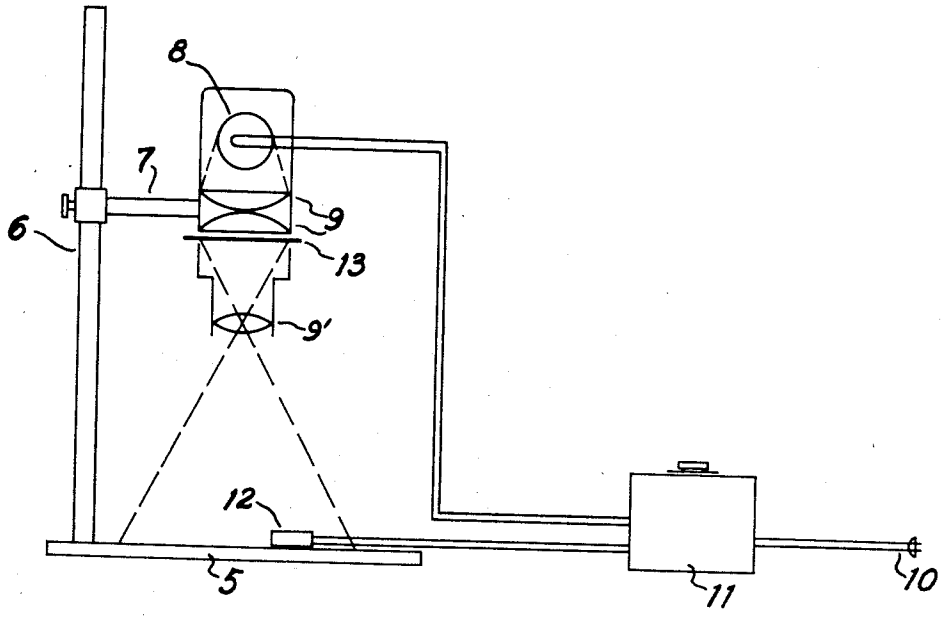
Aug. 18, 1942. H. R. DAMMOND 2,293,425

PHOTOGRAPHIC PRINTING APPARATUS

Filed Aug. 14, 1940 2 Sheets-Sheet 1

Fig. 1



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Fig. 2

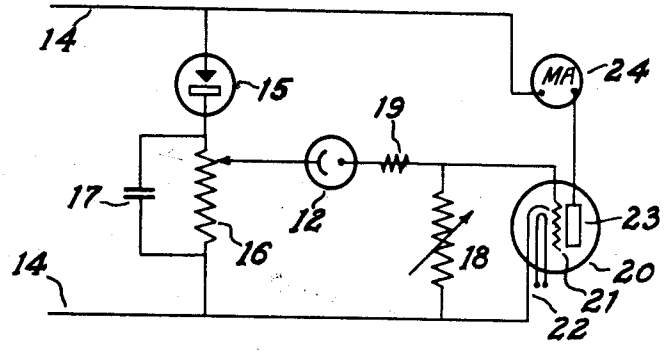


Fig. 3

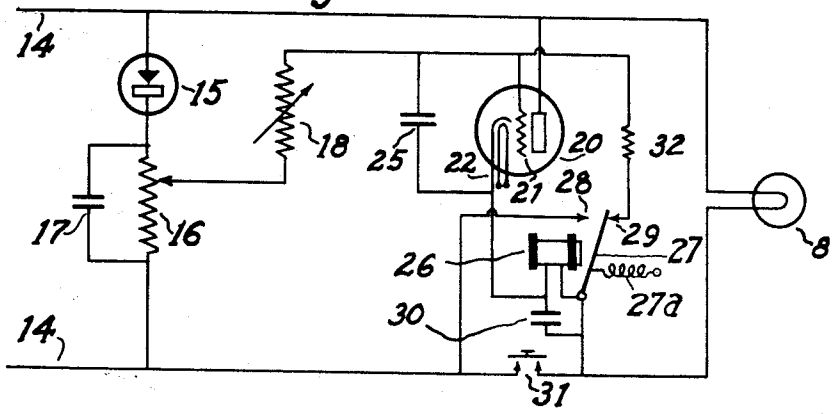
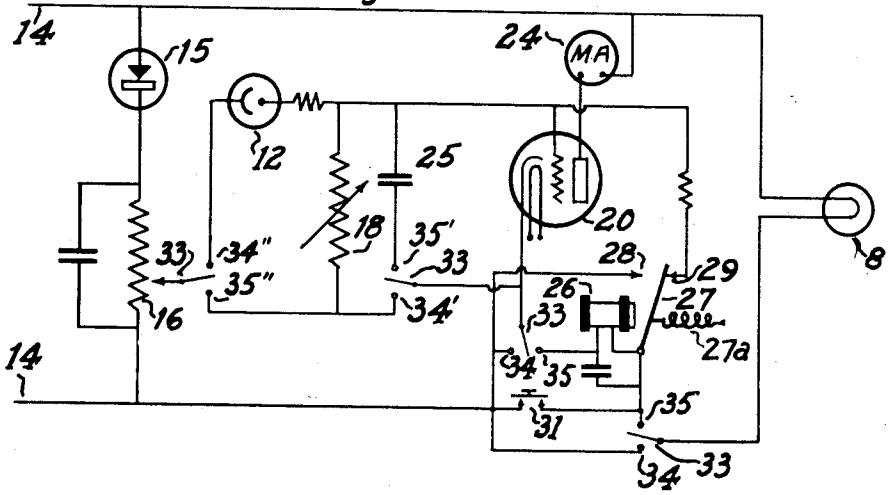


Fig. 4



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PHOTOGRAPHIC PRINTING APPARATUS

Howard Ralph Dammond, Pittsburgh, Pa.

Application August 14, 1940, Serial No. 352,563

5 Claims. (Cl. 88—24)

This invention relates to photographic printing apparatus. More particularly it relates to apparatus for determining and regulating the time during which photographic negatives and sensitive papers are exposed to a printing light for making prints.

The purpose of this invention is to provide apparatus which will simply and accurately determine the correct amount of time any particular negative should be exposed to obtain a properly exposed print and to automatically terminate the exposure at the proper time as first determined.

The proper time for the exposure of a particular negative for a particular intensity of light transmitted through it is determined by the following factors:

1. The density of the negative.
2. The distance of the light from the sensitive paper.
3. The sensitivity of the paper.

My apparatus automatically regulates the exposure time by indirectly measuring the first two factors listed above. In addition, my apparatus may be used to measure the contrast of a particular negative and to thus enable an operator to select the proper type of sensitive printing paper for use with that particular negative.

Briefly stated, the apparatus comprises two electrical circuits. In the first circuit a photoelectric cell is exposed to light passing through a negative from which it is desired to make a print. The amount of light passing through the negative is a function of the relative density of the negative and produces a current through the photoelectric cell proportional to this relative density. This relative density is indicated by changing the value of a variable resistance connected in series with the photoelectric cell. The second circuit is a form of time delay relay in which the value of the resistance as first determined in the first circuit is used to control means for terminating the exposure at the proper time.

In the accompanying drawings I have illustrated a present preferred embodiment of my invention in which:

Figure 1 is a schematic showing of a photographic printer with which my invention may be used;

Figure 2 is a diagram showing the circuit arrangement for measuring the relative density of the negatives;

Figure 3 is a diagram showing a circuit arrangement for controlling the exposure time; and

Figure 4 is a diagram showing a circuit arrangement in which the circuits shown in Figures 2 and 3 have been combined.

In Figure 1 there is shown diagrammatically a photographic printing apparatus such as may be used with my invention. An easel 5 on which the sensitive paper to be printed is placed supports a standard 6 having an adjustable arm 7. The adjustable arm carries a printing lamp 8, together with condensing lens 9 and objective lens 9' of standard construction. The lamp 8 is connected to a suitable source of energy 10 through timing apparatus 11 which will be more fully described hereinafter. A photoelectric cell 12 is connected into and forms part of the timing apparatus 11. The photoelectric cell 12 is placed on the easel 5 in the position occupied by the sensitive paper so that it may be exposed to light, passing through the negative 13, which is positioned between the condensing lens 9 and the objective lens 9'.

Figure 2 shows the electrical circuit which is used to measure the relative density of the negatives when they are in the printing position shown in Figure 1. Alternating current supplied through the wires 14 is changed into direct current by the rectifier 15 which is connected in series with a potentiometer 16. A filter condenser 17 is shunted across the resistance 16 to partially filter the rectified alternating current. The photoelectric cell 12 is connected to the potentiometer 16 and in series with a variable high resistance 18. A small protective resistance 19 for the photoelectric cell may also be included in the circuit. A thermionic vacuum tube 20 is also connected into the circuit by connecting the grid 21 of the tube between the photoelectric cell 12 and the resistance 18 and the cathode 22 to the other end of the resistance 18. The rectifier 15 is so arranged that the grid 21 can be made increasingly negative with respect to the cathode 22. The plate 23 of the vacuum tube is connected through a milliammeter 24 to one of the wires 14 to complete the circuit through the tube.

This circuit is utilized as follows: The photoelectric cell 12 is placed on the easel 5 in the position normally occupied by the sensitive paper which is to be exposed to light through the negative. A negative to be printed is then placed in the enlarger and the printing lamp 8 is turned on. The illumination falling on the photoelectric cell will cause a current to flow through the circuit containing the photoelectric cell 12, increasing the potential drop across the resistance 18, and making the grid 21 more negative with respect to the cathode 22. This will decrease the

anode current flowing through the vacuum tube, giving a reading on the milliammeter 24.

This reading can be changed by varying the resistance 18 to change the difference in potential between the grid 21 and the cathode 22 and thereby vary the current flowing through the vacuum tube. The variable resistance 18 is adjusted until the anode current through the tube is returned to a previously chosen reference value as indicated on the milliammeter. This reference value of anode current is that current which is allowed to flow through the tube by the grid when its potential is that which is caused by the minimum value of photoelectric cell current passing through the resistance when it is adjusted to its maximum value. The minimum photoelectric cell current corresponds to the minimum illumination which will fall on the photo electric cell for the range of negative densities for which the apparatus is designed.

The change in the resistance 18 which is necessary to restore the current passing through the vacuum tube to this reference value will be inversely proportional to the difference between the illumination through the particular negative to be printed and the illumination which will be transmitted through the most dense negative for which the apparatus is designed. Thus, if e_1 and e_2 are the potential of the grid 21 before and after the increase in illumination; i_1 and i_2 the currents through the photocell; and r_1 and r_2 the corresponding values of resistance 18, then by Ohm's law

$$e_1=i_1r_1$$

and

$$e_2=i_2r_2$$

If the resistance is adjusted so that $e_1=e_2$, then

$$i_1r_1=i_2r_2$$

and

$$i_1/i_2=r_2/r_1$$

If L_1 is the original light intensity (expressed in any units) and L_2 the intensity after increasing it

$$L_1/L_2=i_1/i_2 \quad \text{(for a vacuum cell)}$$

therefore

$$L_1/L_2=r_2r_1$$

That is, the value of resistance 18 is inversely proportional to the illumination on the photocell.

As previously stated, the condition when e_1 is equal to e_2 may be determined by reading the milliammeter 24. Since the amount by which the resistance 18 must be changed is inversely proportional to the light passing through the negative to be printed and falling on the photocell, the change in resistance indicates the relative density of the particular negative. The proper value in ohms for the resistance 18 may be determined in a manner which will be hereinafter described.

Figure 3 is a diagram of the circuit which is used for terminating the exposure after the proper time for the exposure has been determined by adjustment of the resistance 18 in the circuit illustrated in Figure 2. It will be noted that some of the equipment used in the first circuit is also used in the second circuit such as the potentiometer 16, the thermionic vacuum tube 20, the printing lamp 8, and the variable resistance 18. One end of the resistance 18 is connected to the grid 21 of the tube 20. The other end of the resistance is connected to the potentiometer 16. A condenser 25 is connected in series with the resistance 18 and in parallel with the grid circuit of the vacuum tube 20 by being connected to the grid 21 and the cathode 22. A relay 26 having an armature 27 and contact points 28 and 29 is connected in the cathode circuit of the tube 20. Movement of the armature 27 against the contact point 28 locks in the relay 26 and movement away from the contact 28 breaks the circuit by which the lamp 8 lighted. A spring 27a holds the armature against the contact 29 when no current is passing through the relay. Since pulsating direct current passes through the magnetic relay 26, a filter condenser 30 is provided to keep the armature 27 from vibrating.

This circuit operates as follows: A push button 31 is pressed to close the circuit which lights the printing lamp 8. This also closes the circuit of the relay 26 and the vacuum tube 20, energizing the relay and moving the armature 27 from the contact point 29 to the contact point 28, thus paralleling the push button 31 so that it may be immediately released. At the same time, the circuit which includes the potentiometer 16, variable resistance 18, and the condenser 25 is completed. Therefore, when the push button 31 is closed the condenser 25 will begin to charge. It will continue to charge until its potential (and therefore the potential of the grid 21) reaches such a negative value with respect to the cathode 22 that current passing through the vacuum tube 20 and the relay 26 is reduced to a value insufficient to keep the relay 26 energized. The armature 27 will then swing over to the contact point 29. The printing lamp circuit is thus broken and the condenser is discharged through the resistance 32.

If the condenser 25 is of the correct capacity (a method whereby the capacity of the condenser 25 may be determined is hereinafter described), the time required for it to charge and therefore raise the grid to the potential mentioned above is dependent on the current which passes through the resistance 18. This current is by Ohm's law inversely proportional to the value of the resistance 18. As was shown in the discussion of the circuit disclosed in Figure 2 of the drawings the value of the resistance 18 is inversely proportional to the illumination of the photocell. Therefore the value of current through the resistance 18 when connected into the second circuit is directly proportional to the illumination falling on the photocell. The value of the resistance 18 was determined by use of the circuit shown in Figure 2. The rate at which the condenser 25 charges is thus directly proportional to the light received by the photoelectric cell through the negative and the time during which the sensitive paper is exposed is thus proper for the illumination falling upon it.

Figure 4 illustrates a circuit arrangement, whereby the two circuits shown in Figures 2 and 3 may be combined for convenience in operation and to avoid duplication of instruments used in both circuits. A four-pole, double-throw switch 33 having contact points 34, 34' and 34'' and 35, 35' and 35'' is provided to connect the various instruments alternatively into one circuit or the other. Thus, in Figure 4 when the switch 33 is closed through the contact points 34, 34' and 34'' the apparatus is connected into the circuit shown in Figure 2. When the switch 33 is closed through the contact points 35, 35' and 35'' the instruments are connected into the circuit shown in Figure 3.

The proper range of values for the variable resistance 18 may be ascertained as follows. The illumination range required for the photographic printing machine is first determined. Thus, it is known that ordinary enlarging paper requires about two seconds exposure for an illumination of 1 lumen per square foot. As an example an ordinary photographic enlarger may be designed for a time range of from 2 to 60 seconds. This corresponds to an illumination range of from 1 to .03 lumen per square foot.

The sensitivity of the photoelectric cell in microamperes per lumen is known so that the current delivered by the photoelectric cell over the available illumination range is likewise known. The potential drop across the resistance 18 caused by the photocell current determines the voltage of the grid of the thermionic vacuum tube. The grid in turn affects the plate current of the tube. Therefore a variable resistance is chosen such that at its maximum value it will give a readable deflection of the milliammeter 24 when the minimum amount of light is falling on the photoelectric cell. This will give the operator a base point for measuring the density of any negative as described above in connection with Fig. 2.

The value of the condenser 25 is determined by first ascertaining the grid voltage necessary to reduce the current through the tube to the drop-out value for the relay 26. This may be determined from data supplied by the manufacturer of the tube. Any exposure time is then chosen, e. g., the maximum, 60 seconds. For this exposure the resistance will be adjusted to its maximum value. These two values are substituted in the equation $T=RC$, to determine the capacity C of the condenser 25. This equation gives the capacity for which at the end of time T the potential of the condenser is equal to 63% of the charging potential, or at which $E_c=.63E_M$.

The charging voltage to be supplied by the potentiometer 16 is determined from the above equation, $E_c=.63E_M$, by substituting for E_c in this equation the grid voltage necessary to cause the relay to drop out.

My invention enables an operator of any photographic printing machine to make properly exposed prints from any negative. The timing mechanism is very simple to operate requiring only one adjustment. After this adjustment is made it can be used repeatedly. All the operator then has to do is to press a switch button to turn on the printing lamp. The mechanism automatically turns off the light when the correct exposure has been made.

The circuit for determining the relative density of the negative gives an accurate measurement of this value since it is exposed to all the light passing through the negative. This is important if the negative is dense. The photocell can be moved from place to place on the easel to measure the contrast of the negative. This in turn will enable the operator to select the right grade of paper for the negative being printed.

My apparatus may be built into a photographic printing assembly so that the entire equipment may be sold as a unit, or it may be connected into any printing apparatus not having a timing mechanism.

While I have described a present preferred embodiment of my invention, it is to be understood that it may be otherwise variously embodied within the scope of the following claims.

I claim:

1. In photographic printing apparatus, mechanism for regulating the exposure time which comprises a circuit for determining the relative density of the negatives to be printed including a photoelectric cell exposed to light passing through a negative in printing position and a variable resistance connected in series with the cell, the value of the resistance being varied to indicate the relative density of the negatives, and a second circuit including said resistance as adjusted in the first circuit and connected to a source of electrical energy, a thermionic vacuum tube relay, means controlled by the relay for terminating the exposure time, and a condenser connected to the input circuit of the relay and to the resistance, the action of the relay being responsive to the charge on the condenser as determined by the resistance.

2. In photographic printing apparatus, mechanism for regulating the exposure time which comprises a printing lamp, a circuit including a photoelectric cell exposed to light passing through the negative when in printing position, and a variable resistance in series therewith, a thermionic vacuum tube having its grid and cathode shunted across the resistance, and means for measuring the current passing through the vacuum tube, a second circuit including a condenser in series with said resistance and connected to the grid and cathode of said tube, a relay connected in series with the cathode and plate of said tube for controlling electric current supplied to the printing lamp, and a switch for connecting the apparatus into either of the two circuits.

3. In photographic printing apparatus, mechanism for regulating the exposure time which comprises a printing lamp, a circuit including a photoelectric cell exposed to light from said lamp passing through the negative when in printing position, an adjustable resistance in series with the cell and in shunt with the grid and cathode of a thermionic vacuum tube, means for measuring the current through said vacuum tube to indicate the magnitude of the photoelectric current, and a second circuit comprising the resistance as first adjusted connected to a source of electrical energy and in series with a condenser associated with the input circuit of a thermionic relay for controlling the current to the printing lamp, the rate of charge of the condenser and thus the length of the exposure time being determined by the adjustment of the resistance, and a switch for connecting the apparatus into either of the two circuits.

4. In photographic printing apparatus having a printing lamp, mechanism for regulating the exposure time comprising an electric circuit including light-sensitive means subject to the light traversing a negative in printing position, a manually variable resistance adapted to be adjusted in accordance with the amount of light traversing the negative and means for terminating the exposure including a thermionic vacuum tube, a relay connected in the plate circuit of said tube and controlling said lamp, and manually operable means for connecting said resistance in the grid circuit of said tube so as to reduce the plate current through the tube below that required to keep the relay operated, after a predetermined time, depending on the adjustment of said resistance.

5. An automatic control system for a photographic printing lamp comprising a relay con-

trolling said lamp, a thermionic vacuum tube, the relay being connected in the plate circuit of said tube, a condenser connected across the input circuit of said tube, a manually variable resistance connected to said condenser, a source of current for charging the condenser, said resistance being manually adjustable and effective to determine the time required for the charge on the condenser to build up to the value necessary to decrease the plate current from the tube below that required to hold the relay operated, a meter connected in said plate circuit, a photoelectric cell subject to the light traversing the negative, and manual means for substituting the photoelectric cell for said condenser in said input circuit to permit adjustment of the resistance to a value corresponding to the negative density.

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