# United States Patent [19]

**Muth**

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[54] **TONER CONCENTRATION DETECTOR**


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[73] Assignee: **Honeywell Information Systems Inc.,** Waltham, Mass.



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[52] **U.S. Cl.** ..... **118/7;** 118/637

[51] **Int. Cl.²** ..... **B05B 5/02**

[58] **Field of Search** ..... 118/637, DIG. 23, 7, 9, 118/10, 11; 117/17.5



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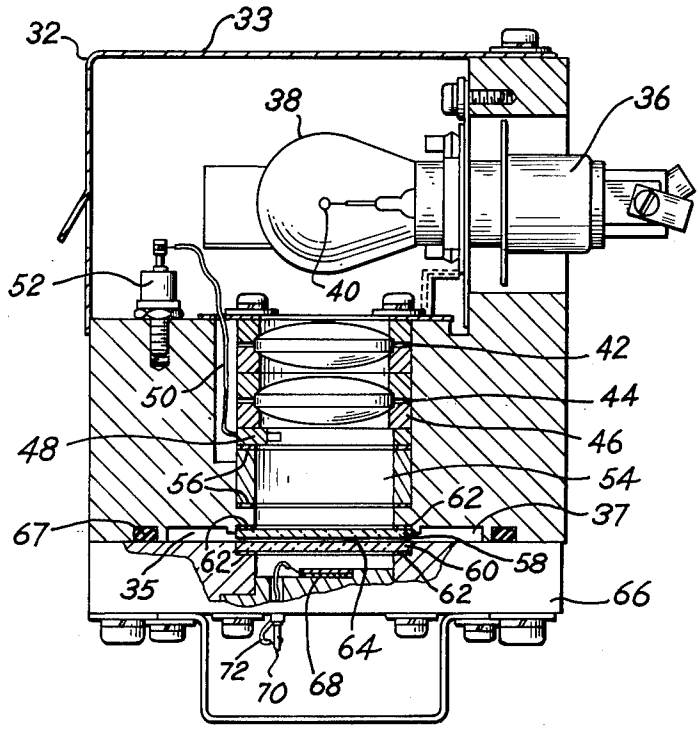
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[57] **ABSTRACT**

An improved apparatus for applying toner solution to a charged recording medium wherein the concentration of toner particles in the solution is continuously monitored and adjusted is disclosed. The apparatus includes means to measure toner concentration comprising a light source, a transparent chamber receiving a continuously flowing stream of toner solution and means for measuring light intensity from the light source as passed through the transparent chamber. Preferably the means for measuring light is particularly sensitive to light in the near infrared region (about 8500 Angstroms). The output signal from the means for measuring light is a measure of the concentration of toner particles in the toner solution and is used to add toner concentrate to the toner solution as the concentration of toner particles in the solution is depleted. In preferred embodiments, means for controlling the output from the light source and for measuring toner concentration independent of the position of the light source are disclosed.


**8 Claims, 6 Drawing Figures**



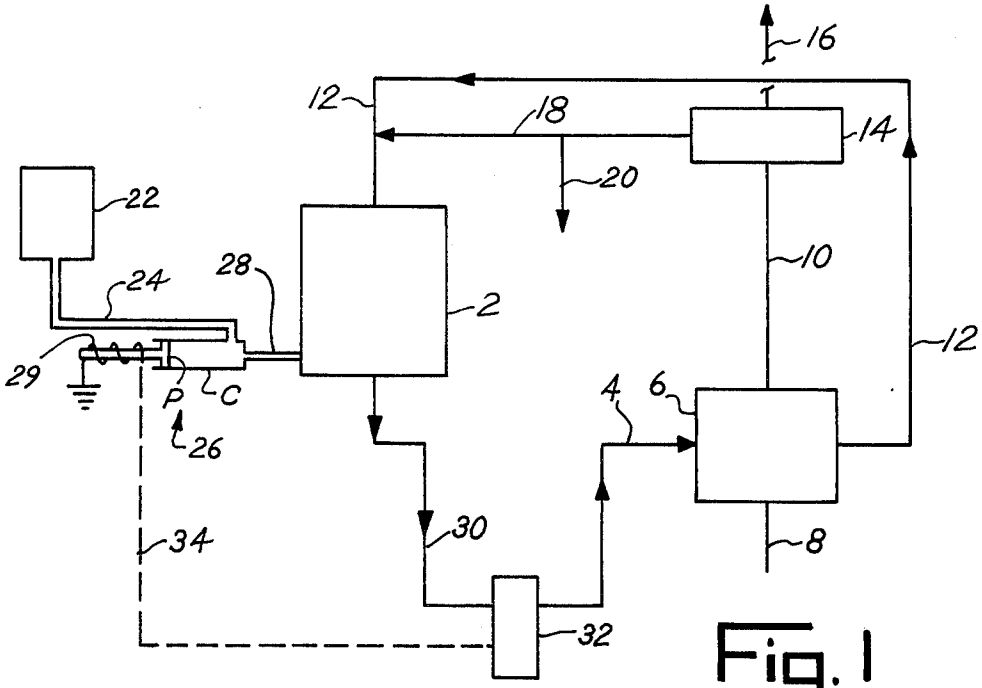

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C
4
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Fig. 1

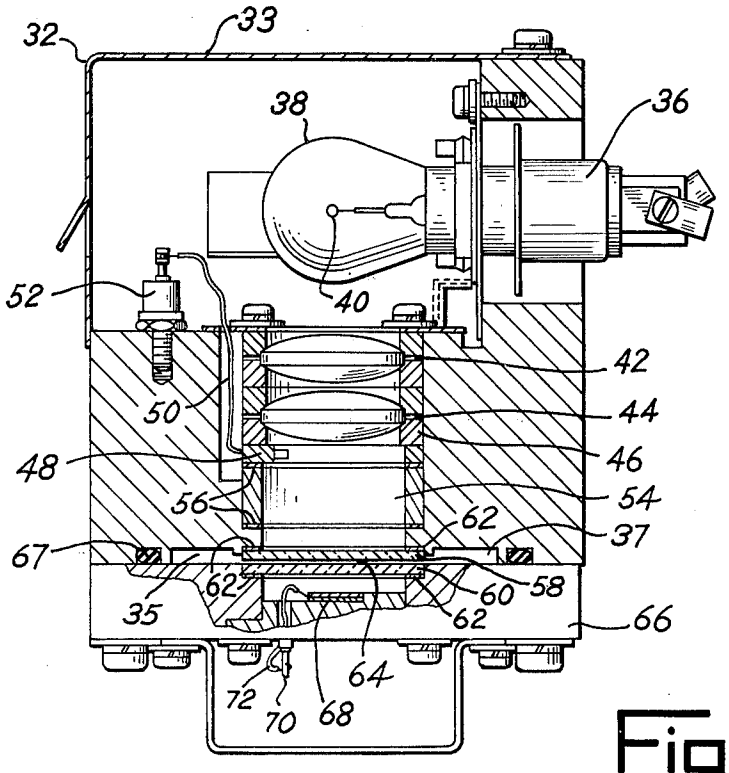

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Fig. 2

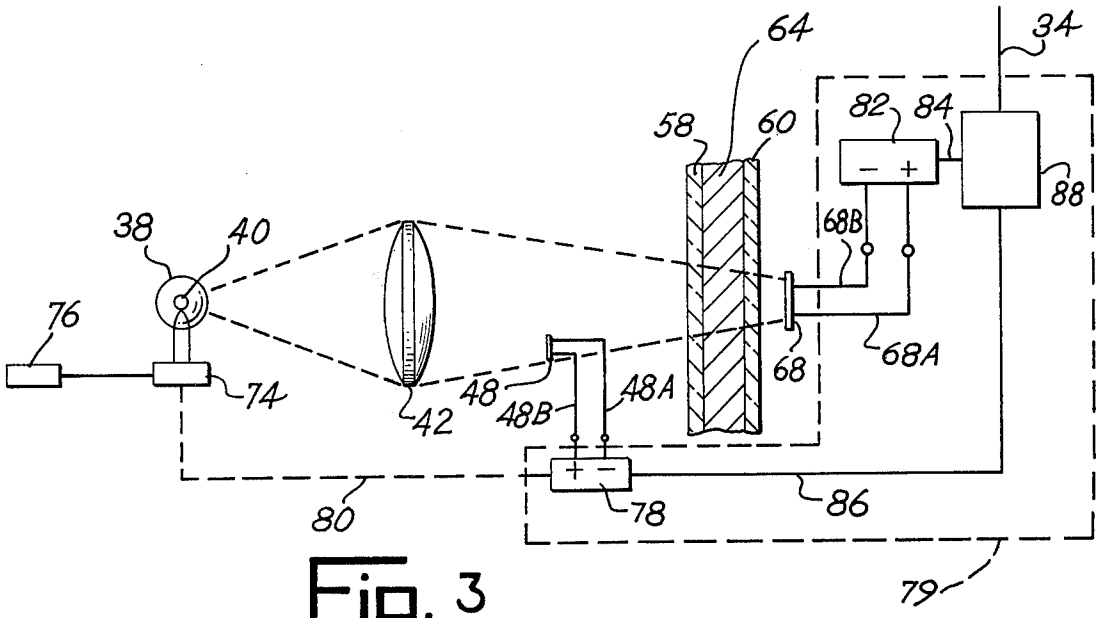

64
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68B
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48B
48A
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68A
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78
86
79

Fig. 3

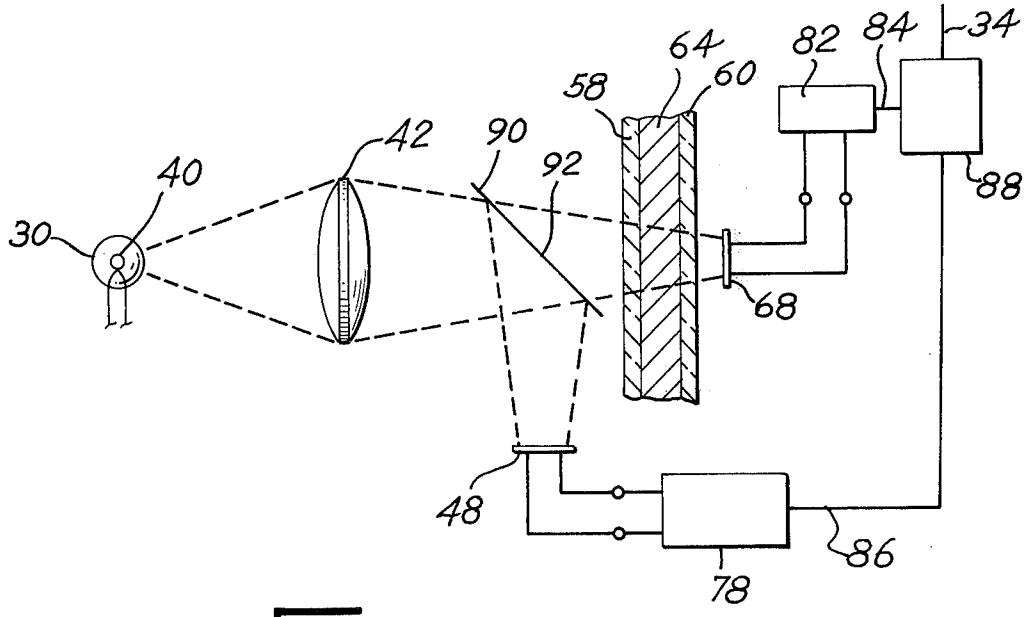

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Fig. 4

Fig. 5A

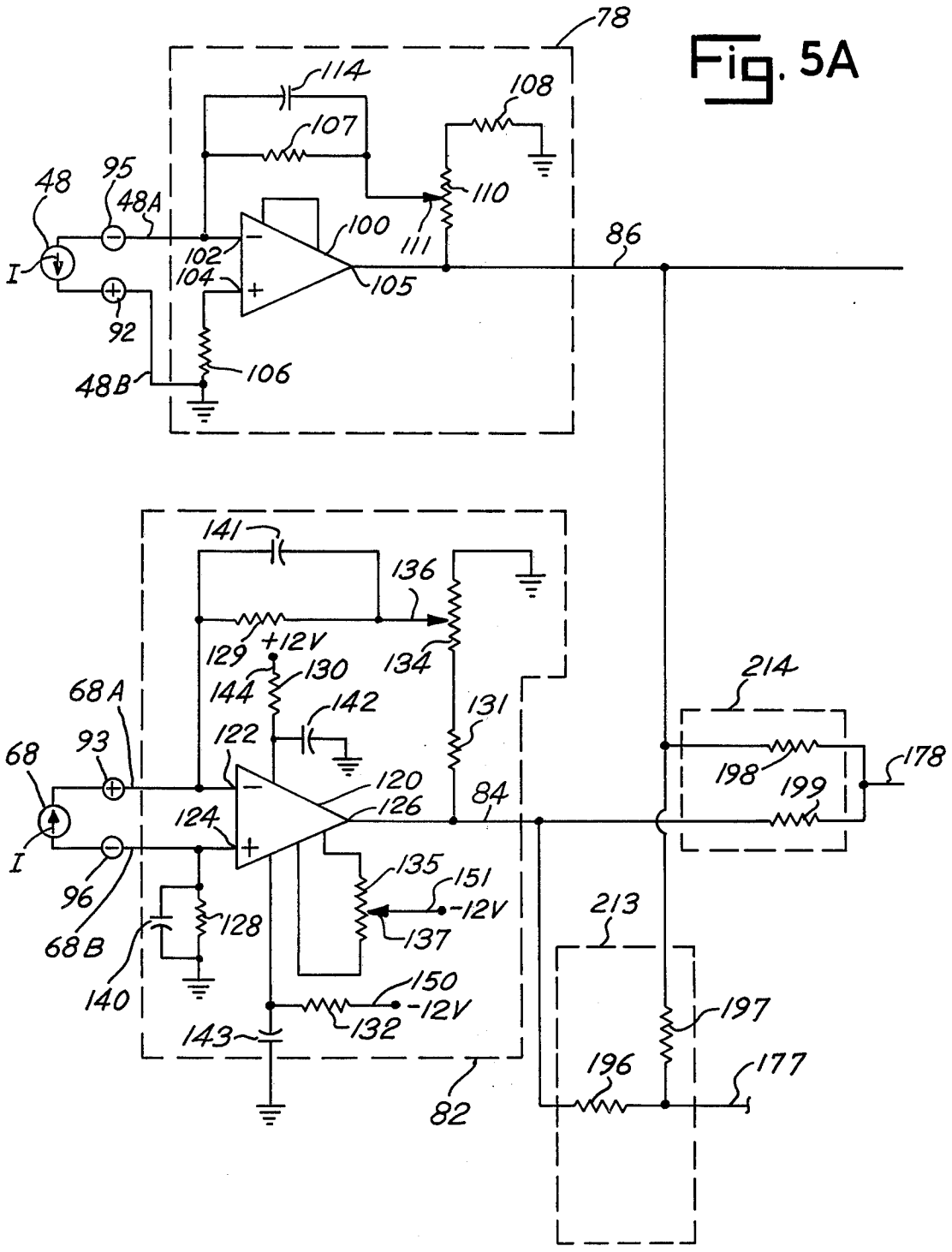
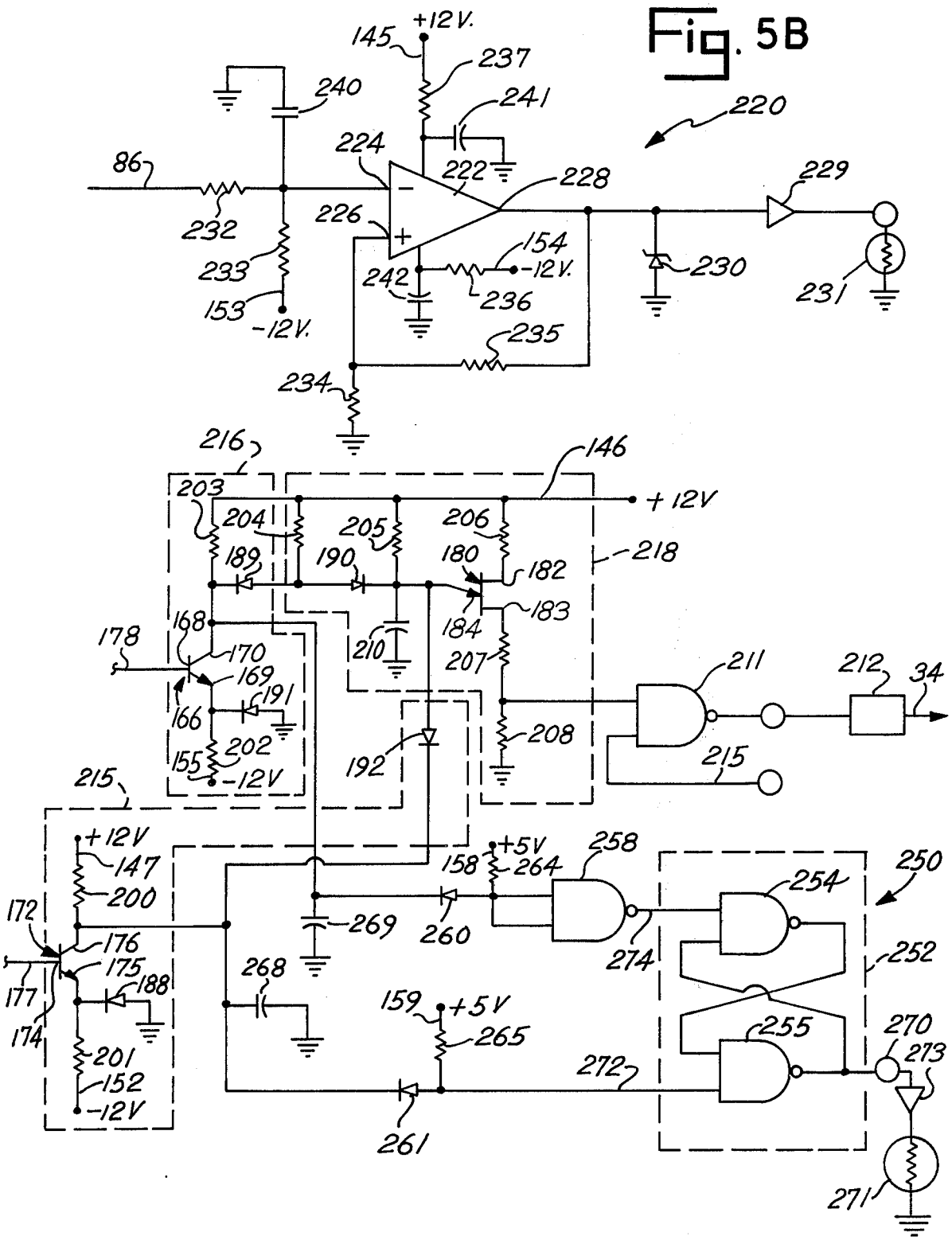

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+12V
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142
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68A
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120
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124
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68B
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128
135
151
-12V
137
150
-12V
132
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214
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213
197
196
177

Fig. 5B


+12V.
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220
224
222
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86
226
232
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153
-12V.
154
-12V.
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+12V
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-12V
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+12V
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172
176
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188
177
174
201
152
-12V
+5V
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252
268
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+5V
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# TONER CONCENTRATION DETECTOR

## BACKGROUND OF THE INVENTION

This invention pertains to an improved apparatus for printing upon a recording medium and particularly, to printing permanent images on a charged paper, such as an electrographic paper, at high speeds.

High speed, electrographic printing is used to produce a computer printout by non-impact printing techniques. Generally, electrographic printing utilizes an electrographic paper medium composed of a conductively treated base that supports a plastic dielectric coating. Latent images are formed on the paper by positioning the electrographic paper between an electrode that contacts the conductive base and a second electrode. The surface of the second electrode conforms to the shapes to be printed or, in an alternative embodiment, the second electrode can be selectively activated to form a predetermined image. Thus, this second electrode can have a fixed format and/or a variable format to produce the shapes to be printed on the dielectric paper. A high voltage (i.e., 500 to 800 volts) applied between the two electrodes excites the paper medium, thereby establishing an electrostatic field across the dielectric coating. The dielectric coating retains a residual electrostatic field that constitutes a charged latent image of the shapes to be printed.

Latent images on the charged paper are developed by contacting the paper with a toning liquid composed of charged carbon-resin particles suspended in a liquid carrier. The liquid carrier is preferably a highly parrafinic solvent such as Isopar L which also functions to soften the charged carbon-resin particles. The residual electrostatic field on the dielectric surface of the charged paper attracts the carbon-resin particles and holds them in position. This makes the latent image visible. The visible image is then fixed, i.e., made permanent, by drying and applying heat to remove the liquid carrier and to solidify the carbon-resin particles and bond them to the paper. A suitable method and apparatus for high speed electrographic printing is described in U.S. Pat. No. 3,701,337, the teachings of which are incorporated by reference herein.

In a high speed electrographic printing operation such as illustrated in U.S. Pat. No. 3,701,337, the charged printing medium is contacted with a recirculating stream of toner solution. The excess toner solution is recovered and recycled for future use. However, since toner particles are removed from the toner solution in developing the latent images, the excess toner liquid recovered after application of the toner solution to the excited paper contains a lesser amount of toner particles. As a consequence, when the toning solution is continuously recycled, additional toner particles must be added to the circulating solution to maintain a constant, high quality printout.

In the prior art, this was accomplished by the operator visually determining the quality of the printout. When the operator noticed that the printout quality was declining and the developed characters were not sharp, he would, at his discretion, manually add additional toner particles, typically in the form of a concentrated solution or suspension, to the circulating toner solution. As a consequence, in the manual prior art method of addition, printout quality frequently varied. Further, in high speed electrographic printing wherein printing speed in excess of 1,000 lines per second commonly occurs, the operator would frequently have to add toner concentrate to the system. Thus, when the machine operated at a high printout rate with a large amount of printing per page, it was difficult for the operator to maintain a constant print quality because of the frequent need to add toner concentrate to the circulating toner solution.



## SUMMARY OF THE INVENTION

It is an object of this present invention to provide a printing apparatus for developing latent charged images on a recording medium with a toner solution wherein the concentration of toner particles in the toner solution is continually monitored and controlled so as to guarantee the production of uniformly high quality prints.

It is another object of this invention to provide a printing apparatus which will automatically add a concentrated toner solution to a working toner solution so as to maintain a relatively constant toner particle concentration in the working toner solution.

It is another object of this invention to provide a printing apparatus for producing high quality images wherein light is passed through a toner solution, the resultant light intensity is measured, and this measured light intensity is used as a means for determining when to add toner concentrate to the toner solution.

It is a specific object of this invention to provide a printing apparatus which measures the concentration of toner particles in a toner solution by measuring the intensity of light passed through the toner solution wherein means are employed for providing a constant intensity light source so as to insure an accurate measurement of the toner particle concentration.

Although a typical toner solution is substantially opaque, it has been discovered that the intensity of light passed through a thin layer of toner solution is inversely proportional to the concentration of toner particles in the toner solution. In other words, a higher concentration of toner particles in the toner solution produces a lower light intensity. This light intensity, I, can be represented by the general formula

$$I = K_1 10^{K_2 C}$$

wherein $K_1$ and $K_2$ are constants depending on the type of toner, the intensity of the light source, and the sensors used to sense the light intensity; and $C$ is the concentration of toner particles in the toner solution being measured. This light intensity can be determined by measuring the voltage or current emitted by a conventional photoelectric or solar cell. This current or voltage, in turn, can be electronically processed to provide a measurement of concentration and a command to add toner concentrate to the circulating toner solution when the concentration of toner particles falls below a predetermined value.

In a broad embodiment, therefore, the present invention relates to an improvement in an apparatus for applying a working toner solution comprising a suspension of black or colored toner particles in a volatile carrier to a charged recording material containing a latent image in a toning station to render the latent image visible. The particular improvement of the present invention includes means for continuously measuring the concentration of toner particles in the working toner solution, transfer means for transferring concentrated toning solution from a reservoir to the working solution, and operating means for operating the transfer means when the toner concentration falls below a

predetermined value as determined by the measuring means and for terminating the operation of the transfer means when the toner concentration returns to the predetermined value.

A preferred apparatus for measuring the toner concentration according to the broad embodiment specified above includes a light source, a transparent chamber spaced-apart from the light source to receive a continuously flowing stream of working toner solution, means for measuring the light intensity from the light source after the light passes through the chamber and means for focusing the light from the light source through the transparent chamber. Preferably, the means for measuring the light intensity is particularly sensitive in the near infrared range; a conventional solar cell having optimum sensitivity in the range of 8500 Angstroms is particularly preferred. The use of light in the infrared region produces particularly accurate, reliable and reproducible results when working with solutions of high opacity, such as a working toner solution. The thickness of the measuring chamber is typically about 0.01 to 0.05 inches thick when dealing with relatively high opacity solutions. However, for different solutions, the width of the chamber can be up to 0.25 inches.

In a more limited embodiment, the apparatus of the present invention further includes means for detecting the amount of light passed to the transparent chamber, means for providing current to the light source and means for adjusting the current to the light source in response to the amount of light passed to the chamber to maintain a predetermined constant light level.

In another limited embodiment, the apparatus of the present invention includes means for detecting the amount of light passed to the chamber from the light source and means for comparing the light intensity on either side of the chamber, as determined by the detection means, said comparison means providing an accurate measurement of toner concentration irrespective of the output from the light source.

In another specific alternate embodiment of the present invention, the apparatus is equipped with means for measuring the uninterrupted light intensity from the light source at a distance from the light source equal to the distance between the measuring means positioned behind the chamber and the light source. This distance is measured by following the light path from the light source to the specified measuring means. Also included is means for comparing the uninterrupted light intensity in front of the chamber to the light intensity behind the chamber, thereby providing an accurate measurement of toner concentration irrespective of lamp placement. This embodiment is particularly useful since the dimensions of lamps and filaments within lamps can vary substantially. In a conventional device in which the length of the light paths from the light source to the means for measuring are unequal, the substitution of one lamp for another can vary the ratio of the light intensities received by the means for measuring. When the two means for measuring, however, are equidistant from the light source, any effect due to variations of the lamp dimensions is removed. Typically, the means for measuring uninterrupted light intensity is positioned in front of the chamber and includes means for reflecting of the light from the light source to this light intensity measuring means.

Other objects and embodiments and a more detailed description of the foregoing embodiments will be found in the following detailed description.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic flow diagram of a nonimpact printer employing a preferred embodiment of the present invention which automatically adjusts the concentration of toner particles in the working toning solution;

FIG. 2 is a detailed cross-sectional view of a specific device to measure the concentration of toner particles in a toning solution according to the present invention;

FIG. 3 is a schematic diagram illustrating the operation of the device illustrated in FIG. 2;

FIG. 4 is a schematic diagram illustrating the operation of an alternate device for measuring toner concentration in FIG. 1, wherein an accurate measurement of toner concentration is obtained irrespective of the position of the light source; and

FIGS. 5A and 5B are circuit diagrams of the operating circuit schematically illustrated in FIG. 3.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2, there is schematically illustrated an apparatus for applying toning solution to a charged electrographic medium. This apparatus includes a storage tank 2 containing a working toning solution which is passed through a line 30, a toner concentration detector 32 and a line 4 to toning station 6. Within detector 32, the bulk of the toning solution passes through cavities 35 and 37. Within toning station 6, working toning solution is applied to a charged electrographic paper 8 containing a latent image to produce a wet paper 10 containing a visible image. This paper in turn, is dried by application of heat in drying station 14 to produce a dried electrographic paper 16 containing a fixed visible image. The evaporated carrier is removed from drying station 14 via line 18 and recycled back to storage tank 2, or is removed from the process via line 20. The toning solution passed to toning station 6 that is not deposited on electrographic paper 8 is removed from toning station 6 via line 12 and is returned to storage tank 2 with a depleted toner particle concentration by any conventional means, such as a pump (not shown).

To maintain a constant predetermined level of toning particles in the working toning solution, a slip stream from cavities 35 and 37 that flows through a chamber 64 is continuously monitored. When the concentration of toner particles in the working solution falls below a predetermined value, concentration detector 32 energizes pump 26 via control line 34 and a concentrated toner solution withdrawn from concentrate tank 22 via line 24 is passed to storage tank 2 via line 28.

Pump 26 comprises a plunger P which reciprocates in a cylinder C. Each time plunger P moves to the right as shown in FIG. 1, a charge of toner concentrate spurts into tank 2 through line 28. Plunger P is moved to the right by conducting a current pulse through a conventional solenoid coil 29. As soon as the current is terminated, plunger P is returned to the normal position shown in FIG. 1 by resilient means not shown. By increasing the repetition rate of the pulses applied to coil 29, the rate at which toner concentrate is added to tank 2 is likewise increased.

The addition of toner concentrate via pump 26 continues until the concentration level of toner particles in

the working solution circulated through line **30** reaches a desired value. In a typical embodiment, the concentration level which actuates pump **26** is the same concentration level at which pump **26** is deactivated. The same concentration level or set point can be used for actuating and deactuating pump **26** because of the large inventory of toning solution contained in tank **2** and circulated through a typical non-impact printer apparatus. Actuating pump **26** when the toner concentration level is falling below the desired value does not immediately result in an increased concentration level at toner concentration detector **32.** Because of the large inventory of toning solution and the physical placement of the tank **2** relative to toner concentration detector **32,** the toner concentration level may actually continue to decline at detector **32** for a time before it begins to increase due to the toner concentrate added at tank **2.** It will take a period of time for the concentration of toner particles in line **30** to build up to the desired value after pump **26** has been actuated.

Preferably, toning concentration detector **32** includes means to increase the addition rate via pump **26** when the concentration of toning particles in the working solution falls below a second predetermined value less than the desired value. This feature allows the apparatus of the present invention to rapidly compensate for any large imbalances in the concentration of toner particles in the toning solution and to rapidly correct the concentration so as to ensure a constant quality printout.

In a typical embodiment, the working toner solution is maintained at 4.0 ± 0.5 wt. % total concentrate, wherein the concentrate contains 17% solids. In other words, the working solution contains about 0.595 to about 0.765 wt. % solids. However, the amount of solids in the working solution is a function of the identity of the specific toner solution being used and the degree of clarity desired on the final developed electrographic paper.

Referring to FIG. **2,** there is illustrated a preferred toner concentration detector **32.** Toner concentration detector **32** comprises an incandescent light bulb **38** containing a filament **40** positioned in light bulb socket **36** located within housing **33.** The light from light bulb **38** is directed through lenses **42** and **44** mounted in lens holder **46,** through glass plates **58** and **60** before impinging on light intensity detector **68.** Light intensity detector **48** is positioned immediately in back of forward lens **44** and measures the light intensity that is passed to glass plate **58.** Light intensity detectors **48** and **68** are conventional silicon solar cells of the type manufactured by Sensor Technology, Inc. These cells are short-circuited and the current generated therein is indicative of the light intensity falling upon the detector. The current generated in detector **48** is passed via lead **50** to standoff **52** and the current generated in detector **68** passed via lead **72** to terminal **70.** The function of these current values in the apparatus of the present invention will be explained in further detail by reference to FIGS. **3** and **4** hereinafter.

The light passing from lens **44** passes through a predetermined distance **54** before contacting front glass plate **58.** The spacing between glass plate **58** and lens **44** is adjusted by washers **56.** Second glass plate **60** is mounted in fixed end piece **66** and is spaced apart from first glass plate **58** to define a space or chamber **64** having a predetermined thickness. In accordance with the present invention, working toning fluid is removed as a slip stream from cavities **35** and **37** and is passed through chamber **64** to measure the concentration of toning solids in the toner solution. Seals **62** provides a tight fit between glass plate **58** and housing **33** and between glass plate **60** and end piece **66.** O-ring **67** provides a leak proof fit between end piece **66** and housing **33.**

In operation, the intensity of the light emitted from light bulb **38** and focused by lenses **42** and **44** is determined by light intensity detector **48.** The light then passes through transparent glass plate **58** and the working fluid contained within chamber **64,** thereby reducing the intensity of the light passing through plate **60.** The light striking light intensity detector **68** is compared with the original light intensity determined by detector **48** to provide a reliable, accurate measurement of the concentration of toning particles in the toner solution passed to chamber **64.**

Referring to FIG. **3,** there are illustrated two embodiments for accurately measuring the concentration of toning particles in the toner solution. In one embodiment, to ensure that light bulb **38** continues to emit a light of a predetermined constant intensity, the light intensity is continuously monitored by detector **48** that is connected by conductors **48A** and **48B** to an amplifier **78** which forms part of an operating circuit **79.** The current produced by detector **48** is amplified by amplifier **78** to provide a control signal. In one embodiment, this control signal is passed via circuit **80** to current regulator **74** which controls the input of current to light bulb **38** from a current source **76.** This configuration provides a constant intensity emission of light from light bulb **38.**

In FIG. **3,** detector **68** produces a DC current proportional to the intensity of the light that passed through glass plate **58,** the toner solution contained in chamber **64** and glass plate **60.** Detector **68** is connected to an amplifier **82** by conductors **68A** and **68B.** The resultant current produced by detector **68** is amplified by current amplifier **82** to produce another control signal on a conductor **84.** Conductors **84** and **86** are connected to a control circuit **88** which produces a pulsating voltage that drives plunger P at a predetermined rate when the concentration of the toner particles in the toner decreases below a predetermined value. The embodiment illustrated in FIG. **3** provides a reliable and accurate method of determining toner concentration that is not sensitive to the efficiency of lamp **38.**

A preferred form of operating circuit **79,** including amplifiers **78** and **82,** as well as control circuit **88,** is shown in more detail in FIG. **5,** consisting of FIGS. **5A** and **5B.** In FIG. **5,** detectors **48** and **68** are represented as current generators having positive terminals **92, 93** and negative terminals **95, 96.** In response to light, the detectors generate an electrical current that flows in the direction of arrows I.

Amplifier **78** comprises a type **747** operational amplifier **100** having an inverting input **102,** a noninverting input **104** and an output **105.** The operational amplifier is controlled by resistors **106–108,** a potentiometer **110** having a slider arm **111** and a capacitor **114,** all connected as shown.

Amplifier **82** comprises a type **741** operational amplifier **120,** having an inverting input **122,** a noninverting input **124** and an output **126.** Amplifier **120** is controlled by resistors **128–132,** potentiometers **134** and **135** having slider arms **136** and **137,** respectively, and capacitors **140–143,** all connected as shown.

A power supply (not shown) furnishes plus 12 volts DC over conductors **144–147** and minus 12 volts DC over conductors **150–155.** A plus 5 volt DC signal is transmitted by the power supply to conductors **158** and **159.**

Control circuit **88** comprises a bipolar transistor **166** having a base **168,** an emitter **169** and a collector **170.** Circuit **88** also includes another bipolar transistor **172** having a base **174,** an emitter **175** and a collector **176,** as well as a unijunction transistor **180** having a base two **182,** a base one **183,** and an emitter **184.** Circuit **88** is controlled by diodes **188–192,** resistors **196–208** and a capacitor **210.** A NAND gate **211** supplies pulses to a one shot multivibrator **212** that, in turn, supplies current pulses through conductor **34** to solenoid coil **29.** A pump inhibit conductor **215** may be switched to a logical 0 state to prevent the operation of pump **26.**

Control circuit **88** is functionally divided into analog circuits **213, 214;** switching circuits **215, 216;** and a signal generator **218:**

Analog circuit **213** comprises resistors **196, 197** which algebraically add and scale the amplified signals on output conductors **84** and **86** to produce a switching signal that is transmitted to the base of transistor **172.** Analog circuit **214** comprises resistors **198, 199** which algebraically add and scale the amplified signals on output conductors **84** and **86** to produce another switching signal that is transmitted to the base of transistor **166.** Since algebraic addition also includes subtraction, circuits **213, 214** can accommodate both negative and positive voltages on conductors **84** and **86.** Since transistors **166** and **172** are switched from their conductive to their nonconductive states by the application of voltages to their bases near ground potential, the ratio of the voltage on conductor **86** to the voltage on conductor **84** at which transistor **166** and transistor **172** switch state is nearly constant irrespective of changes in the intensity of lamp **38,** so that the detection of toner concentration is independent of lamp intensity.

Switching circuit **215** disables signal generator **218** when the concentration of toner particles becomes too great, and switching circuit **216** quadruples the repetition rate of singal generator **218** when the concentration of toner particles becomes too dilute.

A lamp indicator circuit **220** may be used in order to monitor the condition of light bulb **38.** The circuit comprises a type 747 operational amplifier **222** having an inverting input **224,** a noninverting input **226** and an output **228.** Output **228** drives a bulb **231** through an amplifier **229** having its input voltage controlled by a 4.7 volt Zener diode **230.** The operational amplifier is also controlled by resistors **232–237** and by capacitors **240–242.**

A dilute toner indicator circuit **250** may be used in order to indicate to an operator the condition of the toner concentration. The circuit comprises a flip-flop **252** consisting of NAND gates **254** and **255.** The circuit also includes another NAND gate **258,** as well as diodes **260, 261,** resistors **264, 265** and capacitors **268, 269.** An output conductor **270** is connected through an amplifier **273** to an indicator bulb **271.**

In order to adjust amplifier **78,** lamp **38** is turned on the slider arm **111** is moved until amplifier **100** produces a plus 8 volt DC signal on conductor **86.** In order to achieve this result, detector **48** should produce 0.16 to 0.01 milliamps of current. In order to adjust amplifier **82,** tank **2** is loaded with a toner solution of normal concentration and potentiometer slider arm **136** is moved until amplifier **120** produces a −2 volt DC signal on conductor **84.** The adjustment of slider arm **136** will accommodate types of detector **68** capable of producing between 8.0 and 0.4 microamps of current. If detector **68** produces less than 0.1 microamps of current, slider arm **137** also may need to be adjusted.

Because of the reverse polarity connection of detectors **48** and **68** to amplifiers **78** and **82,** the amplifiers produce amplified signals on conductors **84** and **86** which represent the detector current signals inverted with respect to each other.

When amplifiers **78** and **82** are adjusted to produce the normal conditions on conductors **84** and **86** described above, the base of transistor **172** is biased near ground potential so that the transistor is switched to its nonconductive state (i.e., turned off). However, the base of transistor **166** is biased slightly above ground potential so that the transistor is turned on and driven into saturation. As a result, diode **189** is forward biased and diode **190** is reversed biased so that capacitor **210** is charged from **12** volt supply conductor **146** through a 270 K resistor **205.** The values of resistor **205** and capacitor **210** are arranged so that capacitor **210** charges to the emitter firing voltage of unijunction **180** every 2 seconds. When unijunction **180** fires, current is drawn through emitter **184** and resistors **207, 208,** so that a positive pulse of voltage is transmitted to NAND gate **211,** and multivibrator **212** produces a current pulse having a predetermined duration. In this mode of operation, unijunction **180** operates as a pulse oscillator or generator having a period of 2 seconds. As a result, once every 2 seconds, plunger P of pump **26** (FIG. 1) pumps a charge of toner concentrate into tank **2,** thereby increasing the concentration of toner particles in the working toner solution. If the concentration of the toner particles in tank **2** increases slightly above the normal concentration, the voltage on conductor **84** increases slightly above minus 2 volts DC, thereby switching transistor **172** to its conductive state. At this point in time, diode **192** is forward biased so that emitter **184** of unijunction **180** is held to a low voltage, thereby preventing the unijunction from firing. In this mode of operation, no signals are transmitted to pump **26** and the concentration of toner particles cannot increase. At this same time, diode **261** is forward biased, thereby transmitting a logical 0 signal to flip-flop **250** over conductor **272.** This signal forces NAND gate **255** to produce a logical 1 signal of plus 5 volts on conductor **270.** The plus 5 volt signal causes amplifier **273** to light bulb **271,** thereby indicating to an operator that the toner particle concentration is within an appropriate range of values.

As toner solution is applied to recording medium **8** in toner station **6,** the toner particle concentration in tank **2** decreases, and the voltage on conductor **86** also decreases to minus 2 volts DC. At this point in time, transistor **172** again is switched to its nonconductive state and diode **192** is reverse biased, thereby enabling the production of pulses having a period of 2 seconds from unijunction **180.** At the same time, diode **261** is reverse biased so that a logical 1 signal is transmitted to conductor **272.** However, a logical 1 signal continues to be produced on conductor **270** and bulb **271** continues to glow, so that an operator will know that the toner particle concentration is adequate.

If the concentration of toner particles in tank **2** continues to decrease below the normal concentration in

spite of the operation of generator **218** at 2 second intervals, the voltage on conductor **84** continues to decrease. When the concentration decreases to a "too dilute" value at which the voltage on conductor **84** is about minus 7 volts DC, transistor **166** is switched to its nonconductive state (i.e., turned off). At this point in time, diode **189** is reverse biased and diode **190** is forward biased to place resistor **204** (having a value of 47 K ohms) in parallel with resistor **205.** This mode of operation decreases the time constant of the charging circuit for emitter **184** so that unijunction **180** fires approximately every one-half second. As a result, pump **26** operates 4 times as fast as the normal rate. That is, the plunger operates every half second instead of every 2 seconds.

When transistor **166** is turned off, diode **260** is reverse biased, thereby transmitting a logical 1 signal to NAND gate **258.** NAND gate **258,** in turn, transmits a logical 0 signal over conductor **274** which causes flipflop **252** to change state, thereby switching conductor **270** to ground potential and turning off bulb **271.**

After the 2 stroke per second pumping rate of pump **26** increases the toner particle concentration so that the voltage on conductor **84** increases above minus 7 volts DC, transistor **166** is turned on, thereby decreasing the pump rate to one stroke in 2 seconds. At this point in time, diode **260** is forward biased so that a logical 1 signal is transmitted to conductor **274.** However, flipflop **252** continues to hold conductor **270** at ground potential and bulb **271** remains off. Bulb **271** remains off until the toner particle concentration increases slightly above the normal concentration, at which time transistor **172** is turned on in the manner previously described. Bulb **271** exhibits hysteresis due to the operation of flipflop **252** which provides a reliable indication of toner particle concentration.

Lamp indicator circuit **220** is adjusted so that output **228** is at ground potential and bulb **231** is turned off when lamp **38** has at least average intensity. However, if the intensity of lamp **38** decreases below a predetermined value, the voltage on conductor **86** will decrease. When the voltage reaches about 4.7 volts, amplifier **222** produces a plus 4.7 volt signal on output **228.** The signal causes amplifier **229** to turn on lamp **231,** thereby indicating that lamp **38** requires replacement. Resistors **234** and **235** provide about 0.21 volts of the hysteresis to prevent flickering of lamp **231** when conductor **86** slowly changes voltage near the plus 4.7 volt level.

The embodiment illustrated in FIG. **3** is sensitive to the position of filament **40** relative to detectors **48** and **68.** As can be seen in FIG. **3,** detectors **48** and **68** are each positioned at different distances from filament **40.** Although the socket for light bulb **38** is fixed, the position of the filament within the light bulb can vary. If such variance regularly occurs, detectors **48** and **68** would have to be recalibrated each time light bulb **38** is replaced. By use of the apparatus illustrated in FIG. **4,** these deficiencies are avoided. In particular, detector **48** is positioned at the same distance from filament **40** as detector **68** as measured along the light path from filament **40.** More particularly, a portion of the light passing through lens **42** is deflected downward by a beam splitter **90** onto detector **48.** However, since the distance from the center point **92** of beam splitter **90** to detector **48** is the same as the distance from center point **92** to detector **68,** the light which reaches detector **48** must pass the same distance as the light that reaches detector **68.** Accordingly, the apparatus schematically illustrated in FIG. **4** is a further improvement over the apparatus illustrated in FIG. **3** in that light bulb **38** can be changed and an accurate measurement of toner concentration obtained irrespective of the position of filament **40.**

Those skilled in the art will recognize that the specific embodiments described herein may be altered and modified without departing from the true spirit and scope of the invention as defined in the appended claims.

What is claimed is:

**1.** In a printing apparatus for rendering visible a latent electrostatic image carried on a recording medium by applying to the medium at a toning station a working toner solution comprising a suspension of toner particles in a volatile carrier, improved means for maintaining a predetermined concentration of toner particles in the working toner solution comprising, in combination:

a reservoir of toner particles;

measuring means for continuously measuring the concentration of toner particles in the working toner solution, said measuring means including a light source,

a transparent chamber spaced apart from the light source to receive a continuously flowing stream of working toner solution,

first light detection means sensitive to light in the near infrared region of the light spectrum for measuring light intensity from the light source passing through the chamber, and means for transmitting light from the light source through the transparent chamber to the first light detection means along a first path having a first predetermined length;

second light detection means for detecting the intensity of light passed to said chamber from said light source;

means for providing current to the light source;

means for adjusting the current to the light source in response to said second light detection means to maintain a predetermined constant light intensity from the light source;

transfer means for transferring toner particles from the reservoir to the working toner solution at a predetermined rate; and

operation means responsive to the measuring means for operating the transfer means when the toner particle concentration decreases below a first predetermined value and for terminating the operation of the transfer means when the toner particle concentration increases to the first predetermined value.

**2.** In a printing apparatus for rendering visible a latent electrostatic image carried on a recording medium by applying to the medium at a toning station a working toner solution comprising a suspension of toner particles in a volatile carrier, improved means for maintaining a predetermined concentration of toner particles in the working toner solution comprising in combination:

a reservoir of toner particles;

measuring means for continuously measuring the concentration of toner particles in the working toner solution, said measuring means comprising

a light source, a transparent chamber holding a portion of the working toner solution, first light detection means having a positive terminal and a negative terminal for generating a first current signal flowing from the negative terminal to the positive

terminal in response to light, first positioning means for positioning the first light detection means to receive light from the light source that is passed through the chamber, second light detection means having a positive terminal and a negative terminal for generating a second current signal flowing from the negative terminal to the positive terminal in response to light, and second positioning means for positioning the second light detection means to receive light from the light source before the light has passed through the working toner solution;

transfer means for transferring toner particles from the reservoir to the working toner solution at a predetermined rate; and

operating means responsive to the measuring means for operating the transfer means when the toner particle concentration decreases below a first predetermined value and for terminating the operation of the transfer means when the toner particle concentration increases to the first predetermined value, said operating means comprising

amplifier means having

a first output and a second output for amplifying and inverting the first current signal with respect to the second current signal to produce a first amplified signal having a first voltage on the first output corresponding to the first current signal and to produce a second amplified signal having a second voltage on the second output corresponding to the second current signal so that the ratio of the first voltage to the second voltage remains constant irrespective of the changes in the intensity of the light produced by the light source, said amplifier means comprising

a first operational amplifier having an inverting input, a noninverting input and an output comprising said first output;

means for operatively connecting the positive terminal of the first light detection means to the noninverting input of the first operational amplifier and for operatively connecting the negative terminal of the first light detection means to the inverting input of the first operational amplifier;

a second operational amplifier having an inverting input, a noninverting input and an output comprising said second output; and

means for operatively connecting the positive terminal of the second light detecting means to the inverting input of the second operational amplifier and for operatively connecting the negative terminal of the second light detecting means to the noninverting input of the second operational amplifier.

**3.** In a printing apparatus for rendering visible a latent electrostatic image carried on a recording medium by applying to the medium at a toning station a working toner solution comprising a suspension of toner particles in a volatile carrier, improved means for maintaining a predetermined concentration of toner particles in the working toner solution comprising in combination:

a reservoir of toner particles;

measuring means for continuously measuring the concentration of toner particles in the working toner solution, said measuring means comprising

a light source, a transparent chamber holding a portion of the working toner solution, first light detection means having a positive terminal and a negative terminal for generating a first current signal flowing from the negative terminal to the positive terminal in response to light, first positioning means for positioning the first light detection means to receive light from the light source that is passed through the chamber, second light detection means having a positive terminal and a negative terminal for generating a second current signal flowing from the negative terminal to the positive terminal in response to light, and second positioning means for positioning the second light detection means to receive light from the light source before the light has passed through the working toner solution;

transfer means for transferring toner particles from the reservoir to the working toner solution at a predetermined rate; and

operating means responsive to the measuring means for operating the transfer means when the toner particle concentration decreases below a first predetermined value and for terminating the operation of the transfer means when the toner particle concentration increases to the first predetermined value, said operating means comprising

amplifier means having

a first output and a second output for amplifying and inverting the first current signal with respect to the second current signal to produce a first amplified signal having a first voltage on the first output corresponding to the first current signal and to produce a second amplified signal having a second voltage on the second output corresponding to the second current signal so that the ratio of the first voltage to the second voltage remains constant irrespective of the changes in the intensity of the light produced by the light source,

first analog means for algebraically adding and scaling the first amplified signal and the second amplified signal to produce a first switching voltage which varies with the toner particle concentration and which has a first predetermined voltage value corresponding to said first predetermined value of the toner particle concentration;

signal generating means for operating the transfer means; and

first switching means for enabling the signal generating means in response to a first switching voltage less than the first predetermined voltage value and for disabling the signal generating in response to a first switching voltage greater than the first predetermined voltage value.

**4.** An apparatus according to claim **3** wherein the operating means further comprises:

second analog means for algebraically adding and scaling the first amplified signal and the second amplified signal to produce a second switching signal having a voltage which varies with the toner particle concentration and which has a second predetermined voltage value corresponding to a second predetermined value of the toner particle concentration less than the first predetermined value of toner particle concentration; and

second switching means for altering the signal generating means to operate the transfer means at an increased rate in response to a second predetermined voltage less than the second predetermined voltage value.

**5.** An apparatus according to claim **4** wherein the first analog means comprises a first resistor connected

to the first output and a second resistor connected to the second output.

6. An apparatus according to claim 4 wherein the signal generating means comprises a pulse generator having a control gate for producing pulses at a predetermined repetition rate.

7. An apparatus according to claim 6 wherein the first switching means comprises a transistor connected between the first analog means and the control gate.

8. An apparatus according to claim 7 wherein the second switching means comprises means for increasing the predetermined repetition rate of the pulses produced by the pulse generator.

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