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(54) PHOTOGRAPHIC EXPOSURE CONTROL APPARATUS

(71) We, AGFA-GEVAERT AKTIENGESELLSCHAFT, a body corporate organised according to the laws of Germany, of Leverkusen, Germany, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

The invention relates to a device for the automatic exposure control, in microfilm continuous cameras, of an orginal to be copied.

Exposure control apparatus has been proposed, for example in German Offenlegungsschrift No. 1 214 524, which has a measuring station for measuring the reflectance value of the original to be photographed, an illuminating station arranged behind the measuring station, as viewed in the transport direction of the original, for the projection of the original onto a recording carrier, and means for controlling the amount of light impinging upon the recording carrier by means of a control signal obtained from the reflectance measurement. According to this disclosure, an original entering the microfilm continuous apparatus is illuminated by means of a lamp having a constant brightness, and the light reflected from the original is measured by means of a photoelectric instrument of known kind, for example, a photocell. The output signal of the photocell, which varies with the reflectance value of the original, controls a phase-cut control mechanism which in turn controls the brightness of lamps illuminating an exposure station in inverse proportion to the output signal of the photocell. The varying characteristics of the originals to be photographed are thus compensated for by changing the intensity of the exposure station illumination.

The operational efficiency of a continuous apparatus of this type is limited by the relatively low control speed of its control circuit. The phase-cut control mechanism requires about 20 ms to build up its control potential, and in addition to this there is the sluggishness of the illuminating lamps to take into account, which lamps take from about 150 to 250 ms to attain the requisite intensity. Hence there is a relatively low maximum admissible run-through speed for the originals, or else a relatively large minimum required distance between two successive copines.

A further disadvantage of a continuous camera which takes account of the varying reflectance values of the originals to be copied by controlling the brightness of the illuminating lamps, is that the exposure station illuminating lamps may vary in their colour spectrum owing to a variation in temperature, at different intensities, and this, particularly in the colour filming of originals, can have detrimental effects.

The present invention is concerned with the provision of an exposure control device, for a microfilm continuous camera, which has a shorter response time in compensating for the different reflectance values in originals to be exposed for copying, which is suitable for use in colour copying of originals, and which is preferably also operationally reliable and cost saving.

The invention provides exposure control apparatus for a microfilm continuous camera, which comprises means for measuring the reflectance value of an original to be exposed for coyping, an exposure station for the original arranged to be illuminated by a light source of constant intensity, a variable aperture diaphragm for the exposure station, means for measuring the diaphragm aperture effective in the exposure light path, and means for controlling the value of the diaphragm aperture effective in the exposure light path in accordance with the measured reflectance value and the measured value of the said effective diaphragm aperture, for each original to be exposed.

Preferably, the reflectance value measuring means and the means for measuring the diaphragm aperture effective in the exposure light path are arranged to produce signals corresponding to the measured reflectance value and the measured diaphragm aperture, respectively, and there is provided means for forming the product of these two signals and for comparing this product with a predetermined value, the diaphragm aperture control means being arranged to control the diaphragm aperture in accordance with the result of the said comparison, and, advantageously, the diaphragm aperture control means is arranged so to control the value of the diaphragm aperture that the said product is caused to become equal to the said predetermined value.

The amount of light Q impinging on the recording carrier to ensure its optimum exposure has a specific constant value, which we shall call Q_0. This amount of light Q depends on the reflectance value, ρ, of the original to be copied, and on the value of the diaphram aperture, which we shall call b, which is effective in the exposure light path. Q is directly proportional to both ρ and b, that is, $Q \propto b \times \rho$. Since the amount of light incident on the recording carrier in the camera is required to be constant, the product $b.\rho$ must also be a constant for each exposure. With an increased reflectance ρ of the original, the diaphragm aperture b must therefore be reduced to such an extent that the product of the diaphragm aperture and the reflectance value remains constant.

The means for comparing the product $b.\rho$ with a predetermined value corresponding to the desired optimum value Q_0 may, for example, be a difference amplifier connected in series with and behind a multiplier which forms the product $b.\rho$. From the difference between theoretical value Q_0 and the actual value of $b.\rho$ a difference signal can now be produced which, after appropriate power amplification, can be used for subsequently controlling the value of the diaphragm aperture.

Preferably, there is provided store means arranged to register and store a signal, corresponding to the reflectance value of an original to be exposed, transmitted from the reflectance value measuring means, the arrangement being such that the store means registers and stores only one signal from the reflectance value measuring means for each original to be exposed, and there is advantageously provided a light barrier across the transport path of originals to be exposed, and the store means is arranged to register and store the signal from the reflectance value measuring means when the light barrier is broken.

As a result of the control signal being stored only once for each original, a time constant control signal is available for projecting an original, so that a guarantee is given that the diaphragm value does not change constantly, during the filming of an original, in an attempt to compensate for varying brightness in the original, and the undesirable formation of striations on the film is hence suppressed. Moreover, since the control signal obtained from the reflectance measurement of a specific original is still available right up to the storing of the reflectance value of the following original, and the diaphragm aperture need not be changed during this length of time from the exposure of the last original, it is only necessary for the diaphragm aperture to be adjusted from original to original depending on the preceding value, and not, as is usual in other known apparatuses with diaphragm control mechanisms, controlled afresh by a specific, constant initial value at each original. An especially power-saving and rapid control device is thereby produced.

Preferably, the variable aperture diaphragm is a rotary diaphragm and the diaphragm aperture control means comprises a rotary magnet. In this case, the diaphragm is mounted so that it is free from friction and has as low an inertia as possible, and is displaced according to the principle of a rotary coil measuring instrument.

According to a further advantageous feature of the invention, for measuring the diaphragm aperture peculiar to, or effective in the exposure light path, there is placed in front of the diaphragm a lamp of a constant brightness, and behind the diaphragm a light-sensitive element which measures the light passing through the diaphragm from this lamp and produces an output signal analogous to this amount of light. With this arrangement, the lamp should be so arranged relative to the diaphragm that at every angular position of the rotary diaphragm the amount of light passing through the diaphragm from the lamp is proportional to the portion of the light in the exposure beam passing through the aperture of the diaphragm to a camera.

Preferably, there is provided for the means for measuring the reflectance value and for the exposure station, a common illuminating system. This guarantees that the reflectance value of the original in the exposure station, which may possibly be dependent on the colour temperature of the exposure station illuminating system, is also the same at the reflectance value measuring means.

A further advantage ensues, particularly from the point of view of cost and space-saving, if a common illuminating system is provided for the exposure station, for the means for measuring the reflectance value, and for the diaphragm aperture measuring means.

The invention also provides a method of controlling the exposure of a microfilm original to be photographed using a microfilm continuous camera, which method comprises measuring the reflectance value of the original, advancing the original to an exposure station for illumination by a light source of constant intensity and subsequent exposure through the aperture of a variable aperture diaphragm, measuring the diaphragm effective in the exposure light path, and controlling the said diaphragm aperture effective in the exposure path in accordance with the measured reflectance value and the measured value of the said effective diaphragm aperture.

Apparatus constructed in accordance with, and a method according to, the invention will now be described, by way of example with reference to the accompanying drawings, in which:—

Figure 1 is a block diagram of exposure control apparatus, showing the relationship between the various functional components; and

Figure 2 is an electric circuit diagram corresponding to the block diagram shown in Figure 1.

With reference to the drawings, and initially to Figure 1, there is provided a transport path 1 for microfilm originals indicated generally by the reference numeral 2. A light source 3, which is supplied with a constant d.c. voltage, illuminates an original 2 in the region 4 of the transport path for the purpose of measuring its reflectance value, and in the region 5 of the transport path, at an exposure station. Between the exposure station 5 and a camera unit 6 there is located a rotary, apertured diaphragm 7, which may be rotated about its axis by means of a rotary magnet 8 in order to control the exposure of recording material in the camera unit by controlling the effective value of the diaphragm aperture in the exposure light path.

Some light from the light source 3 passes directly through the diaphram aperture of the rotary diaphragm 7 to a station 9 comprising a photoelectric detector. When the aperture of the diaphragm 7 effective in the light path from the source 3 to the photoelectric detector 9 is at its maximum value, that is, when the aperture is fully "open" with respect to this direction, the luminous flux through the diaphragm aperture is $\emptyset_3$. On rotation of the diaphragm 7, so that it is inclined to the direction of light travelling from the source 3 to the photoelectric detector 9, the flux through the aperture of the diaphragm which reaches the photoelectric detector is reduced by a factor b, which is the value of the effective diaphragm aperture in the direction of illumination of the photoelectric detector, to $b.\emptyset_3$. With suitable geometric arrangement of the light source 3 with respect of the diaphragm 7, the photoelectric detector 9, and the exposure station 5, the luminous flux $\rho.\emptyset_2$ in the projection or exposure light path is reduced at any given angular position of the rotary diaphragm 7 by the same factor b as the flux $\emptyset_3$ is reduced with respect to the photoelectric detector 9, so that the output signal of the photoelectric detector is analogous to the effective diaphragm aperture effective in the exposure light path. ρ is the reflectance value of the original.

Viewed in the direction of transport of originals 2 along the transport path 1, a light barrier 10 is arranged across the transport path in front of the exposure station 5. When the leading edge of an original 2 passing along the transport path 1 breaks the light barrier 10, a signal from the light barrier apparatus causes the actuation, or switching in, of a monostable sweep stage 11. The resultant short output signal from the sweep stage 11 causes the momentary reflectance value of the original, measured in the region 4 of the transport path 1 by a reflectance measuring station 12, to be registered and stored in an analogue store 13.

An output signal from the analogue store 13, corresponding to the registered reflectance value, which, for convenience, we shall refer to as ρ, is transmitted to a multiplier 14, where it is multiplied with a signal from the photoelectric detector 9 which is analogous to the current effective diaphragm aperture b of that moment, and the multiplier 14 transmits an output signal analogous to the variable product $\rho.b$. The output from the multiplier 14 is fed to one input of a differential amplifier 15 and a signal corresponding to the theoretical value Q_o of an optimum exposure of the copying material in the camera unit 6 is fed to the other input of the amplifier. The current value of ρ.b. is thus compared with the theoretical, desired value of this product, Q_o. The output signal of the differential amplifier 15, corresponding to the difference between ρ.b. and Q_o, is amplified in a power amplifier 16. The output from the power amplifier 16 is fed to the rotary magnet 8 attached to the axis of rotation of the balanced rotary diaphragm 7, and a finite output signal from the power amplifier 16 causes the rotary magnet to rotate in such a way that the consequent rotation of the diaphragm alters the value b to tend to reduce the difference between the signals corresponding to ρ.b and Q_o, as determined by the differential amplifier 15. When the two signals at the input of the amplifier 15 have become equal, and the outputs from the differential amplifier and the power amplifier 16 thus reduced to zero, the rotary magnet 8, and hence the diaphragm 7, becomes stationary. The time taken for the rotary diaphragm 7 to be adjusted to bring the value of ρ.b equal to the desired value Q_o is in the region 15 ms.

The rotary diaphragm 7 is mounted so that it is free from mechanical restoring forces.

The angular position of the diaphragm 7 thus set is retained until the next original to be exposed in the exposure station 5 passes through the light barrier 10 and a new reflectance value is thereby registered in the store 13.

The construction and operation of the electric circuit comprising the exposure control apparatus of which the block diagram of Figure 1 is a functional representation, will now be described with reference to Figure 2.

The light barrier 10 is seen in Figure 2 to comprise a light transmitter 50 and a photo-transistor 51, whose emitter is earthed and whose collector is connected to a supply of +15 volts *via* a resistor 52. Between the photo-transistor 51 and the resistor 52 there is connected a monostable sweep stage 53 whose output is connected *via* a Zener diode 54 and a resistor 55 both to the base of a transistor 56, and *via* a resistor 58, to a +15 volt supply. The emitter of the transistor 56 is also connected to a supply of +15 volts and its collector is connected *via* a resistor 57 to a supply of −30 volts. The collector of the transistor 56 is also connected *via* a conductor element 59 and through the intermediary of a diode 60 to the gate of a field effect transistor 61.

A photo-element 62 for receiving light reflected from an original in order to ascertain its reflectance value ρ, is connected to the inverting input of an operational amplifier 63, the non-inverting input of which is earthed. The output of the operational amplifier 63 is connected back, *via* a resistor 64, to its own inverting input. A potentiometer 65 is connected across the operational amplifier 63. The non-inverting input of a second operational amplifier 66, which is also provided with a potentiometer 67, is connected to the output of the operational amplifier 63. The output of the operational amplifier 66 is connected *via* a resistor 167 to the source electrode of the field effect transistor 61.

The source and the gate of this field effect transistor are connected together through the intermediary of a resistor 68. The drain electrode of the field effect transistor 61 leads to the gate of a further field effect transistor 69, whose drain is connected to a supply of +15 volts and whose source is connected to a supply of −15 volts *via* a resistor 70. A storage capacitor 71 has one terminal earthed and the other terminal connected between the drain of the field effect transistor 61 and the gate of the field effect transistor 69. The source of the field effect transistor 69 is connected to the inverting input of the operational amplifier 66 *via* a conductor element 72.

The source of the field effect transistor 69 is also connected, *via* a resistor 73, to the inverting input of a third operational amplifier 74 and, *via* a resistor 75, to the output of the amplifier 74. The inverting input of the operational amplifier 74 is earthed *via* a resistor 76. The non-inverting input of the operational amplifier 74 is earthed *via* a resistor 77. A potentiometer 79 is connected *via* a resistor 78 to the non-inverting input of the operational amplifier 74.

A photo-element 80, which is part of the photo-electric detector 9 for measuring the value of the aperture of the diaphragm 7, is connected to the inverting input of a fourth operational amplifier 81, the non-inverting input of which is earthed. The output of the operational amplifier 81 is counter-coupled to its inverting input *via* a resistor 82. A potentiometer 83 is connected across two further inputs of the operational amplifier 81. The output of the operational amplifier 81 is connected *via* a conductor element 84 and through a resistor 85 and a potentiometer 86, to the third operational amplifier 74.

The output of the operational amplifier 74 is connected *via* a resistor 88 to a potentiometer 89, and is also directly connected to the inverting input of a fifth operational amplifier 87. The output of the operational amplifier 87 is counter-coupled *via* a resistor 90 to its inverting input, and the non-inverting input is earthed. Two further inputs of the operational amplifier 87 have a potentiometer 91 connected across them. The output of the operational amplifier 87 leads *via* a resistor 92 to the inverting input of a sixth operational amplifier 93. The non-inverting input of the operational amplifier 93 is earthed *via* a resistor 94. Parallel to this resistor 94 there are connected in series a potentiometer 95 and a resistor 96. The output and the inverting input of the operational amplifier 93 are coupled together *via* a resistor 97.

The output of the operational amplifier 93 leads to a power amplifier comprising two pairs of transistors, 99 and 100, and 101 and 102, respectively, each pair of transistors being disposed in a Darlington circuit arrangement. A resistor 104 is connected at one end to a supply of +15 volts and its other end leads, *via* diodes, 105, 106, 107 and 108, and through a resistor 109, to a supply of −15 volts. The collectors of the transistors 100 and 102 are connected to the positive and negative poles, respectively, of the voltage source. The base of the transistor 99 is connected between the resistor 104 and the diode 105 to the conductor element joining the two resistors 104 and 109, and the base of the transistor 101 is connected to the conductor element between the diode 108 and the resistor 109. The output of the operational amplifier 93 is connected *via* a resistor 98 to that portion of the conductor element between the diodes 106 and 107. A capacitor 111 joins this portion of the conductor element, between diodes 106 and 107, to the emitters of the transistors 100 and 102, which are connected to each other. A conductor element 110 connects the emitters of the transistors 100 and 102 to the coil of the rotary magnet 8.

The method of operation of the above-described circuit is as follows:

The output of the monostable sweep stage 53 normally lies at H-signal (about 14.5 volts). As a result of this, the reversing transistor 56 becomes blocked so that about −30 volts is applied to its collector. *Via* the diode 60, the gate of the field effect transistor 61 is switched in, as a re-sult of which this field effect transistor also becomes blocked. The voltage stored at the storage capacitor 71 (which corresponds to the reflectance value of the original to be exposed for copying is available at the source of the field effect transistor 69.

If the leading edge of an original passing along the transport path 1 now breaks the light barrier 10, then the photo-transistor 51 is blacked out and become blocked. The collector voltage rises to +15 volts, and the output of the monostable sweep stage 53 consequently delivers a negative pulse (about +0.5 volts) of about 0.8 ms duration. The transistor 56 is switched through during this pulse and the potential at its collector thereby rises from −30 volts to about +14.5 volts. As a result of this, the field effect transistor 61 becomes conductive. The light reflected by that portion of the original in the region 4 of the transport path, and subsequently incident on the photo-element 62, produces a current in this photo-element which charges the storage capacitor 71 *via* the current-voltage transformer 63, the operational amplifier 66, the resistor 67, and the field effect transistor 61, which is now conductive. The capacitor 71 now charges up until the voltage at the source electrode of the field effect transistor 69 has reached a value equal to that at the non-inverting input of the operational amplifier 66. When the negative output of the monostable sweep stage 53 has faded out, the transistor 61 becomes blocked again so that the voltage at the capacitor 71 remains in store and is again available as an output signal at the source of the field effect transistor 69.

The output signal from the source of the field effect transistor 69 is multiplied in the multiplier, comprising the operational amplifier 74, with the control signal produced by the photo-element 80, which corresponds to the value of the diaphragm aperture. (The potentiometers 79, 86 and 89 serve to balance the output cur-rent of the multiplier 74 when the multiplier does not switch on).

The output current of the multiplier 74, analogous to the product of the measured reflectance value of an original and the measured diaphragm aperture, is converted by the current-voltage transformer comprising the operational amplifier 87 into a proportional voltage, which is compared in the operational amplifier 93 with the voltage corresponding to the theoretically desired value, Q_o, of the product ρ.b, which is set at the potentiometer 95. If there is a difference between these two voltages, the operational amplifier 93 switches in the following power amplifier, which provides current for moving the rotary magnet.

In the power amplifier arrangement, a transverse current flows through the resistor 104, the diodes 105 to 108, and the resistor 109. This transverse current switches in the transistors 99 to 102, arranged in respective Darlington circuit formations, by means of the falling voltage at the diodes, and the transistors 99 and 102 are switched in to such an extent that no collector current flows at all. If the operational amplifier 93 delivers, for example, a positive output voltage owing to a corresponding measured difference between the signals analogous to Q_0 and ρb, then the potential shift across the diode arrangement is likewise in a positive direction, and the base of the transistor 99 is switched in. As a result, the transistor 100 also becomes conductive so that a control current can flow and the rotary magnet 8 rotates in the appropriate direction. The rotary diaphragm 7, coupled to the rotary magnet 8, is thereby displaced, and the illumination of the photo-element 80 is consequently altered owing to the change in the value of the diaphragm aperture effective in the direction of illumination of the said photo-element.

The rotary diaphragm continues to be displaced until such time as the signal corresponding to the product of the measured reflectance value ρ and the measured diaphragm value b equals the signal corresponding to the desired, theoretical value, Q_0, set at the potentiometer 95.

The potentiometers 65, 67, 83 and 91 serve to offset-balance the operational amplifiers 63, 66, 81 and 87 respectively.

WHAT WE CLAIM IS:

1. Exposure control apparatus for a microfilm continuous camera, which comprises means for measuring the reflectance value of an original to be exposed for copying, an exposure station for the original arranged to be illuminated by a light source of constant intensity, a variable aperture diaphragm for the exposure station, means for measuring the diaphragm aperture effective in the exposure light path, and means for controlling the value of the diaphragm aperture effective in the exposure light path in accordance with the measured reflectance value and the measured value of the said effective diaphragm aperture, for each original to be exposed.

2. Apparatus as claimed in claim 1, wherein the reflectance value measuring means for the means for measuring the diaphragm aperture effective in the exposure light path are arranged to produce signals corresponding to the measured reflectance value and the measured diaphragm aperture, respectively, and there is provided means for forming the product of these two signals and for comparing this product with a predetermined value, the diaphragm aperture control means being arranged to control the diaphram aperture in accordance with the result of the said comparison.

3. Apparatus as claimed in claim 2, wherein the diaphragm aperture control means is arranged so to control the value of the diaphragm aperture that the said product is caused to become equal to the said predetermined value.

4. Apparatus as claimed in any one of claims 1 to 3, wherein the means for measuring the diaphragm aperture comprises light sensitive means located to one side of the diaphragm and arranged to receive light passing through the diaphragm aperture from a source of constant intensity located in opposed relationship to the light sensitive means on the other side of the diaphragm, the light sensitive means being so arranged with respect to the diaphragm that the diaphragm aperture value effective for the light sensitive means is proportional to the value of the diaphragm aperture effective in the exposure light path.

5. Apparatus as claimed in any one of claims 1 to 4, wherein there is provided a transport path through the apparatus for originals to be exposed for copying, the exposure station being located downstream of the means for measuring reflectance value along the transport path.

6. Apparatus as claimed in any one of claims 1 to 5, wherein there is provided store means arranged to register and store a signal, corresponding to the reflectance value of an original to be exposed, transmitted from the reflectance value measuring means, the arrangement being such that the store means registers and stores only one signal from the reffectance value measuring means for each original to be exposed.

7. Apparatus as claimed in claim 6, wherein there is provided a light barrier across the transport path of originals to be exposed, and the store means is arranged to register and store the signal from the reflectance value measuring means when the light barrier is broken.

8. Apparatus as claimed in any one of claims 1 to 7, wherein the diaphragm aperture is arranged to remain in the state which the diaphragm aperture control means has caused it to adopt for the exposure of an original having a particular reflectance value, until further action of the control means casues it to change to a different state appropriate to the subsequent exposure of a further original.

9. Apparatus as claimed in any one of claim 1 to 8, wherein the variable aperture diaphragm is a rotary diaphragm and the diaphragm aperture control means comprises a rotary magnet.

10. Apparatus as claimed in any one of claims 1 to 9, which includes a light source of constant intensity arranged to illuminate both the exposure station and that portion of the transport path of an original to be exposed at which the reflectance value measuring means is ar-

ranged to measure the reflectance value of an original to be exposed.

11. Apparatus as claimed in claim 4 and claim 10, wherein the said light source of constant intensity is arranged on the opposite side of the diaphragm in opposed relationship to the light sensitive means of the diaphragm aperture measuring means.

12. Exposure control apparatus for a microfilm continuous camera substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

13. A method of controlling the exposure of a microfilm original to be photographed using a microfilm continuous camera, which method comprises measuring the reflectance value of the original, advancing the original to an exposure station for illumination by a light source of constant intensity and subsequent exposure through the aperture of a variable aperture diaphragm, measuring the diaphragm aperture effective in the exposure light path, and controlling the said diaphragm aperture effective in the exposure light path in accordance with the measured reflectance value and the measured value of the said effective diaphragm aperture.

14. A method as claimed in claim 13, which comprises producing signals corresponding to the measured reflectance value and the measured diaphragm aperture, respectively, forming the product of these two signals, comparing this product with a predetermined value, and controlling the diaphragm aperture in accordance with the result of the said comparison.

15. A method as claimed in claim 14, which comprises so controlling the value of the diaphragm aperture that the said product is caused to become equal to the said predetermined value.

16. A method of controlling the exposure of microfilm original substantially as hereinbefore described with reference to the accompanying drawings.

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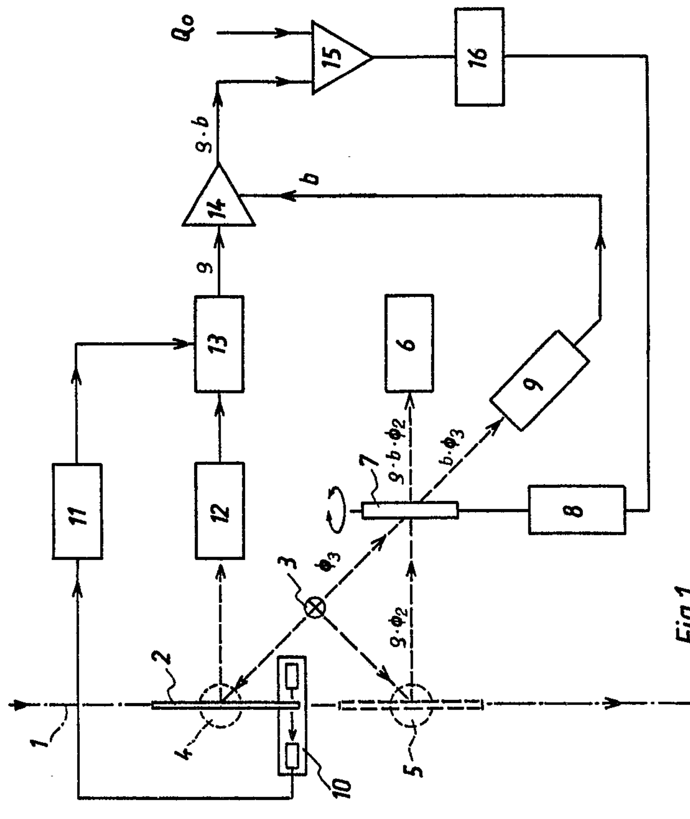

Fig.1

1571818 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

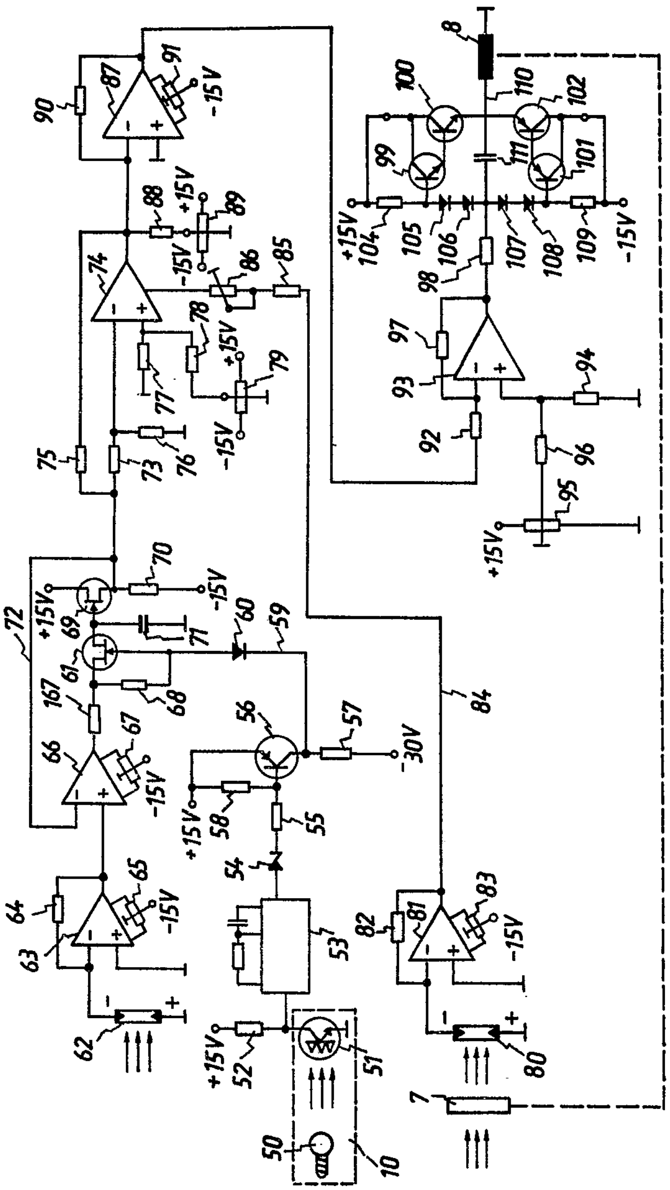

Fig.2