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EP 15963.

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) **International Patent Classification:** G03B 7/10, 15/05 — A1

(11) **International Publication Number:** WO 79/00962

(43) **International Publication Date:** 15 November 1979 (15.11.79)

(21) **International Application Number:** PCT/US79/00252

(22) **International Filing Date:** 19 April 1979 (19.04.79)

(31) **Priority Application Number:** 898,546

(32) **Priority Date:** 21 April 1978 (21.04.78)

(33) **Priority Country:** US

(71) **Applicant:** POLAROID CORPORATION [US/US]; 549 Technology Square, Cambridge, MA 02139, (US).

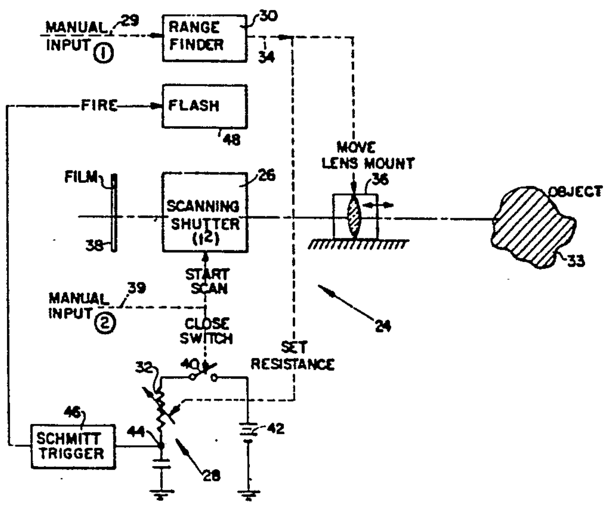
(72) **Inventors:** BIBER, Conrad, H.; 120 Stratford Road, Needham, MA 02192, (US). JOHNSON, Bruce, K.; 27 Summer Street, Andover, MA 01810, (US). WHITESIDE, George, D.; 4 Robbins Road, Lexington, MA 02173, (US).

(74) **Agent:** HORMANN, Karl; 549 Technology Square, Cambridge, MA 02139, (US).

(81) **Designated States:** CH (European patent), DE (European patent), FR (European patent), GB (European patent), JP.

Published with:
International search report

(54) **Title:** PHOTOGRAPHIC FLASH APPARATUS



(57) **Abstract**

An image recording apparatus and method employing a diaphragm shutter (26) having a time variable exposure aperture with flash firing, following actuation of the shutter (26), after a time interval dependent on subject range. The functional relationship between the time interval and subject range establishes a parametric relationship between the brightness of the subject due to its flash illumination and the scan time of the diaphragm shutter (26). The inverse of this parametric relationship constitutes the timewise variation in the exposure aperture area of the shutter (26). Consequently, whenever the subject (33) is within a predetermined maximum distance from the camera (24), dependent upon the maximum aperture area attainable by the shutter (26), the instantaneous product of subject brightness and aperture area will be a constant with the result that proper exposure of the photographic film (38) is achieved independent of the subject range.

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PHOTOGRAPHIC FLASH APPARATUS

Background of the Invention

This invention relates to a method of and apparatus for recording an image as by photography of a subject under flash illumination with optimum exposure independent of the range of the subject.

In the photographic art, exposure systems employing a diaphragm or scanning shutter having an exposure aperture area that varies with time during the exposure interval are known. Representative patents showing scanning shutters are U. S. Patent No. 3,762,299; U. S. Patent No. 3,972,058 and U. S. Patent No. 4,047,190. In the above patents, a scanning shutter is described which includes a pair of counter reciprocal blades each having a primary aperture that traverses the optical axis of the camera during the exposure interval. These primary apertures are shaped so that upon overlying one another during counter movement of the blades, the exposure aperture value, defined in part by one primary aperture and in part by the other primary aperture, increases from zero to a maximum value in a preselected period of time.

In these arrangements, exposure control is exerted by a summing or integrator circuit the resistance of which is constituted by a photocell located behind a photocell aperture formed by secondary apertures in the blades. The photocell aperture value, too, is changed with time, the change being related to the change in the exposure aperture value to provide proper exposure control over a wide range of conditions. The photocell aperture which controls the scene light admitted to the photocell opens simultaneously with or in slightly leading arrangement to passage of first light through the exposure aperture, and when the integrator reaches a given level, a trigger circuit is fired to reverse the movement of the blades, which are rapidly returned to their initial light blocking position.

These known diaphragm shutter systems and exposure controls operate in an ambient as well as a flash mode of operation. The shape of primary and secondary blade apertures is, therefore, important for obtaining proper exposures in either modes. For the flash mode of operation, the blades are stopped at a position resulting in an aperture value related to the position of the camera lens, i.e., to the subject range. Hence, the aperture values are varied prior to flash firing; yet a preselected fixed aperture is actually provided during the flash pulse.

Scanning shutters which utilize varying apertures during the flash pulse are also known from U. S. Patent Nos. 3,570,381 and 4,020,497. In these systems a flash firing switch is adjusted in accordance with lens focusing so that the flash will coincide with a range of aperture values. The range of aperture values is selected automatically in accordance with lens focusing and, hence, subject range. While such flash systems provide satisfactory flash exposure in many instances, they are dependent upon movable switches which is subject to mechanical position errors.

In U. S. Patent No. 4,047,191, a system is disclosed in which an incandescent flash is ignited at the same time as or just prior to opening of a scanning shutter. The flash illumination accordingly is superimposed in a leading arrangement on the aperture opening curve to provide increasing illumination intensity.

Another flash exposure system is suggested by U. S. Patent No. 3,794,422. Here the transmissivity of an electro-optical shutter is varied as a function of the speed of light with a view to providing uniform exposure of all subjects within the flash range. In this arrangement, the shutter is varied from a blocking condition of relatively low transmissivity to maximum transmissivity during the duration of the flash. A subject relatively close to the camera, would be relatively brightly illuminated but for the fact that the light reflected from the close subject is received by the shutter when its transmissivity is relatively low. Under such condition, the shutter attenuates relatively strongly light reflected from a close range so only a predetermined amount passes. However, where the subject is relatively distant, substantially the same amount of light passes even though the subject reflects less light because by the time the light is reflected from the distant subject the shutter transmissivity has increased to a level functionally related to the distance or this dimmer light, as the case may be. Such an arrangement may at least in theory be possible; but the requirements for such an electro-optical shutter present severe complications in terms of size, weight and expense both in the shutter itself and the modulator required to produce the change in transmissivity. Since the shutter is called upon to function with a speed in the order of the speed of light, the precision required for the flash device and its firing time is also unduly burdensome.

It is an object of the present invention to provide a new and improved method of, and apparatus for, photographing a subject under flash illumination to achieve an optimum exposure with such transient illumination.

Another object is to provide a method of, and apparatus for, achieving optimum exposure under combined transient and steady state illumination.

Summary of the Invention

In accordance with an advantageous embodiment of the invention, flash illumination of a subject to be photographed is accomplished by using a scanning shutter having a time-variable exposure aperture area, by driving the shutter at a selected scanning rate and producing a flash of illumination at the end of a time interval measured from actuation of the shutter (i.e., time of first light) and dependent on both the range of the subject and the shutter scan rate. The functional relationship between the time interval and subject range establishes a parametric relationship between the brightness of the subject due to its flash illumination and the scan time of the shutter. The inverse of this parametric relationship constitutes the timewise variation in the exposure aperture area of the shutter. For a given flash output, whenever the subject is within a predetermined maximum distance from the camera (dependent on the maximum aperture area attainable by the shutter) the instantaneous product of subject brightness and aperture area is a constant, resulting in proper exposure of the film independently of subject range. In the preferred embodiments, the timed interval is determined by a rangefinder employing sonic ranging signals.

The method includes the steps of determining a timed interval related to subject range, exposing a recording medium through increasing aperture values the rate of increase of which is correlated to the interval-range proportion, and following initiation of said exposing step, providing a pulse of illumination, after a period related to said timed interval so that the illumination pulse is synchronized with an aperture value, or small range of aperture values, selected in accordance with subject range to provide proper exposure for the subject range.

Where ambient (steady state) illumination is negligible, the timed interval and the flash firing time (following first light through the shutter) are equal;

however, ambient light can be compensated for in accordance with the present invention by triggering the flash after a period dependent on both the ambient light and subject range.

In one of the illustrated embodiments, a sonic rangefinder is utilized for actuating an integrator circuit after an interval of time, subsequent to transmission of a sonic burst, to provide a flash fire time proportional to the range of the subject returning the echo. The integrator includes a resistor in parallel with a photocell exposed to light from the scene, and a trigger circuit responsive to the output of the integrator for firing the flash and closing the shutter when the output reaches a predetermined trigger level. Preferably, the opening of the shutter (i.e., first light) is delayed, after transmission of the sonic burst, by a length of time which is equal to the time which the integrator requires for its output to reach the trigger level when the ambient light on the photocell is negligible. Therefore, at a very low level of ambient light essentially the resistor only is effective in the integrator to trigger the flash and close the shutter a fixed time after the detection of an echo, the fixed time being equal to the delay time in opening the shutter. When ambient light is present, it contributes to the integrator summing to reduce the flash fire time in accordance with the ambient level and the scan rate such that the firing of the flash and closing of the shutter occurs sooner, i.e., at a smaller aperture, than would be the case were the integrator time-out determined solely by the resistor. Consequently, the flash is fired before the exposure aperture area has reached its optimum size with respect to the range of the subject. This reduces the amount of light transmitted through the shutter from the subject due to its flash illumination. This reduction in flash illumination is balanced by the ambient light present such that a proper exposure is obtained.

Brief Description of the Drawings

Embodiments of the present invention are disclosed in the accompanying drawings wherein:

Fig. 1 is a composite plot showing the variation in brightness of a subject under flash illumination as a function of distance of the subject to a camera, and the variation in exposure aperture area as a function of time resulting from the parametric relationship between subject brightness and time arising from the functional relationship between subject distance and time;

Fig. 2 is a block diagram showing a first embodiment of the invention suited for taking photographs under flash illumination when ambient scene light is negligible;

Fig. 3 is a time diagram showing the variation of the exposure aperture area of the scanning shutter shown in Fig. 2;

Fig. 4 is a block diagram of the preferred embodiment of the invention for photographing an object illuminated by both flash and ambient light;

Fig. 5 is a series of plots showing the time relationship between actuation of the shutter and the firing of the flash when ambient scene light is negligible;

Fig. 6 is a plot similar to Fig. 5 but considering ambient light present in the photographic scene under exposure; and

Fig. 7 illustrates an alternate embodiment of the system of Fig. 4 and depicts an arrangement for providing a flash fire interval as a non-linear function of subject range.

Detailed Description

The present invention utilizes a scanning shutter the program, i.e., the time-wise variation in exposure aperture area, of which is selected such that if A is the instantaneous area of the aperture when the flash occurs, and if B is the brightness of the subject illuminated by the flash, A x B is a constant which is independent of range. Therefore, the amount of transient scene light incident on the photographic film through the shutter is always the same. With a given film speed and light output of the flash, proper exposure of the film is assured independently of subject range up to a maximum range determined by the maximum size of the exposure aperture area and the flash output, assuming ambient scene light is negligible.

The term "flash" is intended to include any transient light pulse and while the invention is preferably practiced with an electronic flash or strobe the pulse duration of which is short compared to the scan time of the shutter, it is no less applicable to light pulses of longer duration, such as those from incandescent flash units.

The manner in which a program for a scanning shutter can be selected is illustrated in Fig. 1. The scales have been chosen to fit the curves onto the space available and are of no significance to the present invention. Curve 10 shows the variation in brightness of a subject under illumination by a flash of given output, as a function of subject range from the flash source, or from the camera where the flash is relatively close thereto. Curve 10 demonstrates the inverse square relationship between subject brightness and range, i.e., $B \triangleq f(1/d^2)$. If time intervals are considered as representative of subject range, i.e., $t \triangleq f(d)$, then both the brightness of the subject and the time intervals are functions of the distance. Consequently, the brightness of the subject under illumination by flash is a function of time.

If the interval representing subject range is a function of distance as indicated by curve 12, then curve 14 represents the parametric relationship of subject brightness with time. Curve 14 does not infer that the brightness of a subject illuminated by flash changes with time, but merely shows that if the range of a subject is d_o, whereby its brightness is B_o, then if the flash is fired at time t_o corresponding to the distance d_o, the brightness of the subject will be B_o as indicated in Fig. 1. Since the relationship between range and time is assumed linear as indicated by curve 12, the direct relationship between time and the brightness of the subject due to the flash illumination varies as the inverse square of this time as shown by curve 14.

In accordance with the invention, curve 16, which represents the timewise variation in exposure aperture area of the scanning shutter, is inversely related to curve 14. Curve 16 varies with the square of time for embodiments where the range related time parameter is linear with range.

The shapes of exposure apertures in flat blades for a diaphragm or scanning shutter can be desinged so that the shutter aperture area or aperture values have a time-squared program. However, according to the present invention, the exposure aperture area of the scanning shutter can have programs other than the one shown by curve 16 and, in fact, can be linear or have an arbitrary time variation dependent only on the nature of the range-time function. For example, it may be desirable to have a linear scan program rather than a time-squared scan program for mechanical or design reasons, or to fit an existing scanning shutter camera to practice the present invention. Curve 18 represents such a linear program for the scanning shutter; and it requires the brightness curve 20 to have a 1/<u>t</u> form in order for the product of area and brightness to remain constant. The nature of curves 10 and 20 is such that the range-time variation must satisfy the relationship $t \triangleq f(d^2)$ as indicated by curve 22.

The desired relationship between range and time can be established by utilizing a member having a physical property the value of which is representative of the range of a subject. For example, for a linear range factor the member can be a resistor in an integrator because the value of the resistance in a simple integrator is linearly related to the time required for the integrator output to reach a predetermined value. A linear potentiometer adjustable in response to the setting of an optical rangefinder is a practical way to establish time as a function of range. As another example, the round trip time for a sonic burst to travel between a transmitter and subject is linearly related to the range of the subject. Similarly, for different scanning programs, a non-linear relationship between range and time can be established by suitable modifications of the systems described above.

The embodiments described below are illustrative of movable lens cameras which employ subject ranging to position the lens, that is, however, quite separate from range firing of the flash, and the latter may be employed with a fixed lens or fixed focus cameras.

Referring now to Fig. 2, a camera 24 incorporates an embodiment of the invention utilizing a scanning shutter 26 having a t^2 program as indicated by curve 27 in Fig. 3, and a linear range-time relationship by reason of an integrator 28. A first manual input 29 to a rangefinder 30 is utilized for the purpose of adjusting a linear potentiometer 32 of the integrator to a value directly proportional to the range of an object 33 from the camera 24. Rangefinder 30 can be a conventional optical rangefinder wherein the user views the object and mechanically moves an arm 34 until the object is in proper focus. In such case, the setting of the potentiometer 32 would be responsive to the movement of arm 34. The arm 34 may also move a lens assembly 36 until the lens assembly is in a position at which light from the object 33 will be focused on a photosensitive sheet of film 38 after the shutter 26 is activated by a second manual input 39 which also closes a switch 40 to couple a power source such as a battery 42 to the integrator 28.

As shown in Fig. 3, the second manual input 39 occurs subsequent to completion of the focus; and it is assumed that first-light through the scanning shutter is substantially coincident with the initiation of the integrator 28. The voltage at node 44, which constitutes the output of the integrator, changes exponentially with time and reaches a trigger level which is sensed by a Schmitt trigger 46 after a period of time directly proportional to the range of object 34 from the camera. The trigger 46 responds, when the voltage at node 44 reaches the predetermined trigger level, by sending a firing signal to a flash unit 48 which is preferably, but not necessarily, an electronic flash the duration of which is shorter than the duration of the scanning time as shown in Fig. 3. In this embodiment the firing of the flash 48 occurs, following first light, after an interval of time which is directly proportional to the range of the object.

For the reasons indicated above in connection with the discussion of Fig. 1, the area of the exposure aperture of the shutter 26 is functionally related to the brightness of the object with the result that the amount of light passing through the scanning shutter and incident on the film 38 provides proper exposure, assuming that ambient light is negligible and that the object 34 is within the maximum range of the system as determined by the maximum exposure aperture area. Assuming substantially all of the light incident on the film 38 is derived from the flash 48, the shutter may be closed at any time following completion of the flash pulse.

The timing of the flash in accordance with subject range during shutter scanning synchronizes the flash with a narrow range of apertures in accordance with subject distance, and for an electronic flash, effectively synchronizes the short pulse of illumination with essentially a fixed aperture. That is, in the latter case, any change in aperture during the extremely short flash pulse can often be considered to have minimal effect on the expected exposure.

Rangefinders other than optical rangefinders can be utilized in connection with the apparatus shown in Fig. 2 and, preferably, rangefinder 30 is in the form of a sonic rangefinder. The time required for a sonic burst to pass from a transducer (not shown) to the object and back to the transducer is a function of the range of the object. The echo can be utilized for the firing of flash 48, and the integrator 28 may be essentially eliminated. That is, for a fixed focus camera, the shutter actuation (first light) and the transmit pulse are synchronized, the shutter scans at a time squared program, and the echo triggers the Schmitt trigger to fire the strobe pulse at the appropriate aperture value.

The arrangement shown in Fig. 4 can be utilized wherein camera 24' utilizes a sonic rangefinder in conjunction with a delayed opening of the shutter so that flash fire time predicted by the sonic range time may be reduced to take ambient light into consideration.

Rangefinder 30' shown in Fig. 4 is a schematic illustration of a rangefinder employed for focusing a movable lens. A manual input 50 automatically focusses the lens 36 consistent with the range of the object 34 as indicated and also actuates the scanning shutter 26 after a predetermined time delay δ provided by a delay circuit schematically indicated by block 52. The manual input 50 to rangefinder 30' causes a ranging circuit 54 to issue a transmit command to sonic transducer 56 causing a burst of sonic energy 58 to be emitted from the transducer substantially coincident with manual input 50. An echo detector 66 which detects echo 62 after processing by the ranging circuit, closes a switch arrangement 40' associated with an integrator 28'. When the switch 40' closes, the voltage at the output node 44, of integrator 28', begins to increase exponentially in accordance with the value of capacitor 70 and the effective value of the resistance of the integrator which comprises the parallel combination of a fixed resistor 72 and a photodiode 74 located behind the photocell apertures of the scanning shutter and exposed to light from the scene being photographed when first light passes the exposure apertures of the shutter. When the voltage at node 44 reaches the trigger level, Schmitt trigger 46 fires flash 48 and terminates the scanning operation of the shutter by closing the same.

The manner in which the apparatus shown in Fig. 4 achieves proper exposure over a wide range of ambient lighting conditions is set forth in Figs. 5 and 6. The flash is presumed to be an electronic flash which provides a pulse of relatively short duration. Fig. 5 relates to the condition in which ambient light is negligible as described above in connection with Figs. 2 and 3. In Fig. 5(a), the possible variation in aperture area of the scanning shutter as a function of time is shown by curve 76. In camera 24', as described with regard to Fig. 4, the shutter is actuated so that first light occurs after a time interval δ following manual input 50. Since this time interval is equal to or longer than the time required for an echo to be received from an object located within the maximum flash range of the camera, Fig. 5(a) shows that receipt of echo 62 occurs within the interval δ, and follows the manual input by a period of time functionally related to the range of the object. Thus, switch 40' (Fig. 4) is closed prior to first light through the scanning shutter with the result that battery 42 is connected to integrator 28' coincident with receipt of echo 62. However, since the ambient light is negligible, the resistance of photodiode 74 is high, and the effective resistance of the integrator circuit is essentially the resistance of the resistor 72 which is selected such that the trigger level at node 44 is reached after a time interval δ'. The "delayed echo", i.e., the output of the Schmitt trigger 46, therefore, occurs after a period of time δ' following echo 62 as shown in Fig. 5(a). The flash 48 is fired and the close command applied to the shutter 26 in response to triggering of the trigger 46 which is after first light through the shutter by a delay equal to the period of time between receipt of the echo 62 and the instant of manual input 50. In other words, the flash fire time measured from the instant of camera actuation is equal to the sum of the range related time plus the shutter delay δ. The solid portion 75 of curve 76 represents the change in area from first light to receipt of the closing command. Curve 77 represents the change in area as the shutter responds to the closing command.

Referring now to Fig. 5(b), the voltage at node 44 is shown as increasing from zero at the instant of receipt of echo 62 and reaching the trigger level 78 after a period of time δ' equal to the delay time δ. Upon reaching the trigger level 78, the Schmitt trigger 46 fires flash 48 and closes the shutter. At that time, photocell 74 responds to the impulse-like light output of flash 48 by a sudden decrease in its resistance to a level related to subject range. This produces the step-like increase 80 in the voltage at node 44. However, since the Schmitt trigger has already been tripped, the increase in voltage is of no consequence.

The amount of light incident on the film 38 behind the scanning shutter 26 is shown in Fig. 5(c). During the time interval δ', essentially no light falls on the film since ambient light is negligible. As soon as the Schmitt trigger 46 detects the trigger level at node 44 and fires the flash, the light incident on the film increases to level 79. This level depends upon the product of the light reflected from the object and the area of the shutter aperture substantially at the instant the flash is fired, since flash firing and flash output occur substantially simultaneously, and that the light pulse is very short, as normally produced by electronic strobes. By proper selection of the exposure determining parameters of film speed, light output of the flash, and the design of the scanning shutter, a proper exposure of the film is obtained independently of subject range. The finite closing time of the shutter does not affect the amount of light incident on the film because substantially all of the light came from the very short duration flash.

Where ambient scene light is not negligible, the photocell 74 contributes to film exposure by advancing in time the instant at which the flash is fired. As shown in Fig. 6(a), detection of echo 62 actuates the integrator 28' before first light, and the voltage at node 44 (Fig. 4) initially begins to increase exponentially in the manner shown in Fig. 5(b). At time δ following manual input 50 when first light impinges on the film behind shutter 26, first light also falls on photocell 74. The resistance of the photocell 74 and, hence, the time constant of the integrator 28' are reduced in accordance with the amount of ambient light resulting in the break, shown at 82 in Fig. 6(b), in the summing rate of the output of the integrator. Therefore, the voltage output increases more rapidly and reaches the trigger level 78 in a time shorter than δ', depending on the amount of ambient light. Hence, the instant in time selected for flash firing is advanced in accordance with the ambient light. Double-ended arrow 86 indicates the time-wise positions of step 84 which are dependent on both subject range and the ambient light level.

When the flash is fired by the Schmitt trigger 46 the resistance of the photodiode 74 is rapidly reduced as in the embodiment described above in connection with negligible ambient light, and a step-like increase 84 occurs in the voltage at the output node 44' of the integrator. As the shutter closing signal is applied to the shutter by the trigger 46 at the same time as the flash is fired, the contribution of the ambient light to the exposure is essentially that occurring before the flash.

The amount of light incident on the film 38 as a consequence of ambient light and flash illumination is shown in Fig. 6(c). During the time interval between reception of the echo and first light, no light at all is incident on the film. Between first light and firing of the flash ambient light enters the exposure aperture in increasing amounts as the exposure aperture enlarges. Before firing of the flash the light integrated is at a level 88 depending on the intensity of the ambient scene light. As soon as the trigger 46 detects the predetermined voltage level at node 44, the flash is ignited and light incident on the film increases rapidly. However, since the size of the exposure aperture at the instant of flash firing is smaller than it would be if firing of the flash occurs at time ' (as in Fig. 6c), the contribution of the flash to the exposure is reduced to compensate for the ambient light. The exposure, due to flash as well as ambient light before flash, reaches the level 90, and because of the finite closing time of the shutter, ambient light continues to contribute slightly to film exposure after the short flash pulse as indicated by segment 92 in Fig. 6(c). By the time the shutter is completely closed, the exposure light will have reached level 79 which, as previously indicated, is sufficient to expose the film properly.

The delay in shutter actuation and the delay in firing the flash have been considered equal. This assumes that shutter actuation and first light occur simultaneously. In practice, however, the flash fire delay is slightly longer than the shutter actuation delay by an amount equal to the difference between shutter actuation and first light.

In Fig. 7, the flash firing circuit of Fig. 4 is shown in an alternate embodiment to provide a flash fire interval which is a non-linear function of the subject range for use with a shutter scan rate having other than a time squared program. In this figure, the resistor 72 is replaced by a diode 96 which provides a flash fire time interval as a logarithmic function of the subject range for use with a linear shutter scan rate.

The flash firing time interval may be varied to suit different scan rates by adding a plurality of diodes (not shown) with appropriate series resistors to produce any desired functional relationship between the subject distance and the flash fire time interval. For instance, the embodiment of Fig. 4 illustrates a system having means (e.g., sonic) for defining a time interval functionally related (e.g., linearly) to subject distance and means (switch 44' and diode 96) for converting the above time interval to a flash fire interval non-linearly related to subject distance to accommodate a selected shutter scanning function.

It is believed that the advantages and improved results furnished by the apparatus of the present invention are apparent from the foregoing description of the several embodiments of the invention. Various changes and modifications may be made without departing from the spirit and scope of the invention as sought to be defined in the claims that follow.

1. Apparatus for photographing a subject, comprising:

a scanning shutter which when actuated produces a predetermined, timewise variation in exposure aperture area;

ranging means for providing an output representative of the range of a subject;

a flash unit; and

means for actuating the shutter to start its scanning, the improvement comprising:

means for firing (46) the flash unit (48) to produce a flash of illumination after a time period, measured from the first light through the shutter (26), dependent on the output of the ranging means (30), the relationship between the time period and subject range establishing a parametric relationship between the brightness of the subject (33) due to its flash illumination and the scanning time of the shutter (26), the inverse of this parametric relationship constituting the timewise variation in the exposure aperture area of the shutter (26).

2. Apparatus according to claim 1 wherein said relationship between said time period and range is linear, and the exposure aperture area varies as the square of the time during scanning.

3. Apparatus according to claim 1 wherein the ranging means includes an integrator (28) the output of which is representative of the range of the subject (33) and which begins to integrate in response to actuation of the scanning shutter (26), and wherein the means for firing the flash unit includes a trigger circuit (46) that fires the flash unit when the output of said integrator (28) reaches a predetermined trigger level.

4. Apparatus according to claim 3 wherein said integrator (28) has a resistor (32) the value of which is directly related to the range of the subject (33).

5. Apparatus according to claim 4 wherein the value of said resistor (32) is set in accordance with the range of the subject (33).

6. Apparatus according to claim 3 wherein the range means (30) includes a photodetector (74) responsive to light from the subject (33) for modifying the output of the integrator (28) in accordance with ambient light.

7. Apparatus according to claim 1 including manually operable means (50), the means for actuating the shutter (26) being responsive to operation of said manually operable means for actuating the shutter to produce first light therethrough after a first predetermined time delay, and wherein said ranging means (30) includes an integrator circuit (28) having an electrical element (72) in parallel with a photodetector (74) exposed to light from the subject (33), and a trigger circuit (46) responsive to the output of the integrator (28) for firing the flash (48) and closing the shutter (26) when the integrator (28) output reaches a predetermined trigger level, said integrator circuit (28) being energized, subsequent to operation of said manually operable means (50), after a period of time related to the range of the subject (33), and said electrical element (72) of said integrator (28) having a value such that the output of said integrator (28) will reach said predetermined trigger level in a second time delay equal to said first time delay such that, when the ambient light on the photodetector (74) is negligible, said flash (48) is fired after a time equal to the sum of said first predetermined time delay and said range related time interval.

8. Apparatus according to claim 7 wherein the range means (30) includes a sonic rangefinder which transmits a burst in response to operation of the manually operable means (50), and which processes an echo from the subject such that receipt of the echo initiates said integrator circuit (28).

9. A method for recording the image of a subject illuminated at least in part by actuation of a flash unit to produce a pulse of transient illumination and employing a scanning shutter arrangement actuatable to initiate an exposure interval during which said shutter

arrangement at least initially provides progressively increasing aperture values through which scene light from said subject is transmitted to a photosensitive recording medium, said method comprising the steps of:

determining the distance between said subject and said flash unit and defining a time interval related to said distance;

driving said shutter arrangement at a scanning rate selected in accordance with said relationship between subject distance and time; and

actuating said flash unit to produce said pulse of illumination following said actuation of said shutter after a time period related to said time interval so that said pulse is automatically synchronized with a narrow range of aperture values selected in accordance with subject distance.

10. The method of claim 9 including the steps of determining the ambient light in the scene and reducing said time period proportionately thereto so that said pulse of illumination is synchronized with a second narrow range of aperture values of smaller value than the first-mentioned range.

11. The method of claim 9 wherein said determining and defining step includes defining a range related time interval measured from a given starting time, driving said shutter such that first light thereof occurs after a time delay of a longer time as measured from said starting time than that anticipated for said range related interval, and actuating said flash unit after a time period as measured from said starting point not greater than the sum of said range related time interval and said time delay.

12. The method of claim 11 including determining the ambient light level in the scene and reducing said time period in accordance therewith to define a second time period, and actuating said flash unit after a third time period, as measured from said starting point, equal to the sum of said second time period and said time delay.

13. In a flash exposure control system for recording scene images of a subject to produce a proper exposure of a photosensitive recording medium independent of subject distance, said system having a scanning shutter arrangement actuatable for at least initially providing increasing aperture values during an exposure interval within which scene light is transmitted to the photosensitive recording medium, said shutter arrangement providing said increasing aperture values at a predetermined scanning rate such that following actuation of said shutter arrangement, progressively increasing aperture values are provided at progressively increasing time intervals following said actuation, means for producing a flash of illumination during said exposure interval to illuminate said subject with transient illumination, means for determining the distance of said subject from said flash producing means and for synchronizing the production of said flash with operation of said scanning shutter arrangement so that transient illumination reflected from said subject is transmitted through said shutter arrangement to said recording medium by a narrow range of aperture values selected in accordance with subject distance, characterized by the fact that said distance determining (30) and flash synchronizing means (28) comprises means for defining a range related time interval corresponding to subject distance and for producing said flash of illumination responsive to a lapse of a time period measured from first light of said shutter arrangement and proportional to said range related time interval to thereby produce said flash over a narrow range of aperture values automatically selected in accordance with subject distance.

14. The improvement of claim 13 wherein said distance determining and flash synchronizing means includes a rangefinder (30) which directly produces said range related time interval defined by the elapsed time between transmission of a burst of energy toward the subject and return of an echo of energy therefrom.

15. The improvement of claim 13 wherein said scanning rate is selected to provide aperture values increasing as the square with time, said range related time interval is linearly related to subject distance and said time period is directly proportional to said range related interval.

16. The improvement of claim 13 wherein said scanning rate is selected to provide aperture values increasing linearly with time and said time period is proportional to the square of the subject distance.

17. The improvement of claim 13 wherein said distance determining and flash synchronizing means includes a sonic ranging system (30) for producing a range related time interval linearly related to subject distance.

18. The improvement of claim 13 wherein said distance determining and synchronizing means additionally includes means for evaluating the ambient light level (74) in said scene and for reducing said time period in accordance with ambient scene light.

19. The improvement of claim 13 additionally including means for actuating said distance determining and synchronizing means and for then actuating said shutter to produce first light therethrough after a selected delay, and wherein said distance determining and synchronizing means includes means for actuating said flash producing means after an elapsed time, measured from said system actuation, comprised of the sum of said delay and said time period proportional to said range related interval.

20. The improvement of claim 19 wherein said distance determining and synchronizing means includes a delay circuit for producing a second time period substantially equal to said selected delay and for actuating said flash producing means at the end of said second period, and means for actuating said delay circuit at the end of said range related time interval whereby said flash fire time is substantially the sum of said selected delay and said range related time interval.

21. The improvement of claim 20 additionally

including means for reducing said second time period in accordance with the level of ambient scene light.

22. The improvement of claim 20 wherein said distance determining and synchronizing means includes a voltage sensitive trigger circuit for actuating said flash producing means when said trigger circuit reaches a given voltage level, said trigger circuit including a voltage summing element fed by both said delay circuit and a light sensitive network such that the actuation of said flash producing means is a function of both said subject distance and said ambient scene light level.

23. The improvement of claim 22 wherein said distance determining and synchronizing means includes a trigger circuit (46) for producing a flash fire signal to actuate said flash producing means (48), said trigger circuit including a voltage summing element fed by both a timing network and a light sensing network such that the voltage of said summing element is responsive to both networks, and said timing network provides a timing function related to said subject distance.

24. A method for recording the image of a subject illuminated at least in part by actuation of a flash unit to produce a pulse of transient illumination and employing a scanning shutter arrangement actuatable to initiate an exposure interval during which said shutter arrangement at least initially provides progressively increasing aperture values through which scene light from said subject is transmitted to a photosensitive recording medium, said method comprising the steps of:

transmitting a burst of energy toward said subject and receiving an echo therefrom so as to define a time interval related to subject distance;

driving said shutter arrangement at a scanning rate selected in accordance with the relationship between subject distance and time; and

actuating said flash unit upon receipt of said echo to produce said pulse of illumination, following said actuation of said shutter, after a time period related to said time interval so that said pulse is automatically synchronized with a narrow range of aperture values selected in accordance with subject distance.

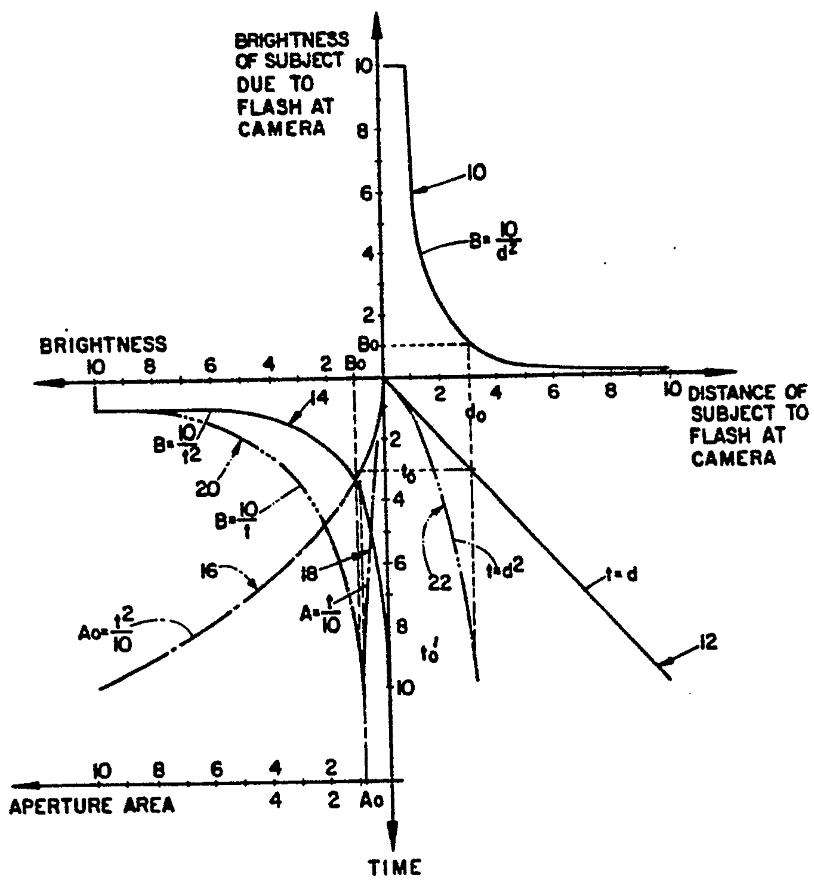
BRIGHTNESS OF SUBJECT DUE TO FLASH AT CAMERA
BRIGHTNESS
DISTANCE OF SUBJECT TO FLASH AT CAMERA
APERTURE AREA
TIME
B = 10/d²
B = 10/t2
B = 10/t
A = t/10
Ao = t2/10
t = d2
t = d
Bo
do
to
Ao
10
12
14
16
18
20
22

FIG. 1

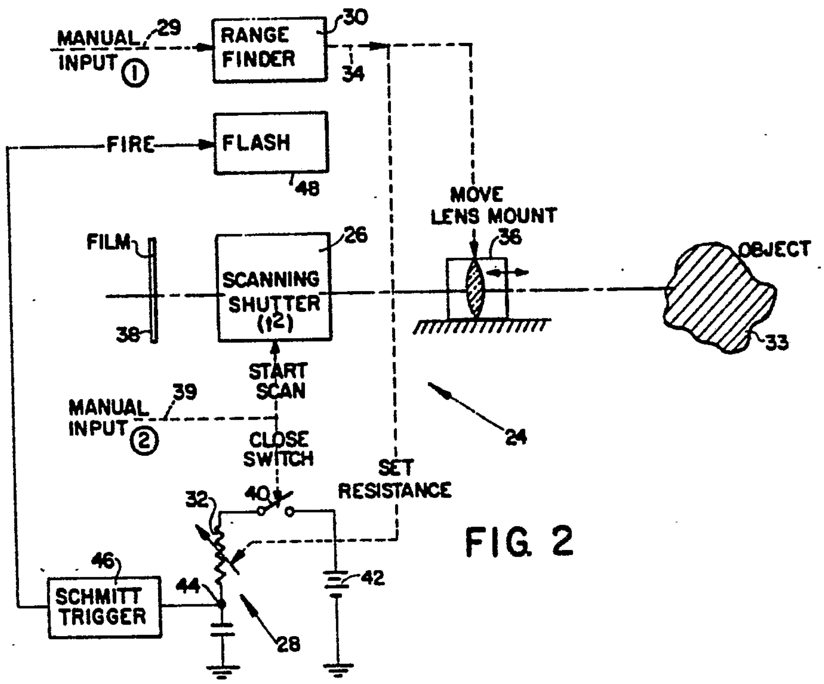
MANUAL INPUT ①
29
RANGE FINDER
30
34
FIRE
FLASH
48
MOVE LENS MOUNT
36
FILM
26
SCANNING SHUTTER (12)
OBJECT
38
33
START SCAN
MANUAL INPUT ②
39
CLOSE SWITCH
24
SET RESISTANCE
32
40
46
44
42
SCHMITT TRIGGER
28

FIG. 2

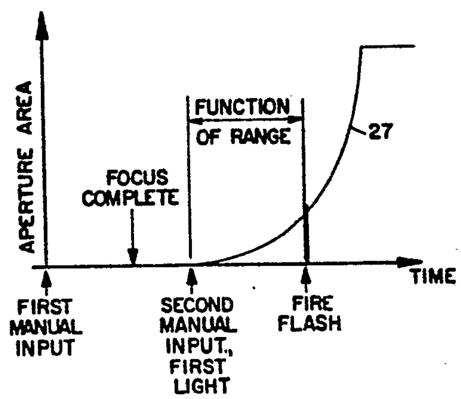
APERTURE AREA
FUNCTION OF RANGE
27
FOCUS COMPLETE
TIME
FIRST MANUAL INPUT
SECOND MANUAL INPUT, FIRST LIGHT
FIRE FLASH

FIG. 3

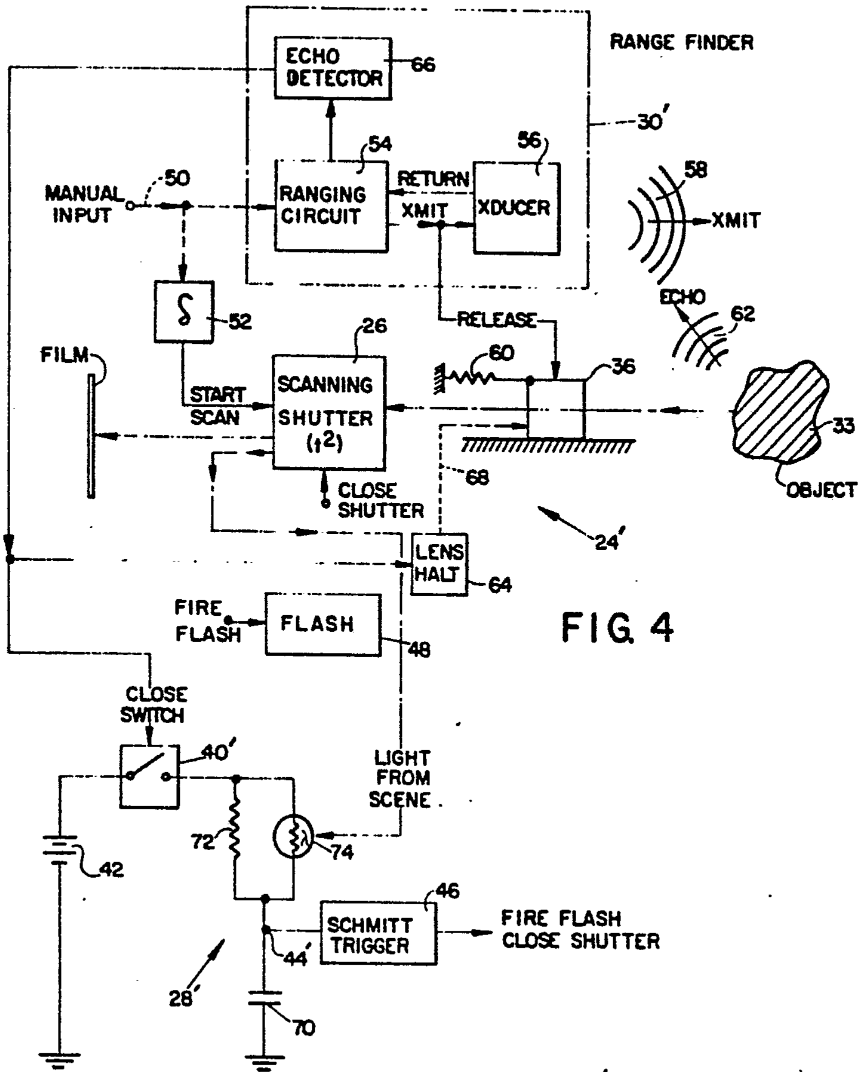
RANGE FINDER
ECHO DETECTOR
66
30'
54
56
58
MANUAL INPUT
50
RANGING CIRCUIT
RETURN
XMIT
XDUCER
XMIT
ECHO
62
52
RELEASE
26
FILM
60
36
START SCAN
SCANNING SHUTTER (t^2)
33
CLOSE SHUTTER
68
OBJECT
24'
LENS HALT
64
FIRE FLASH
FLASH
48
CLOSE SWITCH
40'
LIGHT FROM SCENE
72
74
42
46
SCHMITT TRIGGER
FIRE FLASH CLOSE SHUTTER
44'
28'
70

FIG. 4

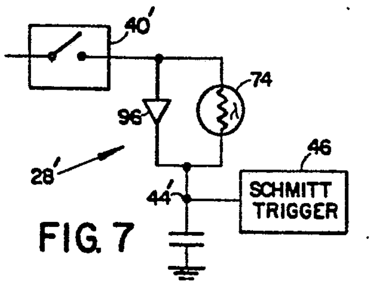
40'
74
96
28'
46
44'
SCHMITT TRIGGER

FIG. 7

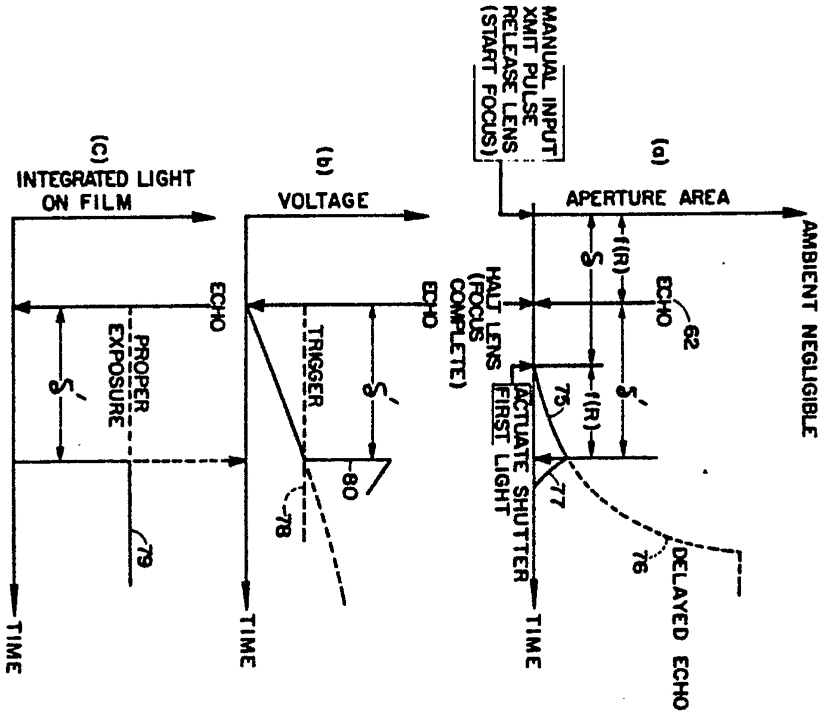
MANUAL INPUT
XMIT PULSE
RELEASE LENS
(START FOCUS)
(a)
APERTURE AREA
AMBIENT NEGLIGIBLE
f(R)
δ
ECHO
62
HALT LENS
(FOCUS
COMPLETE)
75
ACTUATE SHUTTER
FIRST LIGHT
δ'
77
76
DELAYED ECHO
TIME
(b)
VOLTAGE
ECHO
TRIGGER
80
78
(c)
INTEGRATED LIGHT
ON FILM
PROPER
EXPOSURE
79

FIG. 5

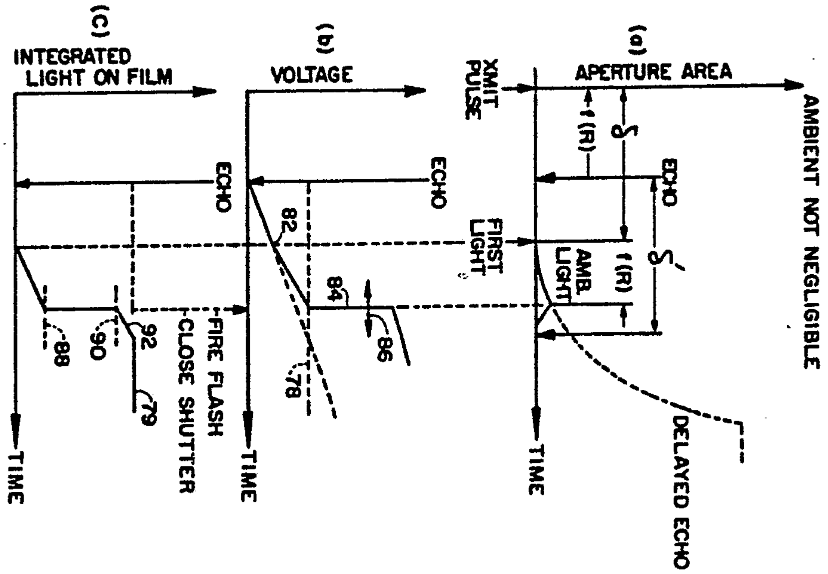
(a)
APERTURE AREA
AMBIENT NOT NEGLIGIBLE
XMIT
PULSE
f(R)
δ
ECHO
FIRST
LIGHT
AMB.
LIGHT
δ'
DELAYED ECHO
TIME
(b)
VOLTAGE
ECHO
82
84
86
78
(c)
INTEGRATED
LIGHT ON FILM
88
90
92
79
FIRE FLASH
CLOSE SHUTTER

FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No PCT/US79/00252

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

US. CL. 354/27, 29, 30, 33, 34, 60F, 137, 139

INT. CL. G03B 7/10, 15/05

WO 79/00962

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	354/25, 27, 29, 30, 33, 34, 60F, 137, 139, 149, 162, 163, 195, 198

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US, A, 3972058, Published 27 July 1976, Johnson et. al.	1-24
A	US, A, 4020497, Published 26 April 1977, Ueda	1-24
A	US, A, 4047190, Published 06 September 1977, Johnson et al	1-24
A	US, A, 4063257, Published 13 December 1977, Mashimo et al.	1-24
A,P	US, A, 4149792, Published 17 April 1979, Fraser et al.	1-24

* Special categories of cited documents: [15]

"A" document defining the general state of the art

"E" earlier document but published on or after the international filing date

"L" document cited for special reason other than those referred to in the other categories

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
11 July 1979	16 AUG 1979
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	M. L. GELLNER M L Gellner

Form PCT/ISA/210 (second sheet) (October 1977)