuring element; and Figure 12 shows one form of density wedge which may be used as a light modifying device.

Referring to Figure 1 of the drawings, a photo-electric cell 1, comprising an anode 2 and cathode 3, is connected between the anode 4 and grid 5 of a triode 6 having a cathode 7 connected to a source of heating current LT. In series with cell 1 and connected between grid 5 and cathode 7 is a condenser 8. A grid bias battery 9 is connected across condenser 8 through a key 10. The anodes of the cell 1 and triode 6 are connected to the positive terminal of a source of high tension current HT, the negative terminal of which is connected through a relay R to the cathode 7. The relay R is connected in series with the filament battery LT and a variable resistance 11, and by suitably setting the latter, the relay may be arranged to trip when the valve is passing any desired anode current. The circuit can be earthed at the negative side of the battery LT as shown.

The apparatus is operated by momentarily depressing key 10. Now, if the light to be measured or a definite fraction thereof is allowed to fall on cell 1, the charge given to the condenser 8 by the battery 9 on depressing key 10 is gradually reduced and the potential of grid 5 is raised at a rate which is directly proportional to the intensity of illumination of cell 1, until the current through triode 6 reaches a value sufficient to trip relay R which is adapted to cut off the source of illumination by any suitable means (not shown).

Assuming the characteristic of the valve to be such that at a grid potential of -5 volts the anode current is 0.4 milliamps. and that at -1 volt the anode current increases to 4.8 milliamps. should the potentiometer be so arranged that the relay trips at this value then the light will be extinguished. The condenser has been charged through 4 volts, so that if, for example, it has a capacity of $0.1\mu.f.$, then 0.4 microcoulombs will have passed through the cell. If the cell has a sensitivity of the order of 10 micro-

amps. per lumen with a potential of about 120 volts; this is equivalent to 10 micro-coulombs per lumen-second, and therefore, in the instance quoted above, the quantity of light which has fallen on the cell is 0.04 lumen seconds. Irrespective of the time taken by the process, whenever the condenser is charged through a range of from -5 to -1 volts, the anode current increasing from 0.4 to 4.8 milliamps., then the quantity of light falling on the cell will have been 0.04 lumen seconds.

The grid bias is preferably of the order of 8 to 12 volts in order to avoid all grid current, the condenser then receiving its charge from the photo-electric cell only.

In putting the apparatus into use, suitable values for the grid bias and potentiometer setting are found for a negative of medium density by the method of trial and error. When once the settings have been determined, they should remain accurate for a very long time, provided that both high and low tension supplies are maintained at a constant figure. When the light has been cut off by the relay at the finish of a print it remains off until the key is again depressed, commencing another print, so that the key represents the only control.

The apparatus above described is effective in giving exposures in accordance with Bunsen & Roscoe's Reciprocity Law, viz: If intensity $\times$ time = constant, the same density is obtained though intensity and time vary. Practically, however, exposures should be given according to the equation:—

$D = \gamma \log I t^p - i$ (where D = density = log opacity).
 γ = slope of part of the characteristic curve of the emulsion in question.

I = intensity.

t = time of exposure.

p = Schwarzschild's constant.

i = inertia = constant.

This may be taken into account by introducing a density wedge into the beam of light proceeding from the negative and entering the photo-electric cell, the said density wedge being moved during the exposure, commencing with the least dense end of the wedge. The density gradient and the rate of movement are adjusted so that the photo-cell is delayed in its process of discharging the condenser, to a degree which depends on the length of exposure.

Negatives of small density are exposed in a short time and only a small portion of the wedge is effective, with a proportionately small delay in the operation of the shutter. With dense negatives, however, the wedge is operative for a longer time and for a longer portion of its length, and the proportion of delay introduced is greater.

Owing to the lack of data relating to the variation of p with density, and further to the difficulty of obtaining perfect insulation in the photo-cell circuit, it is not easy to calculate the wedge gradient and it is therefore more practical to derive the density wedge from indications obtained on the machine.

One convenient form of density wedge which may be used is circular in form, rotated at such a speed that the whole of the wedge passes the photo-cell aperture in the maximum period of exposure allotted to the machine.

Various forms of density wedge or its equivalent may be used. It may be prepared photographically as a plate graded in density over the surface in accordance with the required mathe-

matical or empirical law. In another form it may consist of a perforated metal plate, in which the diameter of the holes and/or their spacing is varied progressively as described and claimed in my co-pending application, Serial No. 431,230, filed February 25, 1930. In a further form two plates or grids with perforations or openings are superposed and adapted to be moved relatively by means of a cam or cams, thereby shutting out light to a variable extent. In every case the light entering the photo-cell is progressively decreased as the exposure proceeds, so that dense negatives receive the extra increased exposure required.

The preferred means according to the invention of applying a correction to the equation $I t = C$ is to provide a leak which tends to maintain the negative charge on the grid of the valve. In this case the time required for the photo-electric current to reduce the negative potential of the grid by V volts is given by the equation

$$t = \frac{VC}{i - i'}$$

where C is the capacity of the condenser system, i the current passing in the photo-electric cell, i' the leak current, both of which are assumed to remain constant throughout the time t . Actually this condition is not quite true for any of the circuits described.

Suppose the currents given by the photo-electric cell for two particular negatives are 1.5×10^{-8} and 6×10^{-8} amps. If the leak current i' is 46×10^{-8} amp., the corresponding exposures will be in the ratio 5.3:1. The equation $I t i p = I' t' p$ requires that, for equal densities to be obtained in printing from two similar negatives one of which passed one quarter as much light as the other, the times of exposure should be in the ratio 5.3:1 if $p = .8$. Thus the leak will exactly compensate for the invalidity of the reciprocity law for two such negatives, and close compensation can be obtained in this way over the whole range of densities encountered in photographic printing.

A very convenient method of obtaining the correct leak is to use a photo-electric cell as the leak. The current passed by this is adjusted to the required value by choosing suitable values of the potential on the cell, and of the illumination, which can be made variable by an iris diaphragm between a suitable source of light and the cell. A leak adjustable continuously over a very large range of values can thus be obtained.

The great advantages of the invention are that in giving consistent uniform prints it takes into consideration any change in intensity of the lamp during printing and enables very short exposures of a fraction of a second to be gauged accurately. In such short exposures the time taken for the lamp to reach its full brilliance may be a considerable part of the whole exposure and the value of the first mentioned advantage then becomes enhanced.

A suitable circuit arrangement employing a photo-electric cell as a leak is shown in Figure 2.

Referring to Figure 2, a photo-electric cell 1 is connected between grid and anode of triode 6, as in the case of Figure 1. Shunting condenser 8, which is connected as before between the grid and cathode of the triode 6, an auxiliary or compensating photo-electric cell 12 is connected as shown. Battery 9 serves to supply the necessary potential to cell 12, key 10 being connected between the grid lead and a tapping on battery 9 which is chosen

to give the required negative bias to the grid when key 10 is depressed. The circuit may conveniently be earthed at E.

An alternative circuit arrangement, in which the photo-electric cell is so connected as to charge the grid of the triode negatively instead of positively, is shown in Figure 3.

Referring to Figure 3, a photo-electric cell 1 comprising an anode 2 and cathode 3 is connected between the grid 5 and cathode 7 of a triode 6, the cathode 3 of the cell being connected through a battery 9 to the cathode 7 of the triode. The anode 4 is connected through relay R to a high tension supply, as before, a condenser 8 and key 10 being connected between grid 5 and cathode 7. The circuit may be earthed at the negative side of the filament supply, as shown.

On momentarily depressing key 10, the triode is rendered conductive, the anode current actuating relay R to switch on the light by means of which printing is effected. A portion of the light falling on cell 1 permits a gradual charging of the condenser 8 at a rate proportional to the intensity of illumination, thus reducing the potential of grid 5 until the anode current traversing relay R falls to such a value that the said relay drops out and thus switches off the light.

A similar arrangement to the above, but employing a compensating cell, is shown in Figure 4. According to this arrangement cell 1 is connected between grid and cathode of triode 6, as in the previous example, a compensating cell 12 being connected, as shown, between the grid and anode of triode 6. A single source of high tension supply (e. g. direct current mains) is connected directly across a potential dividing resistance 13, the positive end of which is connected to the anode 4 and the negative end of which is connected to cathode 3 of cell 1. From a tapping point 14 on resistance 13 a connection is taken through a relay R to one side of the filament supply LT. If high tension batteries are used, the potential dividing resistance 13 may be omitted, the battery being divided at a suitable tapping point corresponding to 14. A connection from a variable tapping point 15 on a potentiometric resistance 16 connected across the filament supply through a resistance 17 to the tapping point 14, passes a current variable from zero up to a maximum value, through the relay R to oppose or assist the anode current, according as to whether R is connected to the negative or positive side of LT, thus providing a means for adjusting the time integral of illumination on the cell 1 at which the relay will operate.

Owing to the fact that when the mains are used for the high tension supply, the grid of the valve and the condenser operate at a potential differing widely from earth potential, the question of leakage becomes of considerable importance. In order to reduce leakage on this part of the system to a minimum, all parts connected directly to the grid of the valve may be mounted on a metal plate connected to the negative side of the valve filament.

The apparatus may be conveniently arranged to operate on two voltages, for example, 110 and 220 volts, by providing a suitable tapping point on the potential dividing resistance for the photo-electric cell cathode connection for use on the higher voltage. The part of the resistance between the negative main connection and this tapping can conveniently be short-circuited when the lower voltage is used.

It will be seen that photo-electric cell 12 will

operate as a leak for the charge supplied to condenser 8 by cell 1.

An electromagnet 10' may be provided to close the switch 10 short-circuiting the condenser when the shutter is closed, the latter preferably being at the projecting lens, the photo-cell being positioned between the shutter and the printing material, so as to secure an accurate integration of the light passing through the shutter, or alternatively reflected from the printing surface.

The circuit described, in addition to making it possible to dispense with high tension batteries, renders unnecessary any device for dealing with fluctuations in main voltage if suitable cells are used. A great advantage is that the valve life is much increased, as its grid voltage can never become positive. Further, the auxiliary current to the relay can now be made adjustable from zero upwards, and the natural leakage of the valve and condenser act so as to help the compensation for the failure of the reciprocity law.

In the form of apparatus shown in Figures 5 and 6, a diffusing box 18 is illuminated by a lamp 19 provided with a reflector 19'. Immediately below a rectangular aperture 20 in the diffusing box is located a gate 21 adapted to receive a negative to be printed, said gate being mounted on a light-tight chamber 22 containing a mirror 23 adapted to reflect the light transmitted through the negative to a projecting lens 24 provided with a shutter 25.

A partially reflecting screen 26 of thin celluloid, interposed between the gate 21 and mirror 23, enables an operator to observe through a window 27 which is fitted with glass adapted to exclude actinic light when the negative is properly positioned in the gate. Mounted within chamber 22 is a photo-electric cell 1 adapted to be illuminated by light passing through the negative, whether directly incident on the cell or reflected from the upper inner surfaces of the light tight box.

Mounted in a position where it will be illuminated directly by lamp 19 is a mirror 28 adapted to reflect light on to a compensating photo-electric cell 12 (see Figure 7). A diffusing screen 29 is interposed between mirror 28 and cell 12, and also an iris diaphragm 30 for controlling the amount of light falling on cell 12.

Shutter 25 is operated by means of a solenoid 31, the core of which carries a tappet 32 engaging one arm of a bell crank lever 33 whose other end works in a slot 34 in an actuating rod 35 secured to the shutter. The shutter is spring-biased to the closed position by means of a coil spring 36, as shown.

A collar 91 (see Figure 7) is attached to or formed on actuating rod 35 and is adapted to be engaged by a trigger member 92' (shown in Fig. 10) when the shutter is open so as to hold the shutter open against the tension of spring 36. The trigger member is adapted to be released by the pull of an electromagnet 92 which is energized by the tripping of relay R, thus allowing the shutter to close and terminating the exposure at the required instant.

Actuating rod 35 carries on a bush 37 of insulating material in ring 38 of conducting material, adapted to complete an electric circuit between a pair of spring contacts 39 when the shutter is open, and to complete a circuit between a pair of similar contacts 40 when the shutter is in the closed position. The extreme end 41 of the shutter actuating rod 35 is adapted to press together a pair of spring contacts 42 when the shutter is

closed. Contacts 39 are connected in circuit with a red lamp 43 (Figure 5) which indicates when an exposure is taking place. Contacts 40 are connected with the magnet 10' associated with the grid circuit of the triode in the exposure timing arrangement, and serve to cut the latter out of action when the shutter is closed. Contacts 42 are connected in circuit with a magnetic clutch operating an automatic paper feed device to be described later.

Mounted at the end of an extension 44 to chamber 22 is a light-tight box 45 in which is mounted a roll 46 of printing paper. The paper from roll 46 passes over guide roller 47 past an aperture or gate 48 against which it is lightly held by a plate 49 under the tension of a spring, plate 49 being pivotally mounted on a link 50 which in turn is pivoted to a support 51. The paper then passes between a pair of feed rollers 52, 53, the latter of which is geared to a drum 54 which is rotatably mounted in suitable bearings in brackets 55. Drum 54 carries rigidly secured thereto a ratchet wheel 56 adapted to be driven by a pawl 57 mounted on the end of an arm 58 pivoted about the axis of drum 54. Arm 58 is connected by means of a link 59 to a rocker arm 60 which is pivoted about a fixed point 61. Link 59 is attached to rocker arm by means of a block 62 which is adjustable in a slot 63 in the rocker arm, so that the effective length of the rocker arm may be varied, and thus the travel of pawl 57 and the amount of paper fed forward at each stroke of the rocker arm.

The rocker arm is actuated intermittently by means of a cam 64 engaging a roller 65 on the said rocker arm, and keyed to a shaft 66 carried in bearings 67 and 68. Shaft 66 is adapted to be rotated intermittently through a clutch 69 and gear box 70 by a continuously rotating motor 71. Clutch 69 is normally disengaged and is brought into engagement by means of a solenoid 72 which is connected in series with contacts 42 above referred to.

The paper issuing from the feed rollers 52, 53 may be discharged through opening 73 in the base of box 45, or it may be led over drum 54, under a roller 74 to a cutting device comprising a slotted bed 75 through which the paper passes, and a shearing knife 76 mounted on one arm of a bell crank lever 77 which swings about a fixed pivot 78. Bell crank lever 77 is actuated by means of a link 79 which carries a roller 80 engaging the face of a cam 81 which is keyed to shaft 66.

Rigidly attached to rocker arm 60 is an arm 85 carrying at the extreme end thereof a roller 86 adapted momentarily to press into engagement a pair of spring contacts 87 which are connected in circuit with solenoid 31 which actuates the exposure shutter. The exposure shutter, however, is intended to be operated only on the return stroke of rocker arm 60, as will be seen from the description of the operation of the apparatus which follows. For this purpose a second pair of contacts 88 is connected in series with contacts 87. Contacts 88 are adapted to be closed by a block of insulating material 89, secured to cam 64, the arrangement being such that both pairs of contacts are closed only on the return stroke of the paper feeding mechanism. It is thus impossible for the exposure shutter to be operated while the printing paper is being fed past aperture 48.

A coil spring 90, attached at one end to link 59 and anchored to a fixed portion of the apparatus at the other end, serves as a return spring

for the paper feeding device, and maintains roller 65 in contact with the working face of cam 64.

The electrical components of the timing circuit with the exception of the photo-electric cells, are conveniently housed in a case 82. A box 83, mounted on a part of a supporting trestle frame 84, is adapted to receive the necessary low tension battery, and also a high tension battery if a direct current mains supply is not available. The timing circuit it is preferred to employ is that illustrated in Figure 4 of the drawings.

Assuming a roll of unexposed printing paper to be in position, and the shutter 25 to be closed, the operation is as follows:—

A negative to be printed is placed in the gate 21 and centralized therein by inspection of the partially reflected image in screen 26. Current is switched on to motor 71 and to the exposure timing circuit.

In view of the fact that the shutter is closed, clutch contacts 42 are closed, and clutch 69 therefore is in engagement. Shaft 66 is therefore rotated and when cam 64 reaches such a position that both pairs of contacts 87, 88 are closed, the circuit to solenoid 31 being completed, the shutter is opened. The opening of the shutter opens circuits contacts 40 which are in circuit with electromagnet 10', thus releasing contact 10 and starting the exposure timing circuit. Contacts 42 are also opened, thus de-energizing solenoid 72 and allowing clutch 69 to disengage. Meanwhile contacts 39 are closed, completing the circuit to the indicating lamp 43.

When the necessary quantum of light, as determined by the exposure timing device has been transmitted through the negative to give a satisfactory print, relay R trips, electromagnet 92 is energized, the shutter trigger is released, and the shutter closes. The closing of the shutter opens indicating lamp contacts 39, closes contacts 40, thus energizing electromagnet 10' whereby contact 10 is closed, and closes contacts 42 so that solenoid 72 is energized, clutch 59 engaged, and shaft 66 rotated. The resultant rotation of cam 64 rocks arm 60, this rocking motion being transmitted to arm 58 by means of link 59. Thus pawl 57 engaging ratchet wheel 56 drives drum 54 in a clockwise direction, as viewed in Figure 5. Rollers 52 and 53 are thus driven in such a direction as to feed forward a length of printing paper which is determined by the setting of adjustable block 62 in slot 63.

As shaft 66 continues to rotate, cam 81 actuates link 79 to operate the shearing knife 76 through bell crank lever 77. Further rotation of shaft 66 allows rocker arm 60 to complete its return stroke under the tension of spring 90; contacts 87 and 88 are closed, and the cycle repeated.

A preferred form of apparatus, in which the various component parts are more compactly and conveniently arranged, and which is intended primarily for operation on direct current mains, or, alternatively, a suitably rectified alternating current, is illustrated in Figures 8 and 9, Figure 10 being a diagram of connections therefor.

It will be seen that parts of this apparatus which are similar to those in the apparatus shown in Figures 5 and 6, bear similar reference numbers, and it is thought that a detailed description of such parts is unnecessary.

This apparatus differs from that previously described in that the diffusing box 18, projecting lens 24 and the printing paper aperture 48, are arranged on a vertical axis. Photo-electric cell

1, in place of being illuminated by stray light passing through the negative, is illuminated by light reflected from a partially reflecting screen 1' of thin celluloid, located between the projecting lens 5 and the printing surface, so that the light falling on cell 1 is a definite fraction of that falling on the printing surface. The compensating photo-electric cell 12 is directly illuminated by lamp 19, the amount of light falling on the cell being controlled by means by an iris diaphragm 30.

As has been pointed out above, the function performed by the compensating photo-electric cell 12 may be performed by varying during the exposure the intensity of the light falling on the photo-electric cell 1. One suitable arrangement for accomplishing this is shown in Figure 11 in which a density wedge W is positioned in the light path between the partially reflecting screen 1' and the photo-electric cell 1. As best shown in Figure 12, the density wedge W comprises a translucent disc graded in density circumferentially which may be prepared in any well-known manner as by a photographic process. The wedge W is mounted on a shaft S of a motor M which is adapted to rotate the wedge W in the direction indicated by the arrow at a rate such that not more than one revolution will be completed during the longest exposure to be made. As shown, the density wedge W is moved during exposure, commencing with the least dense portion of the wedge whereby the intensity of the light falling on the cell 1 is progressively decreased throughout the exposure, and accordingly the photo-cell 1 is delayed in its process of discharging the condenser to the point at which the shutter 25 is operated, by an interval directly proportional to the density of the negative. In other words, the quantum of light falling on the sensitive sheet being printed is increased as an inverse function of the intensity of the light falling on the sheet, and this is the relation desired for compensating for the failure of the reciprocity law.

An improved paper feeding mechanism is employed comprising a continuously rotating motor 71, magnetically operated clutch 69 and gear box 70 as before. The gear box shaft carries a bell crank lever 100, keyed thereto. Mounted on one arm of lever 100 is a pin 101 engaging a slot 102 in an oscillating arm 103 pivoted about one end at 104. Also pivoted at 104 and fast with arm 103 is a shorter arm 105 which carries a pawl 106 adapted to engage and drive in an anti-clockwise direction a ratchet wheel 107 fast with a gear wheel 108 which meshes with a gear wheel 109 keyed to the shaft of a feed roller 110. Gear wheel 109 meshes with a similar gear wheel 111, driving a complementary feed roller 112.

A roll 113 of unexposed printing paper is wound on a tubular spindle 114 which is carried by and is free to rotate on a fixed solid spindle 113. The paper is led over guide rollers 116 and 117, over pressure plate 49, as in the previously described apparatus, thence over guide roller 118 to the feed rollers 110, 112, by which it is fed forward. From the feed rollers the paper continues over a further guide roller 119, and is clipped or otherwise attached to a hollow spindle 120 which is rotatable on a solid spindle 121. The said solid spindle 121 is mounted in a bearing 122 and is adapted to be driven by means of a sprocket 123 and chain 124 from a sprocket 125 mounted on the spindle of feed roller 110. Hollow spindle 120 is recessed axially at one side thereof to receive a small pressure pad 126 which is spring-urged against spindle 121 and is carried by a leaf spring

127 secured to the hollow spindle 120, thus forming a friction drive for said hollow spindle. In this way the paper issuing from the feed rolls 110, 112 is wound into a roll on spindle 120. The unexposed and exposed rolls of paper are housed in removable light-tight boxes 128 and 129 respectively, thus rendering the apparatus suitable for daylight loading.

Bell crank lever 100 carries a short arm 130 pivotally mounted at 131 and provided with a lug 132 to which is attached a coil spring 133, said spring being secured at its other end to the bell crank lever 100. The movement of arm 130 about pivot 131 is limited by a pin on the bell crank lever, which engages a slot 134 in arm 130.

A pin 135, attached to arm 130, projects horizontally at right angles thereto and is adapted to strike a similar pin 135' attached to a bracket 138'' as arm 100 rotates. When pin 135 engages pin 135', arm 130 pivots about 131, thus tensioning spring 133. Further rotation of arm 100 causes pin 135 to slip past pin 135', and to strike a rapid glancing blow to a pair of spring contacts 87, thus momentarily pressing said contacts together and completing a circuit to solenoid. Such an arrangement obviates the possibility of arm 100 stopping in such a position that contacts 87 can be maintained in the closed position.

Referring now to Figure 10, which is generally similar to Figure 4, but in which batteries have been eliminated entirely, 1 is the main exposure determining photo-electric cell, 6 the triode, 8 the condenser adapted to be charged by the photo-electric current from cell 1, and 12 is the compensating cell. The potential dividing resistance of Figure 4 has been divided into two sections 13' and 13'', for the purpose of connecting filament 7 and a variable filament resistance 7' in series therewith. The values of the various resistances are so chosen that the correct filament current and the required potential distribution is obtained when the apparatus is connected to 100 volt direct current mains. An additional series resistance 13''' is provided so that the apparatus may be run off 220 volt direct current mains, without further alteration. The biasing current relay R is obtained by an adjustable tapping 15 on resistance 13' through a resistance 17.

Electromagnet 10' has been eliminated, and the leads for short-circuiting the condenser have been taken direct to contacts 40 (see also Figure 8).

The operation of the above described apparatus with the exception of the paper feed mechanism is substantially the same as in the case of the apparatus shown in Figures 5, 6 and 7. When relay R trips on completion of an exposure, a circuit is completed to electromagnet 92, thus releasing trigger 92' and allowing the shutter to close under the tension of spring 36. Grid contacts 40 and clutch contacts 42 are closed, and bell crank lever 100 is driven in a counter-clockwise direction, thus driving ratchet wheel 107 through pawl 106, feed rollers 110, 112 being driven forward the required amount by gear wheel 108. On the return stroke of pawl 106, and arm 103, i. e. after the feeding forward of the paper has been effected, projection 135 on arm 130 closes contacts 87 and the cycle is completed.

A spring contact connected in series with a buzzer or other warning device and a source of current, for example, a dry cell, may be so arranged to rest on the roll of unexposed printing paper that when the roll of paper is exhausted,

the contact will engage the spindle carrying the roll to complete a circuit to said warning device, thus giving an indication to the operator that a fresh supply of paper is required.

5 In an alternative method the paper is passed between two contacts which are shorted when the paper is exhausted.

10 It is to be understood that although it is preferred to employ a light sensitive device, such as a photo-electric cell, to convert light energy into electrical energy and to integrate such electrical energy with respect to time, by allowing the current traversing the photo-electric cell to vary the charge on a condenser through a given voltage, other methods may be employed to determine the quantum of light passed through the negative.

What I claim is:—

1. Apparatus for the automatic control of exposure in photographic printing, comprising a light sensitive device activated by a definite proportion of the light passing through the negative, an electric storage device whose charge is adapted to be varied by current under the control of the light sensitive device, and an electric relay operable to terminate the printing exposure when the electric storage device is charged to a certain point.

2. In apparatus for the automatic control of exposure in photographic printing of negatives of varying densities and including exposure determining means responsive to the quantum of light falling on the printing surface, and compensating means for automatically varying the characteristics of said exposure determining means in accordance with the average density of the negative.

3. In apparatus for the automatic control of exposure in photographic printing, an exposure shutter, a thermionic relay, means associated with the output circuit of said relay, actuating said exposure shutter to terminate the exposure, capacitative means associated with the input circuit to said relay, and means including a photo-electric cell for varying the charge upon said capacitative means in dependence on the quantum of light falling on the printing surface.

4. Apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, charging means for said capacitative means and a photo-electric cell in series with said charging means, the arrangement being such that the charge supplied to the capacitative means is dependent on the quantum of light falling on the printing surface.

5. In apparatus for the automatic control of exposure in photographic printing, exposure terminating means, a thermionic relay, means associated with the output circuit of said relay, actuating said exposure terminating means, capacitative means associated with the input circuit to said relay, means including a photo-electric cell for varying the charge upon said capacitative means in dependence on the quantum of light falling on the printing surface, and compensating means for modifying the effectiveness of the photo-electric cell in varying the charge on said capacitative means.

6. In apparatus for the automatic control of exposure in photographic printing, exposure terminating means, a thermionic relay, means as-

sociated with the output circuit of said relay, actuating said exposure terminating means, capacitative means associated with the input circuit to said relay, and means including a photo-electric cell for varying the charge upon said capacitative means in dependence on the quantum of light falling on the printing surface, and a density wedge for progressively reducing the intensity of light falling on the photo-electric cell throughout the time of exposure.

7. Apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, and means for giving a predetermined charge to the capacitative means, and a photo-electric cell for reducing the charge on said capacitative means in dependence on the quantum of light falling on the printing surface, and variable resistance connected to modify the rate of discharge of the capacitative means.

8. Apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, charging means for said capacitative means and a photo-electric cell in series with said charging means, the arrangement being such that the charge supplied to the capacitative means is dependent on the quantum of light falling on the printing surface, and a variable resistance connected to modify the rate of charge of said capacitative means.

9. Apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, and means for giving a predetermined charge to the capacitative means, and a photo-electric cell in effective shunt with said capacitative means for reducing the charge on said capacitative means in dependence on the quantum of light falling on the printing surface, and a photo-electric cell whose internal resistance is variable by adjusting the intensity of the light to which it is subjected and connected to modify the rate of discharge of the capacitative means.

10. Apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, charging means for said capacitative means and a photo-electric cell in series with said charging means, the arrangement being such that the charge supplied to the capacitative means is dependent on the quantum of light falling on the printing surface, and a photo-electric cell whose internal resistance is variable by adjusting the intensity of the light to which it is subjected and connected to modify the rate of charge of said capacitative means.

11. Apparatus for the automatic control of exposure in photographic printing, comprising

exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, and means, including a photo-electric cell, for varying the electric charge upon said capacitative means in dependence on the quantum of light falling on the printing surface, and potentiometric means for the provision of the cathode-anode potentials of the cell and the thermionic relay, the filament of the thermionic relay being connected in series with said potentiometric means.

12. Apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, charging means for said capacitative means and a photo-electric cell in series with said charging means, the arrangement being such that the charge supplied to the capacitative means is dependent on the quantum of light falling on the printing surface, and a photo-electric cell whose internal resistance is variable by adjusting the intensity of the light to which it is subjected and connected to modify the rate of charge of said capacitative means, and potentiometric means for the provision of the cathode-anode potentials of the cells and the thermionic relay, the filament of the thermionic relay being connected in series with said potentiometric means.

13. Apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, and means, including a photo-electric cell, for varying the electric charge upon said capacitative means in dependence on the quantum of light falling on the printing surface, said photo-electric cell being illuminated by light reflected from a partially reflecting screen interposed between the negative and the printing surface.

14. Apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, charging means for said capacitative means and a photo-electric cell in series with said charging means, the arrangement being such that the charge supplied to the capacitative means is dependent on the quantum of light falling on the printing surface, and a photo-electric cell whose internal resistance is variable by adjusting the intensity of the light to which it is subjected and connected to modify the rate of charge of said capacitative means, the exposure determining photo-electric cell being illuminated by light reflected from a partially reflecting screen interposed between the negative and the printing surface.

15. Apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, charging

means for said capacitative means and a photo-electric cell in series with said charging means, the arrangement being such that the charge supplied to the capacitative means is dependent on the quantum of light falling on the printing surface, and a photo-electric cell whose internal resistance is variable by adjusting the intensity of the light to which it is subjected and connected to modify the rate of charge of said capacitative means, and potentiometric means for the provision of the cathode-anode potentials of the cells and the thermionic relay, the filament of the thermionic relay being connected in series with said potentiometric means, the exposure determining photo-electric cell being illuminated by light reflected from a partially reflecting screen interposed between the negative and the printing surface.

16. Apparatus for the automatic printing of negatives, including an exposure determining device comprising integrating means responsive to the quantum of light falling on the printing surface and adapted to cut off the light from the printing surface when the latter has been exposed for the required time, and means actuated automatically on the termination of the exposure for feeding forward a strip of printing paper to present a fresh surface to be exposed, and means actuated automatically when the printing paper has been fed forward to start a further exposure, whereby the cycle of operations may be repeated.

17. In combination apparatus for the automatic control of exposure in photographic printing, comprising a thermionic relay, means associated with the output circuit of said relay for actuating an exposure shutter to terminate the exposure, capacitative means associated with the input circuit to said thermionic relay, and means, including a photo-electric cell, for varying the electric charge upon said capacitative means in dependence on the quantum of light falling on the printing surface, with a printing machine having an automatic printing paper feed operative on the completion of an exposure, and means actuated automatically when a fresh printing surface has been fed forward to start a further exposure.

18. In combination apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, charging means for said capacitative means and a photo-electric cell in series with said charging means, the arrangement being such that the charge supplied to the capacitative means is dependent on the quantum of light falling on the printing surface, with a printing machine having an automatic printing paper feed operative on the completion of an exposure and means actuated automatically when a fresh surface has been fed forward to start a further exposure.

19. In combination apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, charging means for said capacitative means and a photo-electric cell in series with said charging means, the arrangement being

such that the charge supplied to the capacitative means is dependent on the quantum of light falling on the printing surface, and a photo-electric cell whose internal resistance is variable by adjusting the intensity of the light to which it is subjected and connected to modify the rate of charge of said capacitative means, with a printing machine having an automatic printing paper feed operative on the completion of an exposure and means actuated automatically when a fresh surface has been fed forward to start a further exposure.

20. In combination apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, charging means for said capacitative means and a photo-electric cell in series with said charging means, the arrangement being such that the charge supplied to the capacitative means is dependent on the quantum of light falling on the printing surface, and a photo-electric cell whose internal resistance is variable by adjusting the intensity of the light to which it is subjected and connected to modify the rate of charge of said capacitative means, and potentiometric means for the provision of the cathode-anode potentials of the cells and the thermionic relay, the filament of the thermionic relay being connected in series with said potentiometric means, with a printing machine having an automatic printing paper feed operative on the completion of an exposure and means actuated automatically when a fresh surface has been fed forward to start a further exposure.

21. In combination apparatus for the automatic control of exposure in photographic printing, comprising exposure terminating means, a thermionic relay, means associated with the output circuit of said relay for actuating said exposure terminating means, capacitative means associated with the input circuit to said thermionic relay, charging means for said capacitative means and a photo-electric cell in series with said charging means, the arrangement being such that the charge supplied to the capacitative means is dependent on the quantum of light falling on the printing surface, and a photo-electric cell whose internal resistance is variable by adjusting the intensity of the light to which it is subjected and connected to modify the rate of charge of said capacitative means, and potentiometric means for the provision of the cathode-anode potentials of the cells and the thermionic relay, the filament of the thermionic relay being connected in series with said potentiometric means, the exposure determining photo-electric cell being illuminated by light reflected from a partially reflecting screen interposed between the negative and the printing surface, with a printing machine having an automatic printing paper feed operative on the completion of an exposure and means actuated automatically when a fresh surface has been fed forward to start a further exposure.

22. Apparatus for the automatic printing of negatives, including an exposure determining device comprising integrating means responsive to the quantum of light falling on the printing surface and which releases an electromagnetically operated shutter, said shutter cutting off the light from the printing surface when the latter has

been exposed for the required time, and means actuated automatically on the termination of the exposure for feeding forward a strip of printing paper to present a fresh surface to be exposed, and means actuated automatically when the printing paper has been fed forward to start a further exposure, whereby the cycle of operations may be repeated.

23. Apparatus for the automatic printing of negatives, including an exposure determining device comprising integrating means responsive to the quantum of light falling on the printing surface and which releases an electromagnetically operated shutter, said shutter cutting off the light from the printing surface when the latter has been exposed for the required time, and means driven through electromagnetically operated clutch means, actuated automatically on the termination of the exposure, for feeding forward a strip of printing paper to present a fresh surface to be exposed, and means actuated automatically when the printing paper has been fed forward to start a further exposure, whereby the cycle of operations may be repeated.

24. Apparatus for the automatic printing of negatives, including an exposure determining device comprising integrating means responsive to the quantum of light falling on the printing surface and which releases an electromagnetically operated shutter, said shutter cutting off the light from the printing surface when the latter has been exposed for the required time, and means driven through electromagnetically operated clutch means, actuated automatically on the termination of the exposure, for feeding forward a strip of printing paper to present a fresh surface to be exposed, and means actuated automatically when the printing paper has been fed forward to start a further exposure, whereby the cycle of operations may be repeated, and means for cutting off lengths of paper which have been exposed.

25. Apparatus for photographic printing with automatic control of the time of exposure according to the density of the negative comprising in combination with the means for transmitting light through the negative to the printing surface, a light sensitive variable resistance to transfer of energy positioned to receive light passed through the negative, a source of energy, an energy storage device in communication with said source through the interposed light sensitive variable resistance, a relay under the control of said energy storage device, and means under the actuation of the relay for cutting off the transmission of light to the printing surface.

26. Apparatus for photographic printing with automatic control of the time of exposure according to the density of the negative comprising in combination with the means for transmitting radiations through the negative to the printing surface, a relay circuit responsive to the radiations passed through the negative, said relay circuit including a device capable of accumulating and discharging energy, means for delaying the response of the relay, and means under the actuation of the relay of said circuit for cutting off the transmission of radiations to the printing surface.

27. Apparatus for photographic printing with automatic control of the time of exposure according to the density of the negative comprising in combination with the means for transmitting radiations through the negative to the printing surface, a relay circuit responsive to the radia-

tions and including light sensitive means exposed to radiations passed through the negative, said relay circuit including a device capable of accumulating and discharging energy, means for shielding to a progressively variable extent said light sensitive means from the radiations to which it is exposed, and means under the actuation of the relay of said circuit for cutting off the transmission of radiations to the printing surface.

28. Apparatus for photographic printing with automatic control of the time of exposure according to the density of the negative comprising in combination with the means for transmitting light through the negative to the printing surface, a light sensitive variable resistance to transfer of energy positioned to receive light passed through the negative, means for shielding to a progressively variable extent the said light sensitive variable resistance from light, a source of energy, an energy storage device in communication with said source through the interposed light sensitive variable resistance, a relay under the control of said energy storage device, and means under the actuation of the relay for cutting off the transmission of light to the printing surface.

29. Apparatus for photographic printing with automatic control of the time of exposure according to the density of the negative comprising in combination with the means for transmitting light through the negative to the printing surface, a light sensitive variable resistance to transfer of energy positioned to receive light passed through the negative, a source of energy, an energy storage device in communication with said source through the interposed light sensitive variable resistance, an energy by-pass between the light sensitive variable resistance and the energy storing device, a relay under the control of said energy storage device, and means under the actuation of the relay for cutting off the transmission of light to the printing surface.

30. In apparatus for the automatic control of exposure in photographic printing, an electric storage device, a source of electromotive force, a light sensitive device in circuit with said storage device and said source, means for applying a proportion of the light passing through a negative being printed to said light sensitive device, an electric relay controlled by the charge in said storage device and exposure terminating means operatively associated with said relay.

31. In apparatus for the automatic control of exposure in photographic printing, an electric storage device, a source of electromotive force, a photoelectric cell in circuit with said storage device and said source, means for applying a proportion of the light passing through a negative being printed to said photoelectric cell, an electric relay controlled by the charge in said storage device and exposure terminating means operatively associated with said relay.

32. In apparatus for the control of exposure in photographic printing, energy storing means, light sensitive means in control of energy fed to the energy storing means, means for measuring the energy stored by said energy storing means, means for terminating the exposure when the amount of stored energy reaches a predetermined value, and auxiliary means for controlling the amount of energy stored by said energy storing means whereby compensation for the failure of Bunsen's reciprocity law is obtained.

33. The method of automatically controlling the exposure in photographic printing which consists in utilizing a proportion of the light passing through a negative in process of being printed to control an electric current according to the average intensity of illumination of the printing surface, utilizing said electric current to build up a potential corresponding to the quantum of light which has fallen on the printing surface since the commencement of the exposure, and applying said potential to terminate the exposure when the said potential has reached a certain value corresponding to the desired value for the quantum of light.

34. The method of automatically controlling the exposure in photographic printing which consists in utilizing a proportion of the light passing through a negative in process of being printed to control an electric current according to the average intensity of illumination of the printing surface, utilizing said electric current to build up a potential corresponding to the quantum of light which has fallen on the printing surface since the commencement of the exposure, and applying said potential to control an electric current which at a certain value produces mechanical movement terminating the exposure.

35. The method of automatically controlling the exposure in photographic printing which consists in utilizing a proportion of the light passing through a negative in process of being printed to control a current of electricity according to the average intensity of illumination of the printing surface, gradually and progressively as the exposure proceeds reducing the proportion of light utilized to control said current in order to compensate for the failure of Bunsen's reciprocity law, obtaining a measure of the amount of electricity which has flowed since the commencement of the exposure, and terminating the exposure when said amount reaches a certain value corresponding to the desired value for the quantum of light.

36. The method of automatically controlling the exposure in photographic printing which consists in utilizing a proportion of the light passing through a negative in process of being printed to control a current of electricity according to the average intensity of illumination of the printing surface but allowing a certain portion of said current to leak away in order to compensate for the failure of Bunsen's reciprocity law, obtaining a measure of the difference between the amount of electricity which has flowed since the commencement of the exposure and that which has leaked away, and terminating the exposure when said measure reaches a certain value corresponding to the desired value for the quantum of light.

37. The method of automatically controlling the exposure in photographic printing which consists in directing light rays passed through a negative from a source of illumination upon a light sensitive device to effect creation of a stored-up charge of energy, and employing said stored-up energy to produce mechanical movement terminating the exposure when the charge has reached a predetermined value.

FRANK TWYMAN.

CERTIFICATE OF CORRECTION.

Patent No. 1,939,243.

December 12, 1933.

FRANK TWYMAN.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, line 109, for the first number of the equation "46" read .46; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 6th day of February, A. D. 1934.

F. M. Hopkins

(Seal)

Acting Commissioner of Patents.