Sept. 15, 1942. L. PLANSKOY 2,296,048

METHOD OF PHOTOGRAPHIC DEVELOPMENT TO A PREDETERMINED VALUE OF CONTRAST

Filed March 17, 1939 4 Sheets-Sheet 1

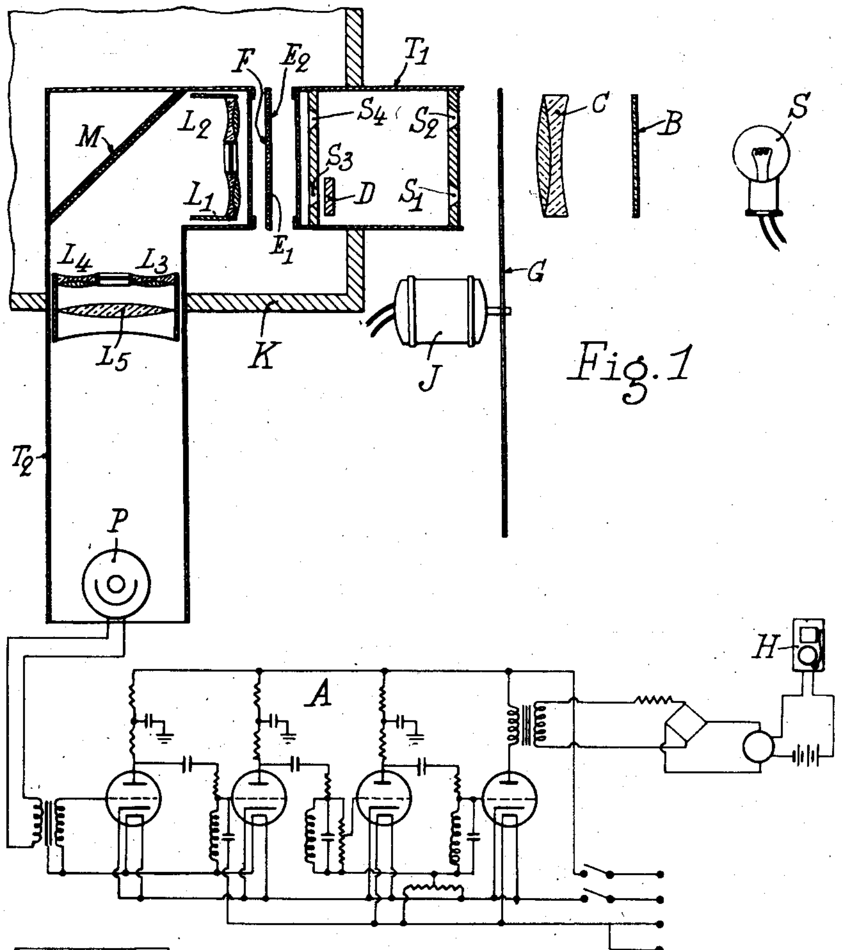


Fig. 1

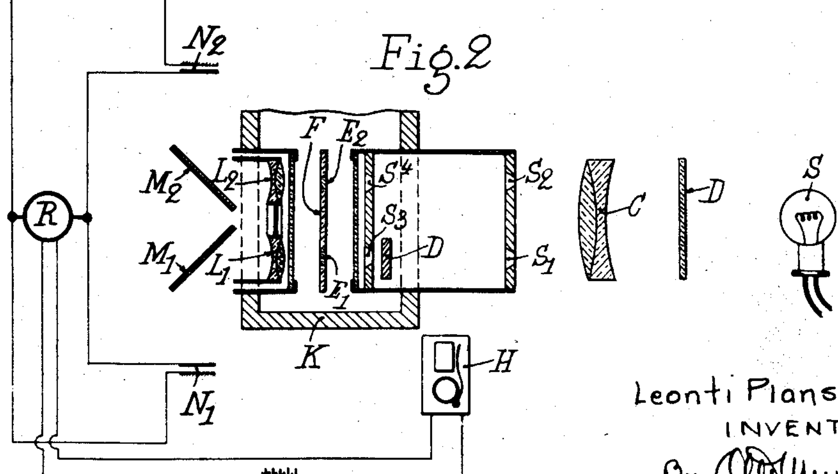


Fig. 2

Leonti Planskoy
INVENTOR

By [signature]
his ATT'Y.

Sept. 15, 1942. L. PLANSKOY 2,296,048

METHOD OF PHOTOGRAPHIC DEVELOPMENT TO A
PREDETERMINED VALUE OF CONTRAST

Filed March 17, 1939 4 Sheets-Sheet 2

Fig. 3

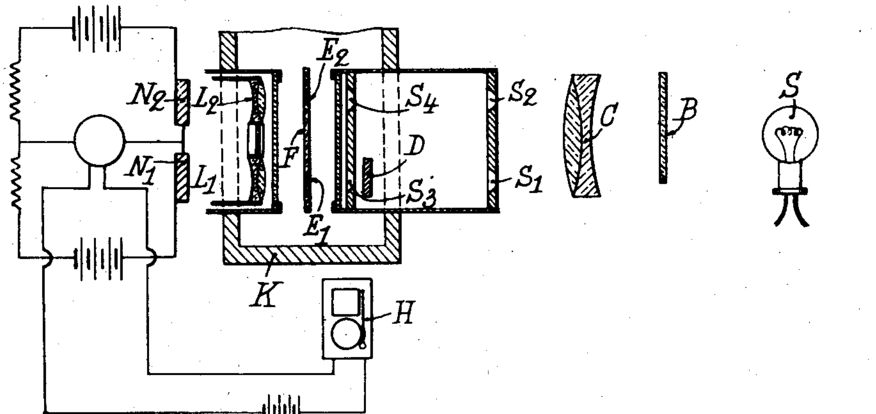
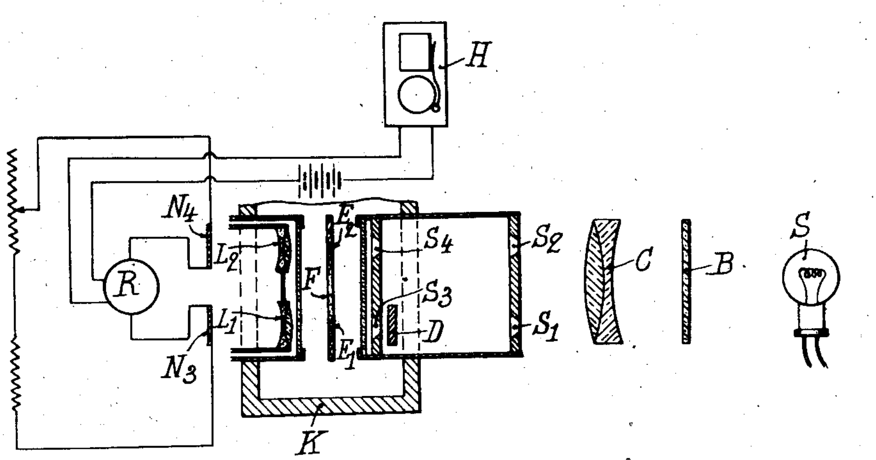


Fig. 4



Leonti Planskoy
INVENTOR
By Otto Munk
his ATT'Y.

METHOD OF PHOTOGRAPHIC DEVELOPMENT TO A PREDETERMINED VALUE OF CONTRAST

Filed March 17, 1939 4 Sheets-Sheet 3

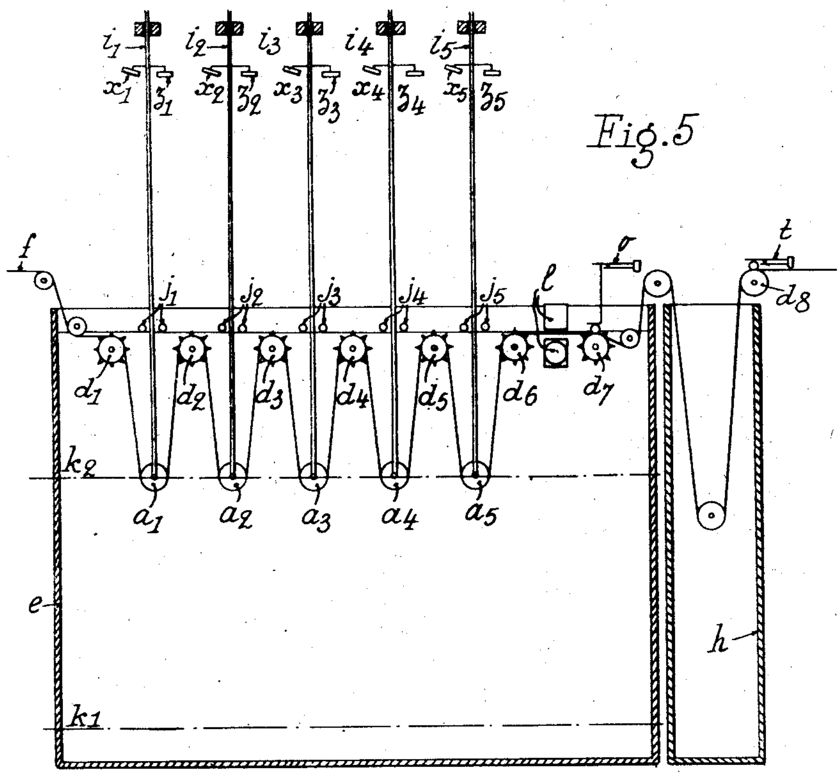


Fig. 5

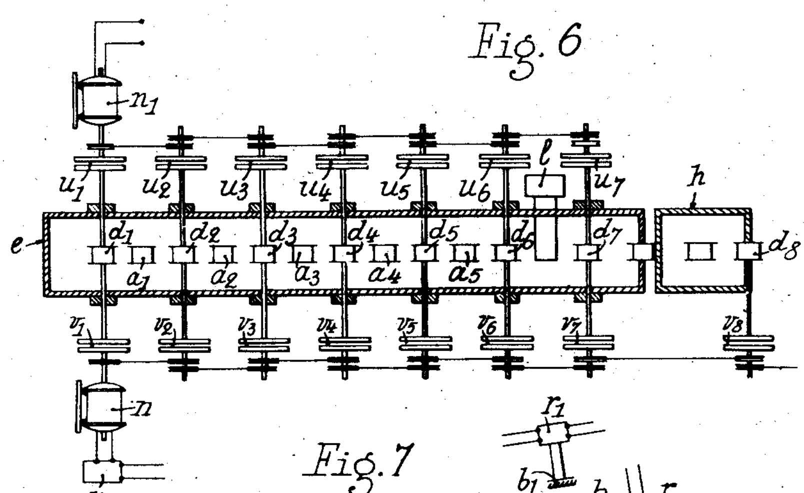


Fig. 6

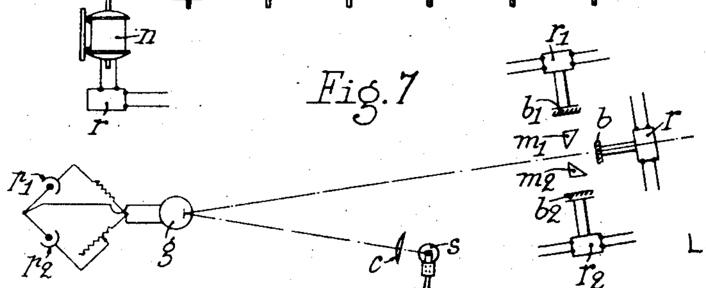


Fig. 7

Leonti Planskoy
INVENTOR
By [signature]
his ATT'Y.

Fig. 8

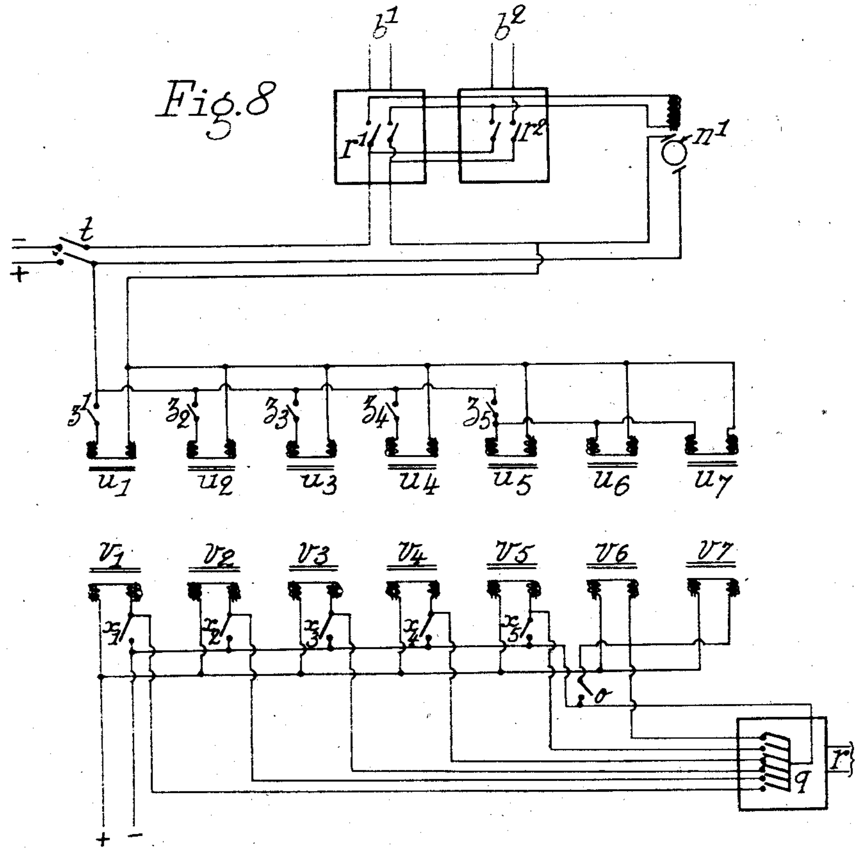
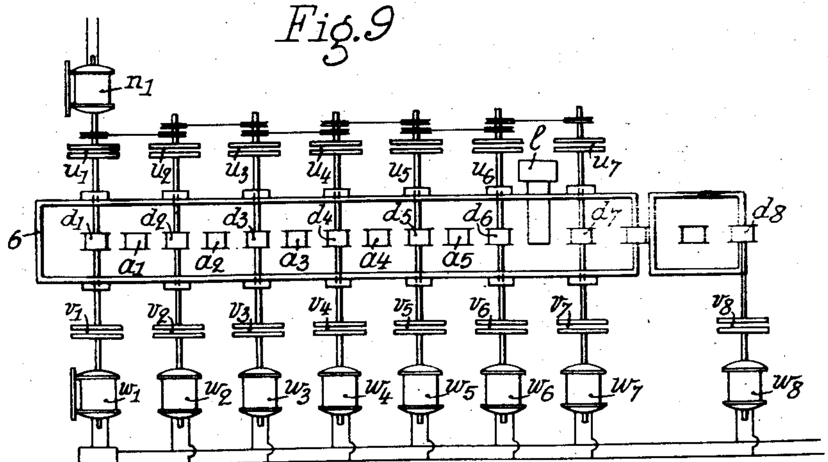


Fig. 9



Leonti Planskoy
INVENTOR
By Otto Munk
his ATT'Y.

Patented Sept. 15, 1942

2,296,048

UNITED STATES PATENT OFFICE

2,296,048

METHOD OF PHOTOGRAPHIC DEVELOPMENT TO A PREDETERMINED VALUE OF CONTRAST

Leonti Planskoy, Paris, France, assignor of one-half to Process Development Corporation, New York, N. Y.

Application March 17, 1939, Serial No. 262,344
In Great Britain March 26, 1938

1 Claim. (Cl. 95—89)

The difference in density by which the photographic emulsion represents the ratio of exposures to which it has been subjected increases with the time of development to a limiting value. The ratio of increase of density in respect of increase of the logarithm of exposure over the straight portion of the characteristic curve of the photographic emulsion is constant for a given emulsion and set of development conditions and is termed "gamma"

$$\gamma=\frac{D_2-D_1}{\log E_2-\log E_1} \quad (1)$$

It is important to be able to stop the development as soon as a definite value of gammae has been reached in order to satisfy the relation for correct reproduction

$$\gamma_R=\gamma_N\times\gamma_P=1 \quad (2)$$

where γ_N is the development constant for the negative record, γ_P that for the positive record and γ_R the overall gamma governing the contrast of the complete reproduction cycle. The Equation 2 shows that the errors in the γ value go on multiplying, which in all cases where the conformity of the record is important, such as colour or sound reproduction, trickwork, duplication of the original negatives, etc., is a cause of undesirable distortion.

The determination of the correct time value for development to a precise value of "gamma" meets with considerable difficulty because of the many variables influencing the final result. The temperature must be kept constant and so must be the motion of the film in respect of the developing solution, as well as the rate of stirring of the latter. Oxydation phenomena, age of the developing solution, method of its preparation, constancy and purity of the commercially available constituent chemicals as well as their reaction with such products as may be used before the development (such as densensitizing dyes) all influence the time after which the gamma reaches the desired value. The time of development varies not only with different emulsions but also with different batches of the same emulsion. The quantity of bromide liberated by the developing process depends on the image characteristics, e. g. more bromide will be liberated when developing a negative image of a small black cross upon white background that when the positive image is developed;—the opposite will apply when the cross is white and the background black. Since the bromide thus liberated acts as a restrainer of development process, the action of developer must be suitably prolonged, without any indication as to the magnitude of this effect during the development proper.

At present the development process is carried out during a time determined by photometrically controlling the finished film or samples of the same emulsion which have undergone the same treatment. The standard practice consists in carrying out experimentally the theoretical conditions of the Equation 1. The film is exposed to at least two known amounts of light E_2 and E_1, so that $\log E_2-\log E_1$ is known. The intensity of illumination is chosen to be such, that the densities D_2, D_1 by which these exposures will be represented after processing are located on the straight portion of the characteristic curve of the emulsion. When these densities are photometrically measured the value of "gamma" can be determined from the Equation 1. If the found value of "gamma" does not correspond with the desirable one, the solution is replenished or else the time of development for the next length of film is varied. This method obviously only permits the control of developed film. Since the result of the control operation is known only after the operation to be controlled is completed, any deviation of the value of gamma from the chosen optimum in the measured sample is obviously repeated in the record as well, and to correct it further operations such as intensifying or reducing must be applied. These not only introduce additional indeterminations in the final result but may also cause undesirable increase of graininess and/or distortion of the gradation of the record. Moreover, when a continuous developing machine is employed, a further length of film is processed during the time lapse between the completion of the development of the control sample and its photometric reading, and this film shows a further deviation of gamma value from that desired. In a unit development machine this deviation can be slightly reduced by keeping the machine idle during the photometric operation. These difficulties are well known and several attempts have been made to shorten the period between the completion of the development and its photometric measurement. One of these attempts consists in the use of the photometers on the developing machine itself before the completion of the drying process. But it is obvious that this solution reduces the delay between the end of the development and the measure only by the time required for the drying process, still delaying the control during the period of fixing and washing; also the method while permitting the control of the finished product does not allow to stop the processing automatically when the desired gamma is reached.

The present invention relates to a method of photographic development to a predetermined value of contrast (gamma), which consists in preliminarily subjecting two areas of the film to be developed respectively to two exposures of different values, and observing through said two areas during the development process respectively two radiant beams, the intensities of which are so chosen that the difference between the logarithms of said intensities corresponds to the difference between the densities to be obtained in said areas after a correct develoment, and continuing said observation until the two radiant beams show no difference in accordance with Equation 6 on page 2.

By this method, it is thus possible to avoid all the above mentioned difficulties encountered in the known methods, and to stop the development process at the exact moment when the desired value of gamma is reached.

In order to develop the film exactly to the predetermined gamma I proceed as follows. Two portions of the film are subjected respectively to two known control exposures so that

$$\log E_2 - \log E_1 = K \qquad (3)$$

If the two exposures are made to be situated well within the straight portion of the characteristic curve of the film, when they are made simultaneously and from a single light source, the slight variation of the film sensitivity or fluctuations of the source are of no importance, because it is the difference and not the absolute value of the exposure which is of importance in the Equation 3. The Equation 1 combined with 3 defines the relation

$$\gamma = \frac{D_2 - D_1}{K} \qquad (4)$$

If a constant value of gamma G is desired the Equation 4 becomes

$$D_2 - D_1 = K\gamma = G \qquad (5)$$

and determines the difference of densities $D_2 - D_1$ which the control film must show when the development has been carried to the desired value of gamma.

The film to be developed and carrying the control exposures is placed into the developing machine and subjected to the development process. The control exposures pass during the development process in the beams of a photometer, and preferably of a physical null method photometer, so that with increased development the intensity of the radiant energy incident on to the physical receptor or receptors decreases at the same time as the densities of the film increase. A ballast calibrated density equal to G or $D_2 - D_1$, is placed into the beam passing through the control exposure corresponding to the exposure of the smaller value E_1, in consequence of which this beam is producing a lesser intensity of the radiant energy on the physical photometric receptor, than that produced by the beam passing through the other control exposure corresponding to the exposure value E_2. When the difference of densities increases sufficiently so that

$$D_2 = D_1 + G \qquad (6)$$

the radiant energy from the two beams is equal, the condition of equilibrium in the receptor or receptors is made to close a relay thus indicating the completion of the development process.

The ballast density may consist of a filter, the density of which is equal to the difference between the densities to be obtained in the two portions which have been subjected to two different exposures. Instead of a filter, use may be made of devices, such as a diaphragm, which reduce the section of passage of one of said beams. It is also possible to insert polarizing optical instruments, such as crossed Nicol prisms, through which only a portion of the incident light passes in a determined direction. Generally speaking, use may be made of any device adapted to lessen the intensity of one of said beams.

The physical photometric receptor must obviously be chosen to be sensitive to radiation to which the emulsion is not sensitive or has been desensitized, so that the beams of radiation passing through the control portions of the film cannot modify the exposure. In case of all normal non-desensitized emulsions a suitable infrared transmitting filter can be placed over the source absorbing all radiation to which the emulsion is sensitive, the receptor being in this case a cesium or a cesium-cesium oxide-silver photoelectric cell, a selenium cell, a thalofide cell or any of the non-selective receptors such as thermopiles, bolometers, radiometers or their like. In case of desensitized films the radiant energy obviously depends upon the type of desensitizer. For infra-red film a radiation of wave-lengths comprised between 500 mμ and 600 mμ and corresponding to the insensitive spectral region of the usual infra-red plates may be employed. In addition to the previously mentioned non-selective photometric receptors, cesium photoelectric cells and barrier E. M. F. photocells can be employed for the measurement of the film densities within this region.

One instrument advantageously used in connection with the method is based upon the known null method of physical photometry in which two beams fall alternately and intermittently on to a photoelectric cell. As long as the intensities of the beams are unequal, a pulsating current is fed from the photocell into a galvanometer; when, however, the intensities of the two beams reach an equilibrium the current flows continuously.

It is to be understood that the present invention does not relate to the measurement of the density or degree of blackening or the image, which depends both upon the exposure and the development; the invention relates to the control of the gamma, i. e. to the control of the degree of contrast of the image, which depends only upon the development.

In the accompanying drawings, given by way of example:

Figs. 1 to 4 show diagrammatically four arrangements adapted to be used in the method of the present invention.

Figs. 5 and 6 are respectively a sectional elevation and a plan view of a continuous developing machine modified according to the present invention.

Fig. 7 shows diagrammatically an electro-optical relay used with the arrangement of Figures 5 and 6.

Fig. 8 shows the electrical wiring diagram of the arrangements shown in Figs. 5 to 7.

Fig. 9 is a plan view of a modification.

With reference to Fig. 1 a sourse S is placed behind a suitable filter B in the focal plane of a collimator C. The parallel beams issued from C pass through two apertures S_1 and S_2, a ballast density D, two secondary apertures S_3 and S_4, the two control exposures E_1 and E_2 of the film F and fall upon the lenses L_1 and L_2 which reconverge these beams upon lenses L_3 and L_4 upon which is formed the image of the source. Since the lenses L_3 and L_4 are chosen of such focal length as to place their focal plane in S_3 and S_4 there issue from them two parallel beams which are reconverged by the lens L_5 on to the photoelectric cell P producing on it an enlarged image of these two apertures, superposed upon each other. It is supposed that a unit developing machine is used, in which a unit length of film travels along a closed path forming a continuous loop on series of rollers. For convenience of the travel of the film the beams issued from L_1 and L_2 can be turned through 90° by means of a prism or a mirror M. A disk G carrying a series of radial apertures is placed in close proximity of S_1 and S_2 and cuts the beams intermittently with a known frequency, kept constant by revolving the disk by means of a synchronous motor J. The optical units are enclosed in tubes T_1 and T_2, the extremities of which in the vicinity of the film have burnished in vitreous silica or glass plates so as to prevent the access of the developing solution into the optical system. Said tubes T_1 and T_2 are inserted in apertures formed in the walls of the tank K containing the developing bath in such manner that they are liquid proof.

The current from the photoelectric tube or cell P passes into an audio-frequency amplifier indicated generally by the reference A. As long as the development has not reached the desired value of γ, the beams falling onto the photoelectric cell are of different intensities and the pulsating current passes through the amplifier A onto the galvanometer relay R. When, however, the gamma reaches the predetermined value, the Equation 6 is satisfied, the two beams become equal and the non-pulsating current issued from the cell cannot pass through the A. C. amplifier. The lack of current through the relay R causes a circuit to be closed which starts either a signal H or a motor which moves the film from the developer into a stop bath. The amplifier A is equipped with frequency filters giving passage only to a narrow band corresponding to the frequencies with which the beams fall upon the photo-cell. It is possible with this arrangement to minimize the pick-up and effects of stray light.

When it is desirable to use non-selective physical receptors or E. M. F. barrier cells, the sensitivity of which decreases considerably with intermittent radiation, the beams from L_1 and L_2 can be turned one through 90° and the other through 270° by means of prisms or mirrors M_1 and M_2 onto two receptors N_1 and N_2 connected in parallel and shown in the way of example for the case of two E. M. F. cells in Fig. 2 or forming 2 arms (Fig. 3) of a Wheatstone bridge. The equality of the intensities of the beams corresponding to the achievement of the development to a desired value of gamma balances the circuit—thus closing the relay R. Alternatively differential E. M. F. barrier cells or bolometer or thermopile receptors N_3 and N_4 can be employed as shown by way of example for a differential bolometer in Figure 4. Obviously no disk is employed in these cases.

It is of course preferable, although not indispensable, to keep the film under continuous observation and consequently the control exposures should preferably be continuous. They can be located on the edge outside the perforations or in the space reserved for sound recording in the picture record and vice-versa or else for use in unit developing machines they can be located on a seperate length of the same emulsion running in the same bath over a separate set of rollers.

This latter course is not possible when it is desired to use continuous developing machines. In such continuous machines, the film *f* is guided as shown in Figures 5 and 6, through a tank *e* containing a developing solution and over a series of driving sprockets d_1 to d_7 in a form of festoons weighted by idle rollers a_1 to a_5, and into a stop bath *h*. Assuming a constant driving speed, the development time for the portion of the film over the final sprocket in the developing tank is proportionate to the sum of the lengths of all the festoons. In consequence the length of the path of the film travel must at first be adjusted to satisfy the variables mentioned in the beginning of the present specification and then be constantly readjusted to compensate for such variations as can take place during the process of development. Furthermore, both the initial adjustment as well as the continuous readjustment must be feasible over a considerable range. According to the present invention all these adjustments may be carried out automatically and are controlled by the previously described instruments. The sprockets d_1 to d_7 immerged in the liquid of the bath are used to drive the film *f* weighted by idle rollers a_1 to a_5. These rollers are guided vertically by rods i_1 to i_5 and they can take any desired position in the solution between the levels k_1 and k_2. Each of the rods i_1 to i_5 carries two mercury switches x_1 to x_5 and z_1 to z_5 which are tripped by safety stops j_1 to j_5 when the idle rollers a_1 to a_5 reach the limiting level k_1. The switches are mounted in opposition so that when any one of the switches x_1 to x_5 is open, the corresponding switch z_1 to z_5 is closed. The measuring device *l* with photometer analogous to one of those shown in Figs. 1 to 4 for measuring the densities of the two control exposures of the film is located between the sprockets d_6 and d_7. It can be for example of the type in which the receptors form two arms of a Wheatstone bridge.

n is a motor revolving a series of frictionless magnetic drives or clutches v_1–v_8 through the switches x_1–x_5, and n_1 is a motor revolving a series of frictionless magnetic drives or clutches u_1–u_7 through the switches z_1–z_5. The potential applied to the drives u_1–u_7 through the switches z_1–z_5 is lower than that applied to the drives v_1–v_8 through the switches x_1–x_5 and consequently the driving torque exerted by the former is smaller than that exerted by the latter. The motor *n* and the drives v_1–v_8 serve to feed the film when the conditions for the desired gamma are fulfilled, and the motor n_1 and the drives u_1–u_7 are used for adjusting the lengths of the festoons when corrections are required in the conditions of the development.

Fig. 7 shows an electro-optical relay used in conjunction with the photometer *l* in which p_1 is a photoelectric cell receiving that beam from the photometer *l* which goes through the lesser of the two control exposures and the ballast density; p_2 is a photoelectric cell receiving the beam going through the greater control exposure. *g* is a mirror galvanometer which projects an image of a lens *c* illuminated by a lamp *s* in the plane of a barrier cell b, the current from which closes the switch q (Fig. 8) through a secondary relay r. m_1 and m_2 are prisms located in such manner that when the galvanometer beam is offset from its null position a portion of the image of c is deviated on to barrier cells b_1 or b_2 depending upon the direction of the galvanometer deviation. The current from b_1 closes the circuit of the motor n_1 through a secondary solenoid self resetting relay r_1 causing the motor n_1 to rotate in the same direction as the motor n, while the current from b_2 closes the circuit of the motor n_1 through a secondary solenoid self resetting relay r_2 causing the motor n_1 to rotate in a direction opposite to that of the motor n. Before the beginning of development, the switches x_1 to x_5 and o are closed, the switches z_1 to z_5, q and t are open, and the machine is threaded with a leader film, the idle rollers having been located on the level k_2 so that the path of the film in the machine is shorter than that required for development in a given solution for a given film. It will be noted that as long as the switch t remains open, the relays r_1 and r_2 remain inoperative. The film is now spliced end to end with the leader and fed into the machine by starting in the usual manner the motor n which revolves the sprockets d_1–d_7 through the magnetic drives v_1–v_7, the circuit of which is closed through the switches x_1 to x_5 and o. When the spliced end arrives at the sprocket d_7, the thickness of the splice lifts the magnetic roller switch o which cuts the current through the magnetic drives v_6 and v_7, whereby the sprockets d_6 and d_7 are held stationary. Since the other sprockets d_1 to d_5 continue to deliver the film, the idle roller a_5 is no longer constrained to remain on the level k_2 and it follows the film by gravity until it reaches the limit level k_1 when the mercury switch x_5 is tripped by the stop f_5 so that the current is now cut in the magnetic drive v_5. In turn the idle roller a_4 leaves the level k_2 and the whole cycle of operation is performed for each of the film loops until the difference between two densities on the film in the beams of the photometer reaches a predetermined value corresponding to the desired gamma. This balances the photometer circuit and closes the switch q through the relay r, whereby all the magnetic drives v_1 to v_7 are now permanently energized. In consequence the film is now being driven along its new path through the development tank e and into the stop bath h.

It will be seen that this new path is set automatically by the physical photometer, and that it takes into account all variables present at the beginning of the development process, the compensation of which variables is required in order to develop the film to a desired value of gamma. However it may be necessary to change this path due to exhaustion or faulty replenishment of the solution or, to variation of temperature during the subsequent stages or development. Any necessity of increasing or decreasing the time of development is represented by a desequilibrium of the photometer circuit and is compensated for through the electro-optical relay in the following manner.

When the splice joining the leader to the film goes over the sprocket d_8 guiding it out from the stop bath h, the second magnetic roller switch t is closed.

When the film reaching the photometer is developed to a lower gamma than that for which the instrument is in equilibrium the beam of the galvanometer is displaced and a portion of the beam is deviated through the prism m_2 on to the barrier cell b_2 in consequence starting the motor n_1 through the relay r_2 in a direction of rotation opposite to that of the motor n. Those of the magnetic drives u_1 to u_7 corresponding to the rollers a_1 to a_5 which are at the level k_1 and corresponding consequently also to the switches z_1 to z_5 which were closed during the preliminary adjustment of the film path through the developing machine rotate now in opposite direction to that of the drives v_1–v_7. Since the current supplied to the drives u_1 to u_7 is of a lesser potential than that supplied to the drives v_1–v_7, the two magnetic forces acting upon the sprockets are not in equilibrium and consequently said sprockets are not stopped. However the extra load which is now the duty of the motor n repercutes by slowing up this motor, which should be chosen of a type, the speed of which is variable with the load, for instance a series motor. This slowing up prolongs the development time of the film until a new equilibrium is reached.

When the film reaching the photometer is developed to a higher gamma than that which is desired, the photometer circuit is offset and a portion of the beam from the galvanometer is deviated through the prism m_1 onto the barrier cell b_1, which starts through the relay r_1 the motor n_1 in the same direction of rotation as that of the motor n, so that the magnetic drives u_1–u_7 corresponding to the rollers at the level k_1 now rotate together with the drives v_1–v_7 in the same direction. Obviously in this case the reverse of what has happened when the motor n_1 revolved in the direction opposite to that of the motor n takes place; the sprockets corresponding to the idle rollers which are at the level k_1 are now driven by the two motors together and in consequence the load on the motor n is reduced, so that the speed of said motor n is proportionately increased. The time of development is thus shortened until a new equilibrium is reached.

Everyone of the clutches v_1 to v_7 may be driven by an independent motor w_1 to w_7, as shown in Figure 9, and the path of the film through the machine can then be reset every time when the original path has to be compensated through the relays r_1 and r_2. Since only those of the magnetic drives u_1 to u_7 which are energized through the switches z_1 to z_5 revolve in opposition or together with the drives v_1 to v_7, only the motors driving their corresponding or opposite drives v_1 to v_7 have their load increased or decreased. In consequence the rest of the sprockets continue to revolve at their normal speed. But the switches z_1 to z_5 supply current to only those of the drives u_1 to u_7 which control the sprockets corresponding to the idle rollers which have already reached the level k_1. In consequence, when the drives u_1 to u_7 revolve in opposition to the drives v_1 to v_7, that portion of the film nearest the photometer is slowed up, but since the rest of the sprockets continue to deliver the film at the normal speed, the take-up is slower than the delivery, subsequent rollers a_1 to a_5 descend to the level k_1 consequently tripping subsequent switches z_1 to z_5 and slowing up their corresponding drives v_1 to v_7. It can be easily seen that in this case a new and longer path through the solution has been automatically determined, and this cycle of operations can be repeated within the capacity of the machine, which is chosen to correspond to the maximum limit of the variations of the developing conditions within the useful life of the developing solution.

When on the contrary the motor n_1 is made to revolve in the same direction as the motors w_1 to w_7, only those of the motors which drive the sprockets corresponding to the idle rollers which are already at the level k_1 have their load reduced and in consequence revolve faster than the rest of the sprockets. The take-up being now more rapid than the delivery of one of the rollers, that roller goes up, thus cutting its corresponding switch z_1–z_5 and de-energizing the drives u_1–u_7 to which it corresponds. It can be seen that in this way a new and shorter path is automatically set in the machine and that this path remains until the developing conditions undergo another change.

Obviously the invention is not limited to the embodiments herein represented and described. Instead of speeding up or slowing down the sprockets d_1 to d_7 by means of the motor n_1 and the clutches u_1 to u_7, any other arrangement adapted to obtain the same result may be used; for instance the motors n or w_1 to w_7 can be shunt motors or motors with separate excitation, the excitation being controlled by the relays r_1 and r_2.

Having now described my invention what I claim as new and desire to secure by Letters Patent is:

An equipment for the photographic development of a film to a predetermined value of contrast (gamma) comprising a developing tank adapted to contain a developing solution, rotatable sprockets adapted to engage a film and to feed said film through said tank, driving means adapted to rotate said sprockets, auxiliary driving means adapted to be rotated in two opposite directions, frictionless magnetic drives inserted between said auxiliary driving means and said sprockets and adapted to transmit to said sprockets a driving torque in the direction of rotation of said auxiliary driving means so as to further or to oppose the action of said first main driving means, optical means adapted to project on two areas of said film while in the developing tank respectively two radiant beams, the difference between the logarithms of the intensities of said beams corresponding to the difference between the densities to be obtained in said areas after a correct development, and a photometric relay disposed in the path of said radiant beams after their passage through said film areas and adapted to control said auxiliary driving means in order to speed up or slow down said driving means and said sprockets according as the value of gamma becomes higher or lower than said predetermined value.

LEONTI PLANSKOY.