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[54] FEEDBACK SYSTEM FOR CONTROLLING IMAGE LIGHT ENERGY IN ELECTROSTATIC PHOTOCOPIERS

[72] Inventors: Robert Clark Du Bois, Fairfield; Wayne H. Miller, Stamford, both of Conn.

[73] Assignee: Pitney-Bowes, Inc., Stamford, Conn.

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[51] Int. Cl. G03b 27/78

[58] Field of Search 355/68, 69, 35, 38, 11, 83

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Primary Examiner—Samuel S. Matthews

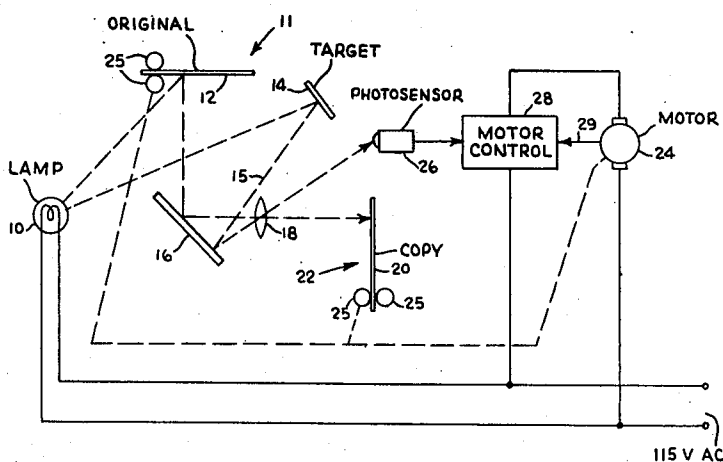
Assistant Examiner—Monroe H. Hayes

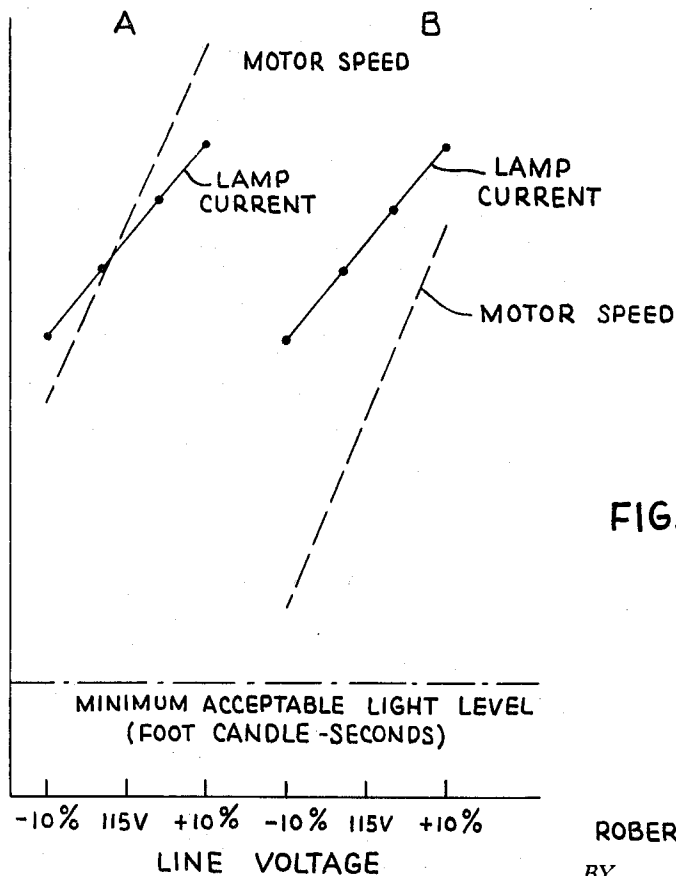
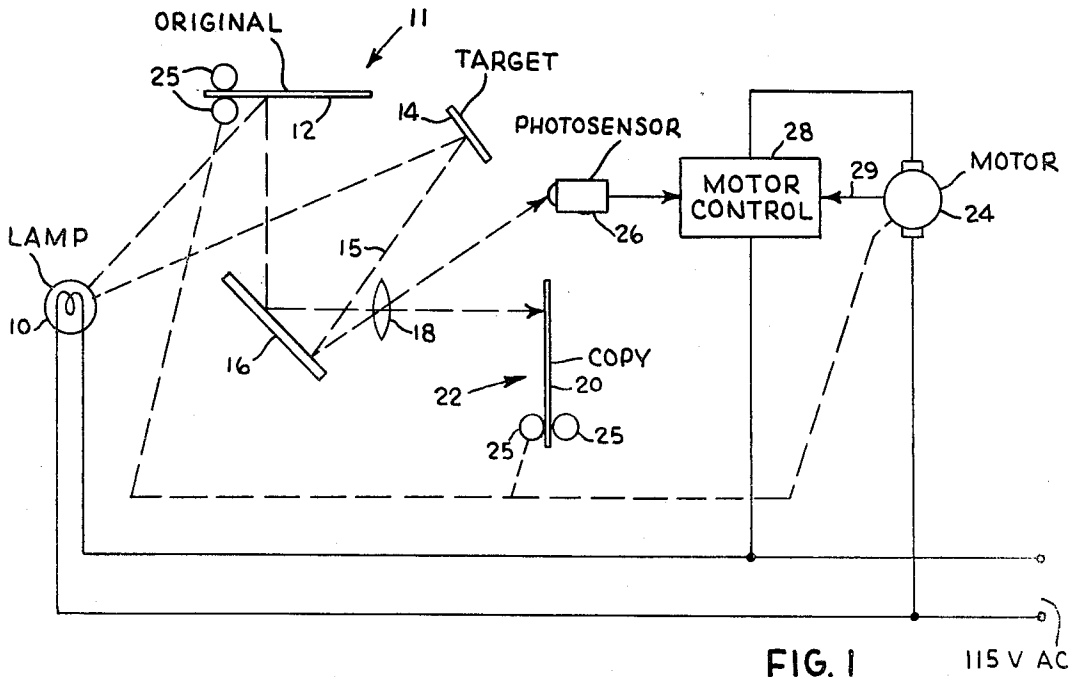
Attorney—William D. Soltow, Jr., Albert W. Scribner, Martin D. Wittstein and Louis A. Tirelli

[57] ABSTRACT

A control system for electrostatic photocopiers monitors the light level of a reference beam. The beam is projected at the imaging station from the projection lamp by way of the illuminating station and the image projection optics to derive a feedback signal for regulating either the copy sheet feed rate through the imaging station or the lamp current to compensate for lamp voltage variations, lamp aging, dirty projection optics, etc.

2 Claims, 6 Drawing Figures





INVENTORS
ROBERT CLARK DUBOIS
BY WAYNE H. MILLER

Markus P. Wittstein

ATTORNEY

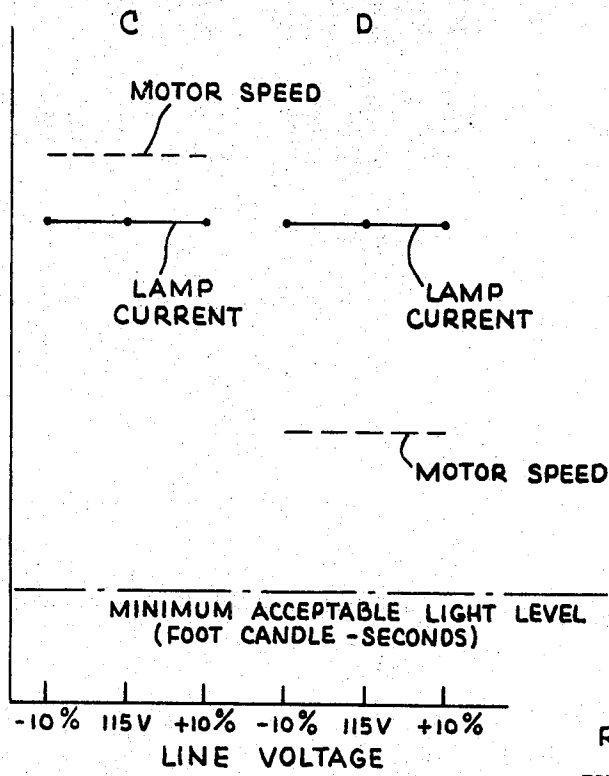
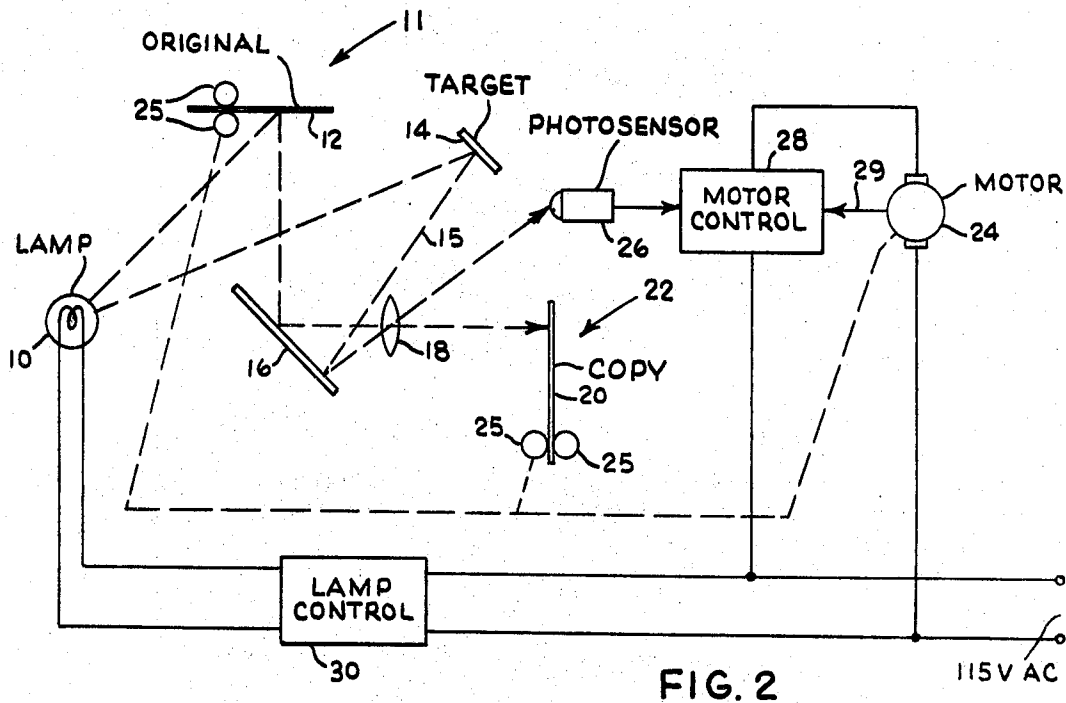
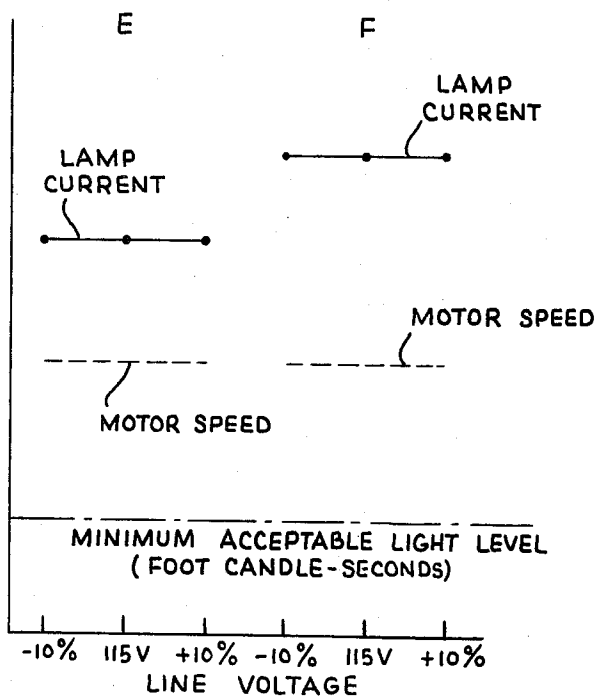
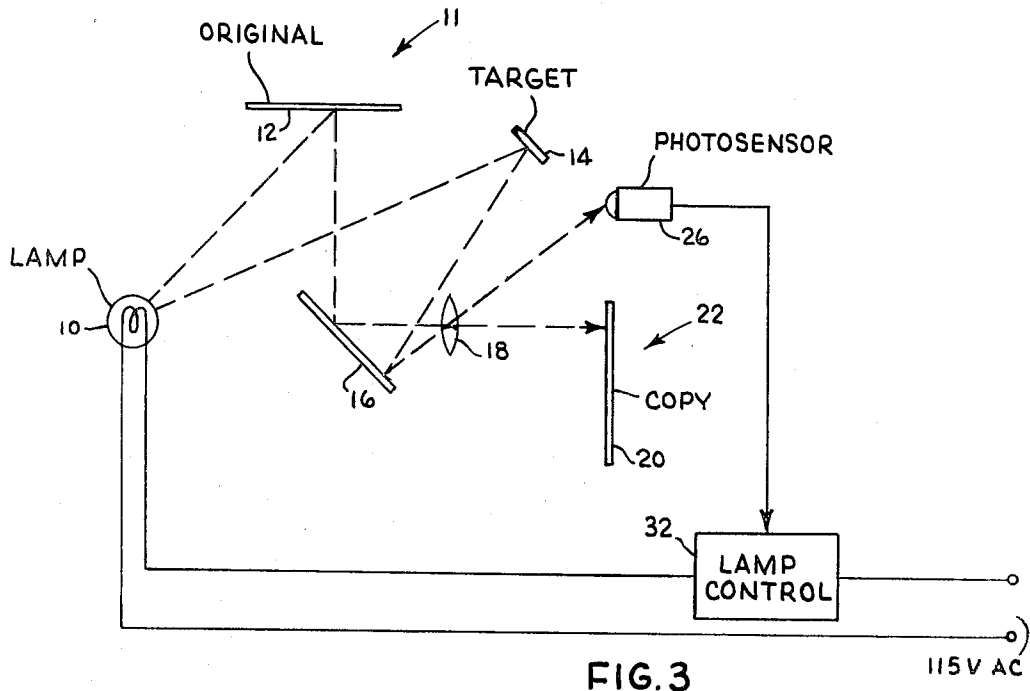


FIG. 5

INVENTORS
ROBERT CLARK DUBOIS
WAYNE H. MILLER
BY

Mark D. Wattstein

ATTORNEY



INVENTORS
ROBERT CLARK DUBOIS
WAYNE H. MILLER
BY

Mark P. Wettstein
ATTORNEY

FEEDBACK SYSTEM FOR CONTROLLING IMAGE LIGHT ENERGY IN ELECTROSTATIC PHOTOCOPIERS

BACKGROUND OF THE INVENTION

In one type of office copying machine an image of the indicia on an original document is projected by means of visible light onto the surface of charged photoconductive copy paper to form a latent electrostatic image. The latent image is then developed and fixed to produce the finished copy. In machines of this type it is important to insure that the image light energy to which the copy paper is exposed is of the proper magnitude to yield good copy. Although copier machines are of course designed to provide the proper level of image light energy at the copy paper, in practice several factors can and do interfere with the maintenance of this light level.

One factor is that over an extended period of use the optical system of the copier accumulates dirt and other contaminants which reduce the intensity of image light below the level it should be for good copy. This of course means that as the copier ages the copies produced will become progressively more underdeveloped unless compensation is somehow made for the dirty optics.

Another factor is the variation in lamp voltage which a copier experiences even under the best of conditions. For example, if the lamp voltage decreases by 10 percent (e.g., from 115v to 103.5v), the light output of the lamp will decrease by about 30 percent.

Several methods have been used to overcome the problems of dirty optics and undervoltage. In some machines a lamp is employed which has a light output considerably greater than needed under the best conditions; for example, twice the minimum light output is common. A mechanical shutter is then used to limit the light transmitted to the level needed. The disadvantages to such a system in which, in effect, light energy is thrown away are that the current requirements and heat load on the copier are far in excess of what would be needed if a more efficient use of the light could be made. This increases the cost of both manufacturing and operating the machine. In addition the necessary high current rating may prevent the use of such a copier in buildings where the wiring or fuse systems provide marginal current capacity. Such a copier also requires manual adjustment of the shutter to correct for any change in light level; this is difficult where the problem involves transient or periodic undervoltage. In any event a need for manual shutter adjustment means that the problem must first be recognized, normally by the appearance of unusable, wasted copies. These procedures are costly and result in annoying inconvenience for the users of copiers.

More recently systems have been devised to automatically adjust the shutter in response to changing light conditions. These latter systems however merely remove the element of manual control. In such an automatic shutter system a lamp having a light output greater than that needed under best conditions is still required. Accordingly the problems resulting from high current requirements and excess heating remain.

Accordingly, representative objects of the present invention are to provide a feedback control system for a photocopier which automatically regulates the available light energy to which the copy paper may be exposed in response to changing conditions, either by controlling copy feed rate through the imaging station or lamp current or both; said system being efficient, economical and reliable in use.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts which will be exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

SUMMARY OF THE INVENTION

The present invention relates to regulating the total light energy available at the imaging station of an electrostatic

photocopier as a means of compensating for lamp voltage variations and/or dirty image projection optics, and more particularly to a feedback control system for performing such regulation.

The feedback control system in general acts to regulate the feed rate of copy paper through the imaging station and/or lamp current; the two factors at the imaging station having a direct effect on the creation of an electrostatic latent image on the copy paper. The system utilizes a sensor which monitors the light level of a reference beam transmitted from the copier lamp through the copier image projection optics to the imaging station. Thus, the reference light beam experiences the same variations which effect the total image light energy projected onto the copy paper. The sensor response, proportional to the reference beam intensity, serves as the source of a feedback signal which is used to effect compensation for spurious variations in the total image light energy available at the imaging station.

Copy feed rate regulation can be used alone or in combination with lamp voltage regulation, which maintains the lamp current at a constant value to eliminate fluctuations in its light output due to variations in line voltage. When lamp voltage regulation is used, feedback regulation of the feed rate compensates for dirty projection optics and lamp aging.

Alternatively, feedback control of the lamp excitation can be used alone in accordance with the invention. This lamp control not only regulates lamp current to compensate for variations in line voltage, but also responds to the feedback signal from the sensor to increase lamp excitation to compensate for the light attenuating effect of dirty optics.

The control system of the invention permits more efficient operation of a photocopier since copy feed rate speed and/or lamp light output may be continuously and automatically maintained at optimum levels. This eliminates among other things the waste of light energy experienced with prior art photocopiers. The system of the invention also eliminates the need and bother of having a manually adjustable mechanical shutter of the type used in many prior art photocopiers.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a schematic representation of a feedback motor control system in accordance with the invention.

FIG. 2 is a schematic representation of the feedback motor control system of FIG. 1 with the addition of a simple lamp control used to regulate lamp current.

FIG. 3 is a schematic representation of a feedback lamp control system in accordance with the invention.

FIG. 4 is a graphical representation of the operation of the system shown in FIG. 1.

FIG. 5 is a graphical representation of the operation of the system shown in FIG. 2.

FIG. 6 is a graphical representation of the operation of the system shown in FIG. 3.

Similar reference characters refer to similar parts throughout the several views of the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, a copier is schematically shown in which copy feed rate is regulated to adjust for varying total light energy available at the imaging station.

Specifically, light from a light source such as a lamp 10 is directed to an illuminating or exposure station 11 accommodating an original document 12 and a target 14 positioned adjacent the document. The light reflected from document 12 is then directed by means of a reflector or mirror 16 through an optical projection system 18 to focus the document borne image to be copied onto the charged surface of the copy paper 20 at an imaging station 22. In a copier of this type the light

from lamp 10 typically scans the surface of the original and the reflected image is scanned over the surface of the copy to create the corresponding latent electrostatic image. This may be accomplished in several ways. The original may be held stationary and the light source scanned over the surface thereof in synchronism with an optical system which simultaneously scans the surface of a moving sheet of copy paper. Conversely, the copy paper may be kept stationary while the original is fed through the copier. In some copiers both the original and copy paper feed through the copier in synchronism. Regardless of the type of mechanism used for scanning however, the total light energy (as for example measured in foot candle-seconds) to which the copy paper is exposed is a function of the image light level and the exposure time.

For purposes of the present description, it will be assumed that the original 12 and the copy sheet 20 are fed in synchronism through the exposure station 11 and imaging station 22, respectively, by feed rollers 25 driven by a motor 24. Accordingly, the speed at which motor 24 operates determines the rate at which the original is scanned and the rate at which the copy paper passes through the imaging station, and in turn the total amount of image light energy to which the copy paper is ultimately exposed. Therefore, by controlling the speed of motor 24 in response to changing light conditions, it can be assured that the copy paper will be exposed to the proper amount of light energy at all times to produce good copies.

As shown in FIG. 1, the system which controls motor speed in the copier comprises a sensor 26 coupled with a feedback motor control network 28. Sensor 26, such as a photoresistor, phototransistor, photocell, etc., is positioned to monitor the light intensity of a reference beam 15 reflected from target 14 after it has passed through the optics of the copier. Since target 14 is closely adjacent to the original document 12, and sensor 26 is in the same relative position in the optical path as the copy paper 20, variables affecting the image light level on the copy equally effect the amount of light reaching sensor 26. Target 14 is preferably white to match the typical image background.

The operating speed of motor 24 is regulated, as shown in FIG. 1, by motor control network 28 which in turn is regulated by a feedback signal derived by sensor 26. Since the feedback signal from sensor 26 is proportional in amplitude to the amount of reflected light from target 14, when the light level sensed by photocell 26 decreases as a result of decreased lamp voltage and/or dirty optics, the feedback signal amplitude reflects the change and signals network 28 to reduce the speed of motor 24 accordingly. As motor 24 slows down, the feed rates of the original and copy paper are likewise slowed. In this way the light energy (foot candle-seconds) of a given image to which the copy paper is exposed can be maintained constant; as the amount of light (foot candles) at the copy paper decreases, the time during which the copy paper is exposed (seconds) increases to keep the product thereof—which is a measure of light energy—the same.

The motor control 28 used in the system of FIG. 1 should be matched to the type of motor 24 provided in the copier, and a number of combinations will function satisfactorily. For example, the motor may be a DC type in which case a silicon-controlled rectifier (SCR) motor control could be employed. Alternately a series wound AC motor may be used with a TRIAC solid state motor control. A TRIAC motor control employs a pair of oppositely poled silicon-controlled rectifiers and acts to vary motor speed by reducing motor voltage; this is done by chopping part of the AC sine wave. However, since series wound AC motors are sensitive to changes in load and line voltage, additional controls should be used to minimize the effect of these factors.

The preferred combination of motor and control, however, is a squirrel cage induction motor with a TRIAC control. The TRIAC control, as in the series wound motor combination, regulates motor speed by regulating motor voltage. With this type system, sensor 26, a photoresistor, functions as the exter-

nal control resistor for the TRIAC circuit. Since the induction motor like the series wound motor may also be line voltage sensitive, additional voltage regulation may be used for stability in this combination as well.

Regardless of the motor-control combination chosen, the sensor 26 used in the system should be carefully matched to the motor. The matching should provide as nearly a linear relationship as possible between the sensor output and the motor speed over the ranges of light and speed which can be expected during the life of the copier. When the proper sensor is selected for the motor, neutral density filters can also be used in the copier to adjust the light on the sensor at the level needed to produce the proper resistance range for motor control.

Additionally, it is advantageous to further stabilize the copier motor speed in many motor-control combinations, particularly when using motors that are load sensitive. Again referring to FIG. 1, this may be accomplished by using the back emf of motor 24 as a negative feedback signal which is supplied over lead 29 to the motor control network 28. Accordingly, if motor 24 slows down under load, back emf decreases and the negative feedback signal to control network 28 allows motor voltage to be increased to bring the motor back up to speed. Alternatively, but less preferably, a tachometer may be incorporated in the speed control circuitry for the same purpose.

Referring now to FIG. 4, a pair of graphs illustrate the manner in which motor speed varies in a system of the type discussed above, in response to changing light conditions. Graph A depicts the situation in a copier with clean optics; as lamp current and light output decrease as a result of undervoltage, motor speed likewise must decrease to maintain at a minimum acceptable level the total light energy of a given image projected onto the copy paper. The minimum acceptable level of light energy (as shown in the drawings) will typically be determined through use of a test pattern original. Similarly motor speed increases to compensate for overvoltage. Graph B depicts the situation where the optics have become dirty to the extent that there is a 30 percent decrease in image light normally transmitted to the copy paper for a given image. In such a situation the entire motor speed curve is shifted to lower speeds to compensate for the dirty optics. The motor speed however varies at the lower level in the same manner as in Graph A to compensate for undervoltage or over-voltage to the lamp.

While the control system described heretofore is satisfactory for many purposes, it can be seen that motor speed will vary both as lamp current changes and as the optics become dirty. Preferably, a more stable system can be obtained if the lamp current is also controlled. In this way motor speed need only be varied as the optics become dirty. Such a system is shown in FIG. 2. The motor control circuit of FIG. 2 is identical to that previously described in conjunction with FIG. 1. The one change in the system of FIG. 2 is that a lamp control 30 is added to regulate the voltage to lamp 10 and maintain it at a constant value. This has the further advantage of permitting the copier to be current rated for the current actually drawn by the lamp rather than having to allow for a possible overvoltage of perhaps 10 percent, as is the case with motor control alone.

The lamp control 30 (FIG. 3) may be a 115 volt regulation transformer; however, for most commercial applications such a transformer is too large and too expensive. More preferably, lamp control 30 comprises a TRIAC solid state control of the type used for motor control 28 and discussed hereinabove. Such a TRIAC control 30 would be used to regulate lamp voltage at, for example, a constant 90 volts AC when operating in a system fed, as in FIG. 2, by 115 volt line voltage.

Referring now to FIG. 5, the variations in copier motor speed resulting from changing light conditions are graphically illustrated for a system in which lamp current is regulated and where motor speed is controlled by sensor 26. Graph C illustrates the situation in a copier with clean optics. Since lamp

current and thus light output is held constant and is independent of line voltage, motor speed is also held constant regardless of changes in line voltage. Motor speed will accordingly only vary as the copier optics become dirty; this is illustrated by Graph D which shows the situation resulting from a 30 percent decrease in image light normally transmitted to the copy paper. Under such conditions the motor speed is slowed to a new level by the motor control to keep the light energy of a given image to which the copy paper is exposed at an acceptable value. However, motor speed is still held constant at the lower level.

Another system for compensating for spurious variations in the amount of light energy reaching the copy paper is shown in FIG. 3. In this system there is no motor control so motor speed and thus the operating speed of the copier remains constant. The voltage to lamp 10 however is regulated in response to variations in the intensity of the reference beam light sensed by photosensor 26. This is accomplished by providing a TRIAC solid state lamp control 32 in the lamp circuit as shown in FIG. 3. The feedback signal from photocell 26 is transmitted to lamp control 32 (rather than to a motor control as in the previously discussed systems). Lamp control 32 serves to maintain lamp 10 at a constant voltage of, for example, 90 volts AC despite variations in the normal 115 volt AC line voltage. However, as the copier optics become dirty with time and the amount of light for a given image normally transmitted to copy paper 20 decreases, lamp control 32 in response to the feedback signal from photocell 26 proportionally increases the lamp voltage and thus the lamp current. In this way proportionally more light is generated by lamp 10 to compensate for the dirty optics.

The functioning of the feedback lamp control system is graphically illustrated in FIG. 6. Graph E shows the situation when the copier optics are clean. Since motor speed remains constant, the lamp current is kept constant and matched to motor speed by the lamp control to provide an acceptable level of light energy at the copy paper for a given image. Graph F illustrates the change occurring when the optics become sufficiently dirty to reduce the light level reaching the photocell sensor by 30 percent. Since motor speed still remains constant, lamp current is increased and maintained as shown at a new value to produce the compensating amount of light needed.

All of the systems described hereinabove permit the elimination of the mechanical type shutter used in prior art copiers. The function of the shutter, however, can be performed in the systems of the invention by means of a manually adjustable potentiometer placed in series with the feedback photoresistor in the control circuit for either the lamp or the motor.

It will be appreciated that the principles of the present invention may be applied to a variety of processes and apparatus

where it is important to control the total energy to which objects are exposed in terms of the factor of intensity and exposure time. Thus, other applications for the present invention are contemplated, such as, for example, Diazo blueprint machines, automated film duplicating machines, and automated apparatus for making photographic prints from film. Moreover, the present invention is not limited to any particular form of energy to be monitored and controlled, and thus applications to forms of radiant energy other than light energy are contemplated.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention, which, as a matter of language, might be said to fall therebetween.

Having described our invention, what we claim as new and desire to secure by Letters Patent is:

We claim:

1. In an electrostatic photocopier having a projection lamp for illuminating a document at an illuminating station and a motor coupled to feed photoconductive copy paper through an imaging station where the copy paper is exposed to a light image reflected from the document and projected by projection optics, a system for regulating the total image light energy incident on the copy paper comprising, in combination:

A. lamp control means operative to maintain lamp current at a predetermined constant value despite fluctuations in line voltage,

B. sensing means for monitoring the light intensity of a reference beam reflected from a target illuminated by the lamp and transmitted through the projection optics,

C. feedback motor control means for varying motor speed and thus the copy paper feed rate through the imaging station, and

D. means coupling a feedback signal from said sensing means to said motor control means proportional to the light intensity of said reference beam,

1. said feedback signal serving to actuate said motor control means to control motor speed in accordance with reference beam light intensity.

2. A system as defined in claim 1 and further including stabilizing means for deriving a signal representative of motor speed for transmission to said motor control means to compensate for any tendency of the motor to slow down due to increased load.

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