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Aasen et al.

[11] **3,739,800**

[45] **June 19, 1973**

[54] **TONER SUPPLY SYSTEM FOR COPYING MACHINE**

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[21] Appl. No.: **140,051**

[52] **U.S. Cl.** **137/93**, 118/DIG. 23

[51] **Int. Cl.** **G05d 11/08**

[58] **Field of Search** ..... 137/92, 93; 118/7, 118/637, DIG. 23; 355/8, 10

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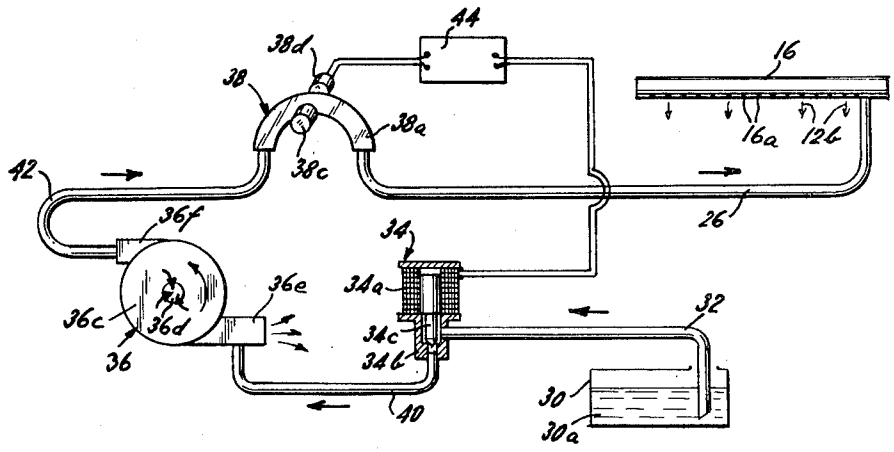
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[57] **ABSTRACT**

A system for continuously monitoring the concentration of toner in an electrostatic copying machine. The need for additional toner concentrate is detected by a photocell which receives varying amounts of light transmitted through a transparent monitoring tube positioned in the toner solution circulation path. If the toner solution has become too dilute, the photocell's resistance lowers to permit a periodically generated enabling pulse from the electronic control circuit to furnish an operating path for a positive-acting solenoid valve. Short timed bursts of toner concentrate are then added to the toner solution at spaced time intervals unitl the concentration exceeds a predetermined value; the concentrate is injected into the solution by an immersed venturi tube arrangement. A manual operating mode is also included for providing an instantaneous burst of toner concentrate independent of the detection circuitry.

10 Claims, 6 Drawing Figures



Patented June 19, 1973 3,739,800

2 Sheets-Sheet 1

FIG. 1.

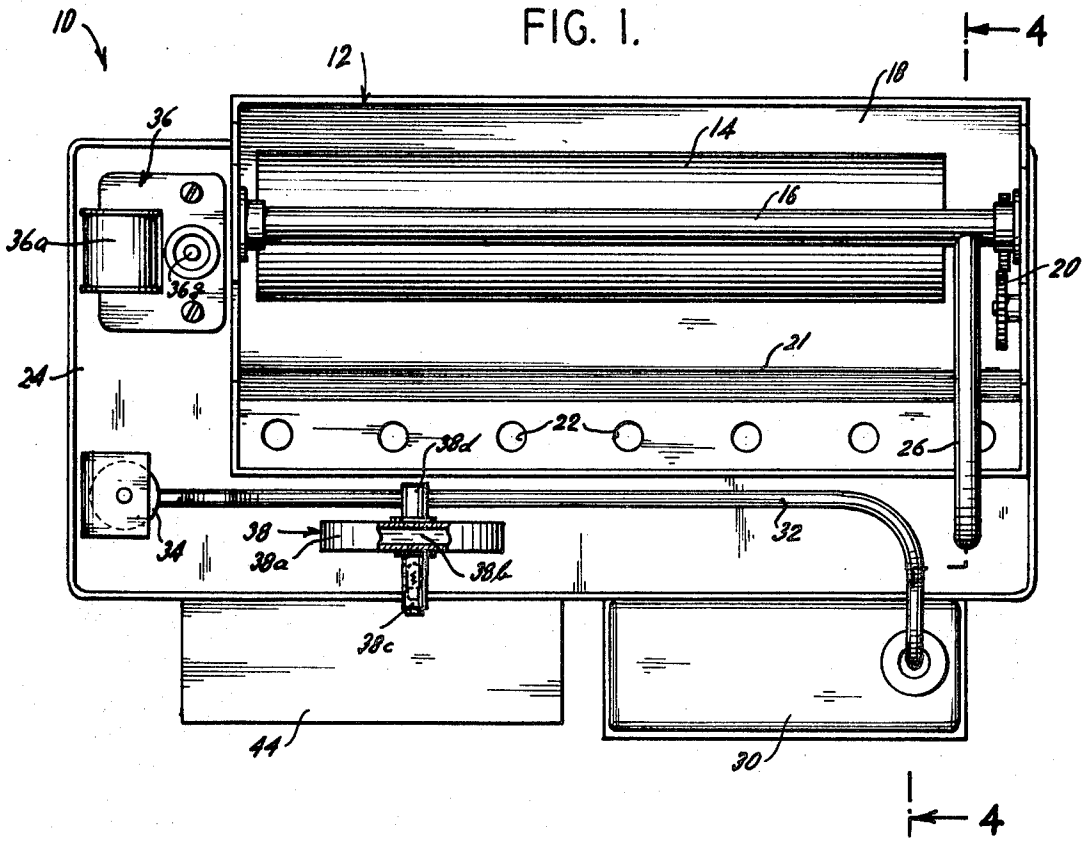
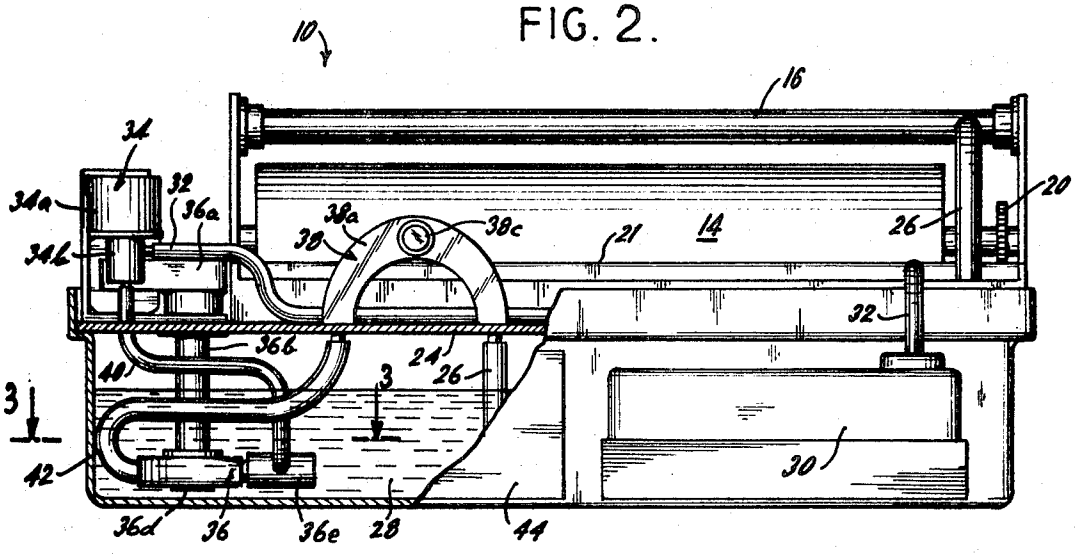


FIG. 2.



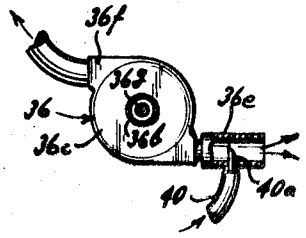


FIG. 3.

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FIG. 4.

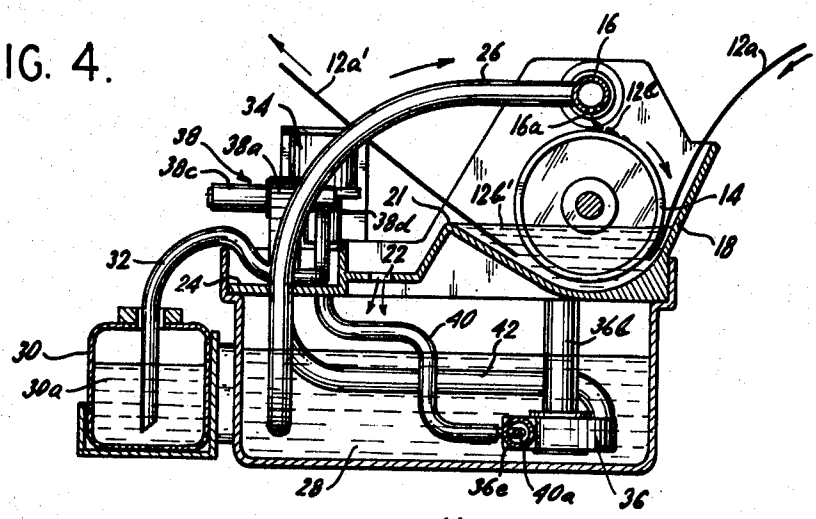


FIG. 5.

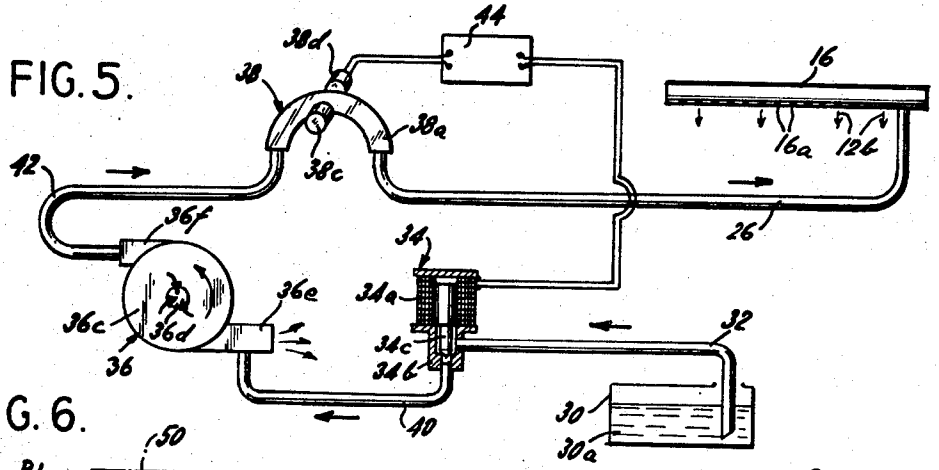
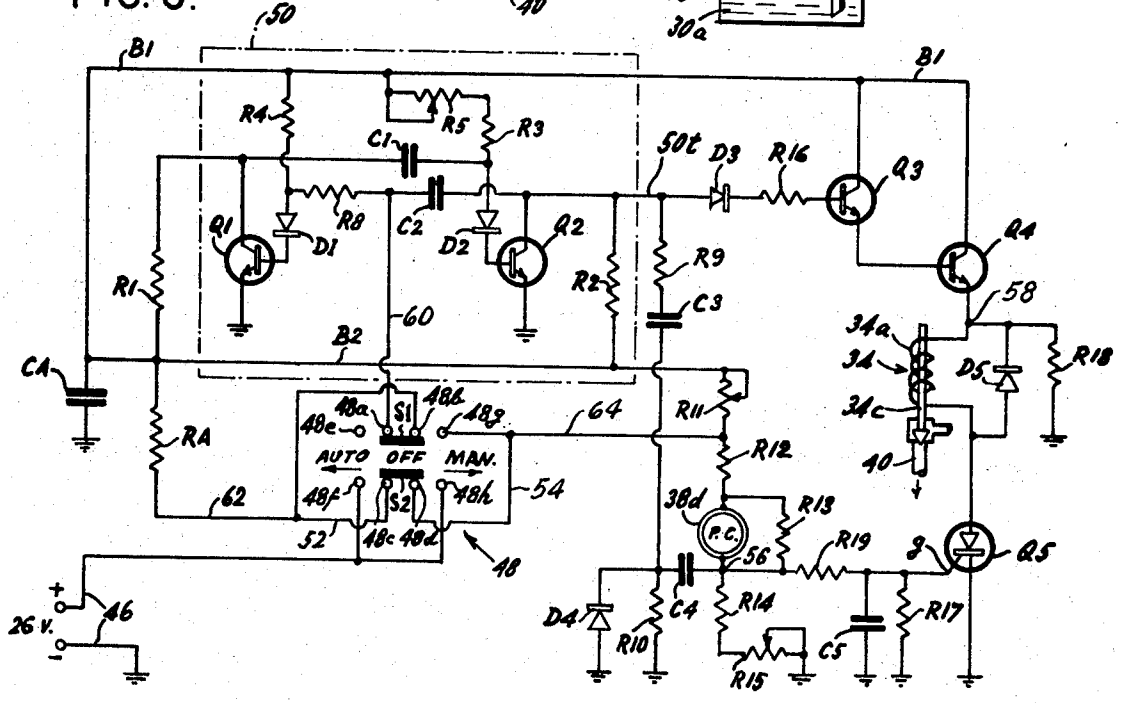


FIG. 6.



TONER SUPPLY SYSTEM FOR COPYING MACHINE

This invention relates to electrostatic copying machines, and more particularly, to such machines which include a toner or developer solution requiring periodic additions of toner concentrate thereto.

In many copying machines currently in use, the principles of electrostaticy are applied to produce the finished copy. For example, in electrostatic copying machines in which a liquid carrier is relied on to duplicate an original image, electrophotographic paper is generally utilized in the exposure step to form a pattern of electrostatic charges corresponding to the original image. Specifically, one surface of the copy paper bears photoconductive particles (e.g., zinc oxide) dispersed in a resin coating. The sensitive copy paper is then passed through a strong electrostatic field, which applies a uniform pattern of electrical charges to the opposite surfaces of the sensitive coating. During the exposure step, light reflected from the surface of the original document is received on the sensitive pick-up surface of the charged copy paper. At this time, the copy paper surface retains its original negative charge in those areas corresponding to dark (i.e., non-reflecting) image areas from the original. The non-image areas on the original reflect large amounts of light to the copy paper surface, thereby neutralizing the charged areas corresponding thereto. Accordingly, once the exposure step has been completed, the copy paper still bears negative charges only in those regions corresponding to the specific image areas on the original document.

Following the exposure step, the copy paper with the selectively located negative charges on its surface, is then fed to a trough containing a developer solution consisting of positively charged toner particles in a liquid carrier. The charged copy sheet is transported through the developing solution in the trough by means of a roller and during this transport, positively charged toner particles in the developer solution are attracted to the negatively charged image areas on the copy paper. When the developed copy paper leaves the solution, the toner particles, which have been attracted to the image areas, remain thereon and are then impregnated and fixed to the copy paper resin coating by a conventional system of squeegee rollers and forced hot-air drying. A machine of this type, with which the invention described herein can be used, is disclosed in U.S. application Ser. No. 725,390, filed Apr. 30, 1968 now U.S. Pat. No. 3,575,503, and assigned to the assignee of the present application.

Since such an electrostatic copying machine is generally used on a continuous basis to make copies, the quantity of toner particles in the developing solution will be reduced. Thus, as a charged copy sheet progresses through the trough containing the developer solution and toner particles are attracted to the charged image areas on the copy paper, toner particles are being withdrawn from the developer solution. Accordingly, the developer solution is becoming more and more diluted by the withdrawal of toner particles. After this process continues for some time, the developer solution will become so diluted that there will be insufficient quantities of toner therein to make a legible copy of an original document. While this condition will not occur immediately, an electrostatic copying machine must be prepared to take prompt, corrective action to

avoid the occurrence of such an unacceptable condition.

The prior art has certainly been aware of this problem since it is basic to the operation of electrostatic copying machines. However, the proposals put forward to deal with this problem have not been entirely satisfactory. For example, some systems provided for the introduction of additional quantities of toner particles (i.e., concentrate) on a continuing basis as long as the machine was being operated. Thus, particles of toner concentrate would be added to the developer solution at a uniform rate, without regard for possibly overloading the system, often resulting in a developing solution which was far too dark. This arrangement has proved to be unacceptable, since a copy which is too dark or perhaps smudged, is at least as unacceptable as one which is too light or even illegible. Another approach has been to provide toner to the developing solution on a selective basis, but in so doing, to utilize an input arrangement which had to be disabled by the application of specific electronic control signals — in other words, the "normal" condition would be for the system to add toner to the developer solution, while the detection of sufficient amounts of toner would then disable the toner input means. This arrangement also suffered from defects, since a failure in the electrical system caused toner to be added on a constant and uncontrolled basis to the developer solution, resulting in a developer solution which was much too highly concentrated in toner, thus giving copies which were either too dark or smudged. Such a system was also unsatisfactory in that it would often require the purging of the entire toner supply and circulation system in the event of an electrical failure. Moreover, the means utilized to introduce the toner were often susceptible of being clogged and thus precluding the introduction of toner when the electronic control system called for it.

Finally, the prior art had failed to provide any truly reliable and dependable technique to detect the precise time at which additional injections of toner would be desirable, or the deviation of such injections.

It is therefore an object of this invention to obviate one or more of the aforesaid difficulties.

It is also an object of this invention to provide dependable and positive-acting controls to replenish the toner concentration in the developer solution of an electrostatic copying machine.

It is a further object of this invention to utilize the continuously varying density of a developer solution in a copying machine to provide continuous monitoring control over the strength of the developer solution.

It is a still further object of this invention to provide "fail-safe" control over the introduction of toner concentrate to a developer solution in an electrostatic copying machine.

These and other objects and features of this invention will become apparent from a consideration of one particular illustrative embodiment of the invention in which a portion of an electrostatic copying machine is disclosed, together with a toner supply and circulation system. Generally, when the copying machine is in operation, copies are being made by the conventional electrostatic copying technique referred to above, wherein paper having photoconductive zinc oxide coating thereon is first passed through a strong electrostatic field to apply a uniform negative charge to one surface of the paper. Then, when the original document is ex-

posed to intense illumination during the exposure step, reflected light is passed to the negatively charged copy paper surface, with negative charges being retained on that surface only in the image areas to which no light has been reflected — all the other areas have their negative charges neutralized. The selectively charged copy paper then proceeds from the exposure position to the developing step.

For developing, the charged copy paper is introduced into a trough contianing the developer solution bath, with the copy paper being transported through the bath by means of a roller. In travelling through the developer, the copy paper attracts to its selectively charged areas toner particles from the developer solution. Accordingly, as copies are continuously being made by this type of electrostatic copying machine, toner particles are constantly being removed from the developer solution. If no toner concentrate were added, the copies obtained from this machine would get progressively lighter, until a point was reached where they would no longer be legible.

The system of the present invention provides for injecting such additional toner concentrate as may be necessary from time to time, into the regular circulation path of the developer solution. Normally, the ciruclation path constantly supplies developer solution to a header which is longitudinally suspended above the main roller. The header is provided with holes on its underside, such that developer solution can regularly flow through these holes onto the roller and down into the developer trough. The quantity of developer solution in the trough is maintained at a constant level by a spillway arrangement which overflows if too much developer solution is supplied to the trough, with the excess being returned to the underlying developer solution storage chamber or sump.

The circulation path for the developer solution can be considered to begin in the main sump chamber from which the solution is pumped through an outlet channel into a sensing device. The sensing device includes a transparent window and photoelectric cell arrangement which permits visualization of the density of the flowing developer solution. If there is a sufficient concentration of toner particles in the developer solution, the sensing device will be in its normal state and the control circuit will not call for the introduction of toner particles. The circulation of the developer solution then continues beyond the sensing device through conventional tubing to the header which is longitudinally suspended over the main roller.

As toner is progressively withdrawn from the developer solution by virtue of the attraction of the toner particles to the charged image areas on the copy paper being transported through the developing solution, the optical density of the developer solution is gradually being reduced. This density is continuously monitored by the sensing device and photoelectric cell arrangement, and when a reduction of the density below a predetermined tolerance level is detected, the control system responds by calling for additional bursts of toner concentrate. Based on a predetermined setting, in which a low level of optical density of the developer solution is equated with a need for toner particles, a reduction of the resistance of the photoelectric cell activates the electronic control system.

When the control system is in its "Automatic" mode, pulses of a specified duration are being generated at periodic intervals of time. However, these output pulses are only effective to lead to the introduction of additional toner particles when the foregoing resistance reduction has occurred in the photoelectric cell. At such times, the timed "call" signal is permitted to bias a trigger circuit (e.g., including a silicon controlled rectifier) into its "on" condition. As a result thereof, a control signal generated in response to the timing circuit pulse enables a controlling solenoid valve in an auxiliary branch of the developer solution circulation path. In its normal or unoperated condition, the solenoid includes a movable plunger which blocks the auxiliary path from a bottle of toner concentrate to the developer solution injection point.

However, when the control circuit enables the solenoid in response to the energization of the trigger circuit, the solenoid plunger is withdrawn from its rest position, thus establishing a path from the toner concentrate bottle to the injection point, particles of toner concentrate are thereby drawn from the bottle to the injection point, which is located at an outlet of the system's pump into the main developer solution reservoir. This "drawing" technique operates as a venturi tube, wherein the input from the toner concentrate is a small tube inserted in a narrowed portion of the pump outlet tube. The velocity of the developer solution flowing past the toner inlet tube at the pump outlet location establishes a reduced pressure at that point which serves to draw the toner concentrate into the developer solution when the toner input solenoid valve is caused to open by the trigger signal. In addition, the venturi tube is continuously immersed in developer solution, thereby precluding clogging.

The solenoid valve only remains open for so long as the control signal lasts — this is a predetermined time period to allow for the introduction of a burst of toner concentrate which would generally be sufficient to increase the concentration of the developer solution to a tolerable level, but one which would not permit excessive quantities of toner to be introduced such that copies produced thereafter would be too dark or perhaps smudged. In the Automatic mode, the trigger signals causing the injection of toner concentrate occur periodically until the detection device and photocell indicate that no more bursts of toner concentrate are required. At that time, even if the system is in its Automatic mode with timing pulses being produced normally, no toner injection will occur as long as the photocell maintains its high resistance condition indicative of an acceptable toner concentrate level in the developer solution. Since this parameter is being continuously monitored by the detection device, the injection of toner concentrate may be interrupted after any given burst when the existence of an acceptable level is detected.

In a "manual" mode of operation of the invention, toner injection is achieved by momentarily selecting the manual position of the main control switch — by so doing, the timing circuit of the control system is immediately caused to generate 2 "call" signal, overriding the detection portion of the circuit. Accordingly, the system is thereby instructed to introduce an immediate burst of toner concentrate, although this burst will also be controlled by the timing circuit to the extent of limiting the duration of the burst. Additional such bursts may be added by the operator by repeating this procedure.

It is therefore a feature of an embodiment of this invention that a positive-acting control valve blocks a toner concentrate introduction path in its normal condition, and opens said path only upon receipt of a specified control signal.

It is another feature of an embodiment of this invention that a combined pump and venturi tube arrangement is utilized to introduce toner concentrate into a developer solution.

It is a still further feature of an embodiment of this invention that timing controls are included in an electrostatic copying machine for furnishing periodic bursts of toner concentrate in an automatic mode wherein the level of concentrate in the developer solution is continuously monitored.

It is yet another feature of an embodiment of this invention that means are included in a control circuit to override the continuous monitoring of the toner concentrate level in the developer solution to provide instantaneous injections of concentrate as may be determined by an attendant.

The above brief description, as well as further objects, features and advantages of the present invention, will be more fully appreciated by reference to the following detailed description of a presently preferred, but nonetheless illustrative embodiment demonstrating objects and features of the invention, when taken in conjunction with the accompanying drawing, wherein:

FIG. 1 is a top view of an embodiment of a copying machine which incorporates the system of the invention;

FIG. 2 is a front view of the machine illustrated in FIG. 1, with portions broken away for clarity;

FIG. 3 is a fragmentary plan view of a portion of the toner injection and developer solution circulation system, taken along the line 3—3 of FIG. 2 in the direction of the arrows;

FIG. 4 is a side sectional view of a copying machine equipped with the system of the invention, taken along the discontinuous section line 4—4 of FIG. 1 in the direction of the arrows;

FIG. 5 is a partially schematic view of the developer solution circulation system and the auxiliary toner replenishing system of the invention; and

FIG. 6 is a schematic diagram of the electrical control circuit of the invention.

The present invention is adaptable for use in connection with monitoring the flow of developer solution in an electrostatic copying machine of the type disclosed in Van Auken et al., application Ser. No. 725,390 filed Apr. 30, 1968 now U.S. Pat. No. 3,575,503. Parts of this type of machine are generally illustrated in FIGS. 1 and 2, in which a machine **10** incorporating the system of the invention is disclosed. The machine **10** includes a basic developing section **12** in which is mounted longitudinal main roller **14**; in the usual manner, roller **14** is rotated at a continuous rate to advance copy paper through the developing solution and this rotation is controlled by gearing **20**. Suspended along the developer solution trough **12** and above roller **14**, is developing solution header **16**, which is supplied with developer solution through the normal circulation path of the system and which, as illustrated in FIG. **4**, continuously flows developer solution **12***b* down onto the top and rear of roller **14** by virtue of flow holes **16***a*.

As can be seen from a consideration of FIGS. **1** and **4**, the normal level of developer solution **12***b'* in trough **18** is controlled by an overflow arrangement built into the geometry of the trough; if the level of developer solution **12***b'* rises above the height of control point **21**, the solution will spill over into the overflow area and will pass, via overflow apertures **22**, back into the principal developer solution storage region or sump **28**.

The main circulation path of the developer solution can be seen by considering FIGS. **1**, **2** and **4**, illustrating the machine itself, as well as FIG. **5** representing a selective schematic diagram of the circulation system. Specifically, FIG. **5** symbolically illustrates the flowing of developer solution **12***b* onto roller **14** (not shown in FIG. **5**, but see FIG. **4**), by means of arrows **12***b*. The developer solution circulation system is operated principally in response to pump **36**, which has its motor **36***a* mounted at the upper surface of the machine on plate **24**. Motor **36***a* is connected via shaft **36***g* within tube **36***b* to pump circulation manifold **36***c*, which provides a counterclockwise circulation flow as indicated on manifold **36***c* in FIG. **5**.

Under the influence of pump **36**, developer solution is drawn into manifold **36***c* from intake **36***d*, (see three symbolic arrows in FIG. **5**) which opens directly into sump **28** (see FIGS. **3** and **4**). Pump **36** circulates the developer solution around manifold **36***c*, some of the solution entering back into the sump **28** at outlet **36***e*, with the principal portion of the circulating solution entering the recirculation system at pump outlet **36***f*. From that point, the solution is pumped through tube **42** in the direction indicated by the path arrows in FIG. **5**, and arrives at sensing device **38**.

The sensing device **38** includes transparent arch **38***a* with a window region **38***b* disposed between light source holder **38***c* and photocell module **38***d*. In the normal situation where the optical density of developer solution flowing through arch **38***a* (see FIG. **1**) is sufficiently high, indicating an adequate concentration of toner particles therein, the solution merely flows on through arch **38***a* to supply tube **26** and then to header **16**. As previously indicated, and as illustrated in FIGS. **4** and **5**, the developer solution **12***b* then flows down through holes **16***a* onto roller **14**, eventually arriving at the developer solution bath **12***b'* in trough **18**.

In one type of electrostatic copying machine to which this invention is applicable, the copy paper **12***a*, bearing negative charges at the selected image areas from the exposure step, is fed into the developer solution bath **12***b'* and transported therethrough under the influence of roller **14**. During the travel of charged copy sheet **12***a* through bath **12***b'*, particles of toner concentrate from solution **12***b'* adhere to the charged areas on copy sheet **12***a*. Thus, as the sheet reaches the end of the developer solution and is being withdrawn therefrom as indicated at **12***a'* in FIG. **4**, the paper has withdrawn a certain quantity of toner particles from solution **12***b'*. After a number of copies are made, and depending in part upon the frequency of use of the machine and the nature of the original documents which have been copied, the concentration of toner particles in the developer solution will reach an undesirably low level. This level may be pre-set in advance at slightly above the minimum level of legibility of the copy image which can be tolerated — obviously, it will be desired to avoid even slightly "illegible" copies, so that the injection of additional toner particles should occur well before the absolute minimum concentration level is reached. This will also be discussed below in connec-

tion with the initial adjustments made on the control circuit.

As to the specific operation of the toner injection arrangement, a supply of toner is included in supply bottle **30.** The toner concentration level in the developer solution had been reduced below the minimum set by the control circuit. The toner concentrate **30***a* is introduced into the main circulation system via a path including tube **32,** controlling solenoid valve **34,** inlet tube **40** and pump **36.** Normally, when no additional toner concentrate is called for, the circulation path from toner bottle **30** to pump **36** is blocked at solenoid valve **34** by the unoperated condition of the valve and the downward position of movable plunger **34***c*. However, when there is a reduction in the optical density of the developer solution below the minimum tolerance level, light passing from source **38***c* to photocell **38***d* through the solution flowing in arch **38***a* energized control circuit **44** (FIG. **5**) to activate solenoid **34.** The coil **34***a* of solenoid **34** is energized and electromagnetically responsive plunger **34***c*, contained within lower housing **34***b*, is withdrawn upwards into a temporary path-opening clearance position. At that time, the previous blockage of the circulation path between tubes **32** and **40** is no longer present.

In order to appreciate the manner in which toner concentrate is added to the system, consideration must be given to the injection apparatus at pump outlet **36***e* (FIGS. **2, 3** and **5**). Thus, when movable plunger **34***c* is withdrawn upwards, toner concentrate **30***a* is available to be drawn from toner bottle **30** all the way into sump **28.** This introduction of toner is achieved by utilizing the principle of venturi tube. Specifically, when pump **36** is in operation and circulation of developer solution is occurring in a counterclockwise direction around manifold **36***c* as previously noted, there is a flow of developer solution out into sump **28** via secondary pump outlet **36***e*.

This flow through outlet **36***e* (at a constricted portion thereof as illustrated in FIG. **3**), provides an increased developer solution velocity at that point. In accordance with well-known hydraulic principles, the increased velocity reduces the pressure at the tip of bevel-edged inlet conduit **40***a* of toner supply tube **40.** A stream of toner concentrate **30***a* is thereby drawn from toner bottle **30** into the flow of developer solution in outlet **36***e*, from which the toner concentrate and the existing developer solution are then expelled into sump **28.**

By this technique, and by the subsequent recirculation of the developer solution throughout the main circulation system, the toner concentrate is permitted to adequately disperse in the developer solution over a relatively brief period of time. This, together with the limitation on the duration of toner concentrate injection, serves to prevent too much toner from being added to the solution, which might tend to darken the solution either excessively or at least too rapidly (causing smudged copies, for example). The utilization of the venturi tube arrangement permits the toner concentrate to be conveniently and uniformly dispersed in the developer solution in sump **28;** as the newly enriched developer solution circulates, detection arrangement **38** will promptly and immediately monitor the increased density of the solution so as to determine if additional timed bursts of toner concentrate are still needed. If they are needed, the system operates to inject a toner burst as before. If no more toner concentrate is required, detection device **38** will cause its photocell **38***d* to return to its relatively higher resistance condition, thus precluding the energization of the trigger circuit and returning plunger **34***c* of solenoid **34** to its normal blocking condition. Under these circumstances, the toner injection path from tube **32** to tube **40** is closed off and no more toner concentrate can be added to the system.

It is also noted that the normal condition of injection nozzle **40***a* is immersed in flowing developer solution within pump outlet **36***e*. This arrangement prevents clogging of nozzle **40***a* by toner particles, a problem which has plagued the prior art; since the exit port of nozzle **40***a* is always "wet," no clogging of the type which has heretofore been a problem can occur.

The Control Circuit

The electronic control circuit of the invention is illustrated in FIG. **6,** with those portions of the circuit having any relationship with structure illustrated in FIGS. **1–5** bearing identical reference designations as used in those figures. Generally, the control circuit will be contained within module **44** mounted at the front of the machine **10** as illustrated in FIGS. **1** and **2.**

The circuit of FIG. **6** includes a basic voltage supply provided across conductors **46** to power the entire circuit—the illustrative circuit voltage as shown in FIG. **6** is 26 volts, but the circuit can operate equally well with different supply voltages as long as the values of the various components are adjusted accordingly.

The main control or function switch **48** of the system has three positions. When symbolic switch arm bars S1, S2 (which are mechanically coupled together) are in their normal position as illustrated in FIG. **6,** with bar S1 bridging terminals **48***a* and **48***b* and bar S2 bridging terminals **48***c* and **48***d*, the system is "Off" and no operation of the toner injection system is possible. (However, as will be explained below, part of the timing circuit discharges during the Off cycle to prepare the control circuit for subsequent operating cycles.)

When the switch is moved to the "Automatic" position, switch arm S1 bridges terminals **48***a* and **48***e*, while switch arm S2 bridges terminals **48***c* and **48***f*. During this mode of operation, the control circuit operates automatically to periodically generate timing pulses which serve to energize solenoid **34** and to inject additional amounts of toner concentrate into the developer solution as also will be explained below. Switch **48** will remain in the "Automatic" position until the attendant returns switch arms S1 and S2 to their "Off" positions.

Finally, there is the "Manual" mode of operation, in which switch arm S1 bridges terminals **48***b* and **48***g*, and switch arm S2 bridges terminals **48***d* and **48***h*. In this mode, as will be explained in more detail below, the detection circuit, including photocell **38***d*, is overridden by providing a relatively high voltage (e.g., the 26 volt supply) directly to a biasing circuit to immediately trigger an output pulse, resulting in the correspondingly immediate injection of a timed toner burst. The Manual mode is included when there is either no need or desire to wait for the timing circuit to provide the toner injection as in the Automatic mode. Because the selection of the Manual mode overrides the detection circuit, switch arms S1 and S2 are only permitted to remain in their "Manual" position if the attendant holds the switch arms (e.g., in the form of a pushbut-

ton) in that position — if the switch arms are not so held, they will return, for example by spring action, to the "Off" position. This precludes the accidental or erroneous insertion of excessive amounts of toner in the Manual mode, and also gives sufficient time for the newly injected toner concentrate to adequately disperse in the developer solution.

The Timing Circuit

The timing circuit shown within box **50** is essentially a free-running multivibrator which provides a positive output control pulse only when one of its two transistors is in a specified state. The components of the timing circuit are selected such that the critical timing pulse is provided when transistor **Q2** is in its "off" condition, a time period which can be adjusted by the setting of potentiometer **R5.**

The multivibrator **50** is activated (in either the Automatic or Manual modes) when the supply voltage is furnished, through resistor RA, to main busses **B1** and **B2.** Thus, when switch **48** is in its Automatic position, the 26 volt supply is provided to multivibrator **50** over a path including positive lead **46,** terminal **48*f*,** switch arm **S2,** terminal **48*c*,** conductor **52,** conductor **62** and to resistor RA. In the "Manual" position of switch **48,** the supply voltage is furnished to busses **B1** and **B2** over a comparable path consisting of the positive conductor of pair **46,** terminal **48*h*,** switch arm **S2,** terminal **48*d*,** conductor **54,** terminal **48*g*,** switch arm **S1,** terminal **48*b*,** conductor **62** and to resistor RA.

When the supply voltage is initially provided to bus **B1** in either the Automatic or Manual mode, transistor **Q1** will turn on, while transistor **Q2** will be maintained in its off condition. Transistor **Q1** is turned on because resistor **R4,** between the base of transistor **Q1** and voltage bus **B1,** is significantly larger than the sum of resistors **R3** and **R5** which are located between the base of transistor **Q2** and voltage bus **B1.** For example, resistor **R4** may have the illustrative value of 100 kilohms, while resistor **R3** is 4.7 kilohms and potentiometer **R5,** even at its maximum setting, is 20 kilohms. Thus, when multivibrator **50** is initially activated, there will be a relatively greater voltage level at the base of transistor **Q1,** and that transistor will turn on. In so doing, ground is applied through the emitter-collector path of transistor **Q1** and beyond capacitor **C1** (which cannot charge instantaneously) and diode **D2** to the base of transistor **Q2,** thus "clamping" transistor **Q2** in the off condition by the application of a negative pulse to its base.

An output timing control signal will be provided from multivibrator **50** on output lead **50*t*** as long as transistor **Q1** remains on and transistor **Q2** remains off. This pulse is furnished at lead **50*t*** by virtue of the relatively high impedance of transistor **Q2** in the off state — accordingly, at the junction of resistor **R2** and the collector of transistor **Q2,** the sudden appearance of a voltage substantially equal to the supply voltage (less the drop across resistor RA) will result in the provision of a positive pulse on output lead **50*t***. The dual effect of this output signal will be described below in connection with the operation of the pulse-forming network and the trigger circuit.

As soon as transistor **Q1** turns on, with transistor **Q2** being maintained off and the output aiming signal being present on lead **50*t***, capacitor **C1** (in the timing circuit for transistor **Q1**) begins to charge towards the supply voltage. Specifically, the charging path includes ground, the emitter-collector path of transistor **Q1,** capacitor **C1,** resistor **R3,** potentiometer **R5** and to the supply voltage through the previously traced path via resistor RA. Following the passage of the charging time period for these resistors and capacitor (e.g., 3 seconds), the base turnon voltage for transistor **Q2** will be reached and transistor **Q2** will be reached and transistor **Q2** will be placed in its conducting state. When this occurs, ground from the emitter of transistor **Q2** will be applied, via the collector of transistor **Q2** and through capacitor **C2** (instantaneously), resistor **R8** and diode **D1,** to the base of transistor **Q1.** The application of ground to the base of transistor **Q1** serves to drive that point sharply negative relative to the positive voltage which had appeared at that point up to that time. Accordingly, transistor **Q1** is immediately turned off. When transistor **Q2** has turned on, the positive pulse on output lead **50*t*** is terminated; although a negative pulse now appears on that lead, such negative pulse will have no effect on the remainder of the circuit, since it will be short-circuited to ground through diode **D4.**

When transistor **Q2** is on, its timing capacitor **C2** begins to charge towards the supply voltage level over the path including ground, the emitter-collector path of transistor **Q2,** capacitor **C2,** resistors **R8** and **R4** and dropping resistor RA. When the charging of capacitor **C2** exceeds the turn-on voltage of transistor **Q1,** transistor **Q1** turns on and this causes transistor **Q2** to turn off because of the application of ground from the emitter of transistor **Q1** through the emitter-collector path of transistor **Q1,** capacitor **C1** (instantaneously), diode **D2** and to the base of transistor **Q2.** The turning off of transistor **Q2** thereby terminates the negative pulse on output lead **50*t*** and commences the generation of the positive pulse at that location, representing the jump from ground to approximately 26 volts. The cycle of multivibrator **50** thereupon commences anew and will continue as previously described in free-running fashion for so long as selector switch **48** is in its "Automatic" position.

By the appropriate selection of values for capacitor **C1** and resistors **R3** and **R5** (relating to the on time of transistor **Q1**) and of capacitor **C2** and resistors **R4** and **R8** (relating to the on time of transistor **Q2**), the total period of multivibrator **50** and the individual periods of on time for transistors **Q1** and **Q2** are established. Illustratively, the total period of multivibrator **50** can be approximately 15 seconds, with transistor **Q1** being on to provide the positive output control signal at output lead **50*t***) for approximately 3 seconds, and with transistor **Q2** being on for approximately 12 seconds. These time periods are purely illustrative, but for the sake of clarity, they will be assumed to exist in the system for the remainder of this description.

The Toner Injection Trigger Circuit

As has been previously explained in connection with **FIGS. 1–5,** additional toner concentrate **30*a*** will be withdrawn from bottle **30** and transported over tubes **32** and **40** to pump outlet **36*e*** only when movable plunger **34*c*** of solenoid valve **34** is elevated to its upper non-blocking position between tubes **32** and **40.** The movement of plunger **34*c*** is controlled by a trigger circuit which is energized in response to the 3-second positive output signal appearing at lead **50*t***. This signal is passed to the base of transistor **Q3** via diode **D3** and resistor **R16.** The application of the positive pulse to the

base of transistor Q3 turns that transistor on; the resulting signal at the base of transistor Q4 (from the emitter of transistor Q3) turns on transistor Q4. Transistors Q3 and Q4 act together as a "Darlington pair" to achieve current amplification, and an output signal is provided at the emitter of transistor Q4 when the pair of transistors is turned on as indicated above.

When transistor pair Q3, Q4 is on, the voltage on bus B1 (essentially +26 volts) is applied through the collector-emitter path of transistor Q4 to the junction point of coil 34*a*, diode D5 and resistor R18. Diode D5 functions to suppress any transient pulses which may appear in the output signal supply from the emitter of transistor Q4; resistor R18 is an auxiliary resistor which provides a direct path to ground if silicon controlled rectifier Q5 (the operation of which will be described below) is not "on" at the time the output signal from Q4 is generated. Such a ground path acts as constant input impedance to load down the output of transistor pair Q3, Q4 and thus acts as a load on multivibrator 50 — this stabilizes the circuit and provides constant load impedance regardless of the on or off condition of SCR Q5. If SCR Q5 has not been triggered on when transistor Q4 provides its output signal, that signal will pass to ground through resistor R18.

If, on the other hand, SCR Q5 has been triggered into its on condition by an appropriate triggering signal at its gate electrode *g* (to be explained below), a complete energizing path to ground is provided from the emitter of transistor Q4 through coil 34*a* of solenoid 34 and through the anode-to-cathode path of SCR Q5. This electromagnetically energizes coil 34*a* and attracts plunger 34*c* upward, establishing an unblocked circulation path for toner concentrate 30*a* from tube 32 to tube 40 and into the developer solution via pump outlet 36*e*. As long as plunger 34*c* remains in its elevated position, toner can be withdrawn from bottle 30 and is passed along the previously traced path to pump outlet 36*e* by virtue of the venturi tube effect previously described. This toner injection interval will therefore last for as long as solenoid 34*a* is energized by the passage of current from transistor Q4 to ground through coil 34*a* and SCR Q5 — this condition will endure as long as there is a positive output timing signal on lead 50*t*, approximately 3 seconds as assumed above.

When the positive output timing signal at lead 50*t* terminates and is replaced by a negative signal (indicative of the turning on of transistor Q2 and the turning off of transistor Q1, e.g., for the next 12 seconds), the negative pulse at the base of transistor Q3 turns off that transistor and its dependent transistor Q4. The de-energization of transistor Q4 deprives coil 34*a* of its energizing current and thus permits plunger 34*c* to return to its rest position, thereby blocking the path between tubes 32 and 40. At this time, therefore, the injection of toner concentrate into sump 28 from pump outlet 36*e* is also terminated.

The Voltage Level and Pulse-Forming Networks

As has been noted previously, the toner injection circuit of this invention operates when SCR Q5 is energized to permit a current pulse to pass to ground through coil 34*a* of solenoid 34. The triggering of SCR Q5 is controlled by the application of a suitable voltage level to gate electrode *g* of SCR Q5. The signal presented to gate electrode *g* is the combination of a base voltage level and a smaller voltage spike superimposed on the base level. The base voltage is established by a voltage divider consisting of potentiometer R11, resistor R12, resistor R13 in parallel with the resistance of photocell 38*d*, resistor R14 and potentiometer R15. The energizing voltage appearing at terminal 56 is fed through dropping resistor R19 to gate electrode *g*. However, as noted above, the system of the invention does not use a steady state d-c voltage to trigger SCR Q5. Instead, a periodically occurring pulse or spike, which is dependent upon the existence of the appropriate output timing signal on lead 50*t*, is superimposed on the d-c voltage level at point 56 to provide the final triggering effect for SCR Q5.

The base voltage level which is supplied to gate electrode g is the voltage appearing on bus B2 (the supply voltage less the drop across resistor RA) as divided at terminal 56 by the previously mentioned voltage divider. Specifically, it can be seen from FIG. 6 that the voltage between bus B2 and ground is dropped across potentiometer R11, resistor R12 and resistor R13 (in parallel with photocell 38*b*) to develop the critical voltage at terminal 56; the remainder of the voltage divider path to ground is through resistor R14 and potentiometer R15. In practice, the settings of potentiometers R11 and R15 are determined initially (as explained below) and remain generally constant throughout the cyclical operaton of the system. The only variable in the voltage divider during such operation is the resistance of photocell 38*b*.

When the optical density of the developer solution flowing through arch 38*a* and past window region 38*b* (FIGS. 1 and 2) is sufficiently high, the amount of light transmitted therethrough from source 38*c* and thus detected by photocell 38*d* will be relatively low. This will cause photocell 38*d* to remain in its relatively high resistance condition, with approximately 50 K ohms across its output terminals. When the optical density of the developer solution decreases as toner concentrate particles are withdrawn during successive developing steps, increasing amounts of light will be detected by photocell 38*d*; accordingly, the resistance of photocell 38*d* across its output terminals (in parallel with resistor R13 in FIG. 6) will correspondingly decrease.

When photocell 38*d* is in its relatively high resistance condition, indicating no need for additional toner, the circuit parametersare such that the voltage at terminal 56 (and at gate electrode g of SCR Q5), is insufficient to turn on SCR Q5, even when an additional voltage spike is superimposed —— this precludes the passage of an enabling pulse from transistor Q4 through coil 34*a* of solenoid valve 34. Any current pulse produced by the turning on of transistor Q4 is diverted to ground through resistor R18. In this situation, the path between tubes 32 and 40 remains blocked and no additional toner concentrate can pass from toner bottle 30 into developer solution sump 28. However, when the resistance of photocell 38*d* lowers sufficiently in response to a reduction in the optical density of the developer solution passing through arch 38*a*, the voltage on bus B2 will establish a relatively higher potential at terminal 56 which, when passed to gate electrode *g* of SCR Q5 will be quite close to the turn-on voltage for the latter device — however, the actual triggering of SCR Q5 will await the superimposed voltage spike resulting from the control signal on lead 50*t*, to be described below.

Initial adjustments are made in the voltage divider to provide for predetermined limits which are equated with the maximum and minimum concentrations of toner in the developer solution. When only the minimum concentration is present, the system should provide a sufficient combined voltage on lead *g* to trigger SCR Q5 and thus result in the injection of additional toner particles into the developer solution. On the other hand, when a toner concentration in excess of the minimum tolerable value is achieved (e.g., by infrequent machine use or by injection of new bursts of toner concentrate), the system must be set so that the base voltage supplied by the voltage divider to gate electrode *g* will not be sufficient, even when the timing pulse is superimposed thereon, to trigger SCR Q5.

In order to make these adjustments, a typical procedure would be to set switch **48** at its "Automatic" position, which will thereby connect the +26 volts supply from leads **46** to bus **B2.** Assuming the developer solution in the system is at its maximum concentration level (e.g., 16 cubic centimeters of toner per quart of solution), both potentiometers **R11** and **R15** are initially set to their full "out" position — i.e., both potentiometers are set to have zero resistance across their terminals. Since this will result in a relatively low resistance in the upper branch of the voltage divider (that portion which is above terminal **56** in FIG. **6**), the voltage level at terminal **56** and thus at gate electrode *g*, will be relatively high; this voltage will be sufficient, when the relatively small magnitude timing pulse is added to it, to trigger SCR Q5, despite the relatively high resistance of photocell **38***d* which exists when the developer solution exhibits a high optical density.

In making the initial "maximum" adjustment, potentiometer **R11** is gradually adjusted to insert its resistance into the voltage divider circuit. Assuming the optical density of the developer solution remains at its maximum level through the adjustment step, the introduction of additional resistance from potentiometer **R11** will cause the voltage level at terminal **56** to gradually be reduced. The final setting of potentiometer **R11** is based on the reduction of the voltage level at terminal **56** to the point where the level will no longer be effective to energize SCR Q5 from its gate electrode *g*. Typically, this setting will occur when potentiometer **R11** has a resistance of approximately 5 K ohms out of a maximum setting of 6.8 kilohms.

After the foregoing "maximum" setting has been made on potentiometer **R11,** the "minimum" setting is made based upon the presence of the lowest tolerable concentration of toner particles in the developer solution (e.g., 3 cubic centimeters of toner particles per quart of developer solution). With such a minimum concentration solution present in the system, low level potentiometer **R15** is gradually adjusted from its maximum rating to withdraw resistance from the voltage divider circuit, thus gradually reducing the voltage at terminal **56.** At some point during this adjustment step, despite the relatively low resistance value across the terminals of photocell **38***d* in the presence of a low optical density for the developer solution, the setting of potentiometer **R15** will be such that the voltage level supplied to gate electrode *g* will not be sufficient to trigger SCR Q5. When this "no call" condition is reached in the adjustment of potentiometer **R15,** this is taken as the "minimum" setting for that potentiometer — each time that the concentration of toner particles in the developer solution reaches a value of 3 cubic centimeters per quart of solution or less, the voltage at terminal **56** will be sufficient when coupled with the low magnitude timing pulse) to turn on SCR Q5 at its gate electrode *g*. A typical "minimum" setting for potentiometer **R15** is 100 ohms of its maximum setting of 300 ohms.

The Pulse-Forming Network

The relatively low magnitude spike or pulse which is super-imposed on the d-c voltage level which exists at terminal **56** is generated by a resistor-capacitor pulse-forming network including resistor **R9,** capacitor **C3,** resistor **R10** and capacitor **C4.** It has already been noted that when the transistor Q2 turns off, a positive timing signal will appear on lead **50***t*. This positive voltage step on lead **50***t* is differentiated by the RC network just mentioned, and a small positive voltage spike is therefore presented to terminal **56.** This spike is applied to gate electrode *g* of SCR Q5 through lead-in resistor **R19,** and if the combined magnitude of the spike and the base d-c voltage level at gate electrode *g* is sufficiently high, SCR Q5 will be triggered into its on condition.

The components of the pulse-forming network are chosen such that the presence of a positive voltage step of nearly 26 volts on lead **50***t* will result in a voltage spike of approximately 0.1 volt at gate electrode *g*. In particular, the resistance of resistor **R9** will be sufficiently high so as to appropriately limit the amplitude of the voltage spike supplied to gate electrode *g*. In determining the base voltage on which the spike is superimposed, it is first assumed that photocell **38***d* is exhibiting its high resistance condition in response to relatively little light being transmitted through the developer solution flowing through arch **38***a* (i.e., no injection of toner particles required). The combined series resistance in the voltage divider is that of potentiometer **R11** (when set at 4 K ohms), **R12** (3.3 K ohms) and the parallel combination of photocell **38***d* (> 12 K ohms) and resistor **R13** (10 K ohms), amounting to a total greater than 12.8 K ohms; the remainder of the voltage divider to ground consists of **R14** (220 ohms) and potentiometer **R15** (set at 125 ohms). It will thus be appreciated that under these conditions with no additional toner concentrate being desired, the base voltage level at **56** will be a fraction of 26 volts (less than 350/13,100) such that terminal **56** exhibits a voltage level of approximately 0.70 volts. Note that **R16** and **R17** form another voltage divider and this reduces the voltage at *g* to a fraction (5.6K/7.8K) of the voltage at **56,** i.e., slightly less than 0.50 volts. Since the maximum magnitude of the spike generated by the pulse-forming network is 0.1 volts at *g*, the maximum total voltage appearing at g is slightly less than 0.60 volts. Since a voltage level of at least 0.60 volts is required at *g* to trigger SCR Q5 on, it can be readily seen that under the above described conditions SCR Q5 will not turn on.

However, as more and more light begins to be transmitted through the flowing developer solution, the resistance of photocell **38***d* will drop. Assuming the same potentiometer settings as indicated above, a critical point will come when the resistance across the terminals of photocell **38***d* reaches approximately 10 K ohms. The parallel combination of that value with the 10 kilohm value of resistor **R13** will yield an equivalent resistance of approximately 5 K ohms. The voltage divider will therefore establish a voltage level of approxi-

mately 0.73 volts (350/12,500 × 26) at terminal **56** and a corresponding level of 0.52 volts at gate electrode *g*. This base voltage level establishes a plateau from which SCR Q5 can be triggered on when the voltage spike is generated by the pulse-forming network. Since the magnitude of that pulse is approximately 0.1 volt, the combined voltage level of approximately 0.62 volts is sufficient to turn on SCR Q5 and thus energize solenoid valve **34** as previously described.

The enabling voltage spike is created by the positive-going step signal generated on lead **50***t* when transistor Q2 turns off; when transistor Q2 turns on approximately 3 seconds later, a negative-going pulse appears on lead **50***t* which will also be differentiated by the pulse-forming network. However, diode D4 will act to shortcircuit that negative spike to ground, thus preventing it from interfering with the triggering circuit.

It is also noted that the use of this "combination" voltage approach for triggering SCR Q5 serves to reduce the chances that noise or other spurious signals will energize SCR Q5 at gate electrode *g*. Thus, in addition to protecting SCR Q5 from the direct application of a possibly excessive d-c voltage, the circuit establishes an interval, equivalent to the duration of the positive pulse on lead **50***t*, during which SCR Q5 can possibly be triggered on. When that pulse terminates as transistor Q2 turns on, the ground level from the emitter of transistor Q2 is connected through its emitter-collector circuit and via resistor R2, to bus B2, thus clamping that bus at ground level. This effectively terminates the period during which the appearance of the voltage spike from the pulse-forming network can be effective to trigger on SCR Q5. But during the effective period when the voltage divider is operative and, assuming a need for a toner burst, the base voltage level at gate electrode *g* will be perhaps 0.1 volts away from the triggering voltage. The generation of undesirable transients and noise signals at gate electrode *g* will only serve to inadvertently trigger on SCR Q5 if those signals are in excess of 0.1 volt, the normal magnitude of the voltage spike of the pulse-forming network. Since those transients are not likely to have that magnitude, there is almost no likelihood of improperly energizing SCR Q5 in response to a spurious signal, and thus giving a toner burst when none is required by the system.

Finally, it is also noted that capacitor C5, connected between resistor R19 and ground, serves also to short circuit any noise which might otherwise be directed to gate electrode *g* of SCR Q5; and resistor R17 acts as a conventional gate resistor for SCR Q5, allowing for leakage of anode-to-gate current to ground.

The Automatic Mode

The system of this invention can operate either in an Automatic or a Manual mode. In order to select the Automatic mode, function switch **48** is set to its left position, thus placing switch arm S1 across terminals **48***a* and **48***e*, and switch arm S2 across terminals **48***c* and **48***f*. Switch **48** is arranged to permit switch arms S1 and S2 to remain in their "Automatic" setting for an indefinite period of time — the system permits this position to last indefinitely since the timing and detection circuitry will automatically prevent unnecessary or excessive bursts of toner particles from being added to the developer solution.

When switch arms S1 and S2 are placed in the "Automatic" positions as just described, the +26 volt d-c supply will be connected to various components of the circuit across the upper conductor of pair **46**, terminal **48***f*, switch arm S2, lead **52** and to resistor RA. Resistor RA is connected to bus B1 which controls the supply for multivibrator **50** and for current amplifying transistor pair Q3, Q4; resistor RA is also connected to bus B2 to supply the voltage divider which establishes the base voltage level utilized in the triggering of SCR Q5. Upon placing switch **48** in the "Automatic" position, thereby supplying essentially +26 volts to bus B1, the previously specified values of resistors R4 (supplying voltage to the base of transistor Q1) and R3 and R5 (supplying voltage to the base of transistor Q2), result in the turning on of transistor Q1. As previously described, transistor Q2 is thus clamped in its off condition by the application of ground from the emitter-collector circuit of transistor Q1.

On an instantaneous basis, the voltage present at the collector of off transistor Q2 is practically equal to the supply voltage of +26 volts d-c (whether considered from bus B1 or bus B2). Accordingly, the voltage at that point (and thus at output conductor **50***t*) has jumped from essentially zero (when the circuit if off) to +26 volts, thus creating a positive voltage step on lead **50***t*. This signal will last for approximately 3 seconds, the predetermined time period set by the RC circuit comprising resistor R3 in series with potentiometer R5 together with capacitor C1 — this RC circuit starts to charge at the beginning of the cycle. The positive output of approximately 26 volts in magnitude will remain on lead **50***t* for the charging period of that RC circuit, until the turn-on voltage for transistor Q2 is reached — it will be assumed herein that transistor Q2 turns on 3 seconds after the initial energization of the circuit.

The appearance of the positive output control signal on lead **50***t* causes a number of responsive actions by the circuit. The positive input through diode D3 and resistor R16 to the base of transistor Q3 turns that transistor on, and the collector-emitter current flow in transistor Q3 drives the base of transistor Q4 positive into saturation, turning the latter transistor on as well.

This applies a 26 volt positive potential from bus B1 through the collector-emitter circuit of transistor Q4 to terminal **58**. If SCR Q5 has been triggered on by this time, indicating a need for additional toner particles, the positive potential from terminal **58** will be connected to ground over a path including solenoid coil **34***a*, and the anode-to-cathode path of SCR Q5; if SCR Q5 has not been triggered on, indicating no immediate need for a burst of toner particles, the positive potential at terminal **58** will be diverted to ground through resistor R18.

The two other operative results of the appearance of the positive control signal on lead **50***t* relate to the previously described pulse-forming network and the voltage divider. If it is initially assumed that the developer solution in the machine has sufficient toner particles to make legible copies (e.g., the concentration of toner in the solution is greater than 3 cubic centimeters per quart), the system is arranged not to call for the injection of additional toner particles. Thus, when the toner concentration is greater than the predetermined minimim setting, relatively lesser amounts of light will be transmitted through the solution flowing through transparent arch **38***a*, and photocell **38***d* will therefore exhibit a relatively high resistance (e.g., 30 K ohms)

across its output terminals. The other components of the voltage divider, in combination with this high resistance level of photocell **38***d* (in parallel with resistor **R13**), will establish a voltage at terminal **56** of perhaps 0.60 volts, a level which is far too low to trigger SCR Q5 at its gate electrode *g*. Thus, even though the appearance of the positive control signal on lead **50***t* will create a voltage spike of approximately 0.1 volts via the pulse-forming network previously described, the base d-c voltage level at terminal **56** is so low (since most of the voltage on bus **B2** will be dropped by the series combination of potentiometer **R11**, resistor **R12** and the high resistance of photocell **38***d*), that no triggering of SCR Q5 can possibly take place. Accordingly, the positive potential from bus **B1**, supplied to terminal **58** through the collector-emitter path of transistor **Q4**, will be ineffective to energize the coil **34***a* of solenoid **34**, instead being diverted to ground through resistor **R18**.

However, as document copies are made and toner particles are withdrawn from the developer solution, the concentration of toner in the solution gets lower and lower and begins to approach the minimum tolerance level. This minimum level, which was preset by adjusting potentiometer **R15** as described above, is ultimately reached at some point in the further operation of a machine incorporating the invention. At this time, the optical density of the developer solution flowing through arch **38***a* is reduced to a point at which light transmitted therethrough from source **38***c* falls on photocell **38***d* in relatively large quantities. This causes the resistance of photocell **38***d* to drop appreciably, for example to 10 K ohms. At this moment the division of the voltage from bus **B2** to ground changes such that less voltage is dropped across the resistance branches above terminal **56** in FIG. **6**. Accordingly, the voltage at terminal **56**, which establishes the base level upon which the voltage spike will be superimposed, is much higher than it was previously, and can illustratively be considered to have the value of about 0.73 volts. Then, when the voltage spike of approximately 0.1 volts, attributable to the positive-going step of the control signal appearing on lead **50***t*, is generated, the combined voltage signal at gate electrode *g* of SCR Q5 through resistor **R19**, will be approximately 0.62 volts or perhaps somewhat greater, thus causing SCR Q5 to be triggered into its on state.

With SCR Q5 triggered on, the positive potential from bus **B1** appears at terminal **58** and establishes a current path to ground over coil **34***a* and through the anode-to-cathode path of SCR Q5. This energization of coil **34***a* electromagnetically withdraws plunger **34***c* from its rest position and unblocks the path between tubes **32** and **40** in the auxiliary toner supply system. Toner particles from bath **30***a* are therefore drawn from bottle **30**, through tube **32**, into tube **40** via unblocked valve **34** and from tube **40** into pump outlet **36***e*. As indicated in FIG. **5**, the counterclockwise action of pump **36** in manifold **36***c* causes the dispersal of the toner concentrate particles into main sump **28**. The injected toner particles therefore enter the developer solution circulation system and circulate from sump **28**, through pump **36**, tube **42**, detecting device **38**, supply tube **26** and to header **16**. As previously explained, the developer solution then flows through holes **16***a* onto roller **14** and ultimately overflows peak **21** and returns to sump **28** through holes **22**.

The injection step lasts as long as plunger **34***c* remains withdrawn from its rest position by the electromagnetic action of coil **34***a*. This, in turn, is controlled by the length of time that SCR Q5 stays on, which will be for so long as a sufficient current flow takes place from bus **B1** through transistor **Q4**, coil **34***a* and SCR Q5. More specifically, transistor Q4 will remain on, in response to the on state of transistor Q3, throughout the duration of the positive control signal on lead **50***t*. As assumed herein, that signal lasts while transistor Q1 is on and transistor Q2 is off, approximately 3 seconds. Accordingly, the termination of the toner burst will be initiated by the action of multi-vibrator **50** when transistor Q2 turns on and transistor Q1 turns off. The application of ground to lead **50***t* turns off transistors Q3 and Q4 and interrupts the current flow through coil **34***a* when SCR Q5 turns off. The de-energization of solenoid coil **34***a* permits plunger **34***c* to return to its rest position, blocking the toner particle circulation path between tubes **32** and **40**. This ends the first toner burst.

If this single injection of toner particles into the developer solution is sufficient to increase the toner concentration therein beyond the minimum tolerance level, there will be no additional bursts for awhile. As multi-vibrator **50** continues its timing operation, transistor Q2 will stay on for approximately 12 seconds, thus preventing any further toner bursts for at least that interval. However, when transistor Q1 again turns on, thus turning off transistor Q2, the cycle repeats, beginning with establishing an available current flow through coil **34***a*. However, such current flow will only be effective to add still further toner particles to the circuit if SCR Q5 is triggered on. This is controlled, as described above, by the combined action of the voltage divider and the pulse-forming network. Depending upon the effect of the initially injected toner particles on the optical density of the developer solution, the resistance of photocell **38***d* may have risen sufficiently such that more voltage is dropped in that portion of the voltage divider above terminal **56**; in this event, the base voltage level at terminal **56** will be insufficient, even when the small voltage spike from the pulse-forming network is superimposed thereon, to trigger SCR Q5 on. SCR Q5 will therefore remain off and coil **34***a* of solenoid valve **34** will not be energized, thus continuing the normal blockage between tubes **32** and **40**. No toner particles will therefore be injected into the developer solution if the first injection of toner particles was sufficient to adequately increase the concentration of toner in the solution.

However, it is quite possible that the first injection of toner particles will not be sufficient to increase the concentration of toner particles in the developer solution beyond the minimum tolerance level. This will be detected by the system as the developer solution flows through transparent arch **38***a*, and relatively large amounts of light will still be detected by photocell **38***d* from source **38***c*. The resistance of photocell **38***d* will therefore not be appreciably greater than its value at the time of the initial toner burst and a sufficiently larger proportion of the voltage from bus **B2** to ground will be dropped by the upper portion of the voltage divider to establish a relatively higher base voltage level at terminal **56**. Under these conditions, when the voltage spike is superimposed on that voltage level from the pulse-forming network, the voltage at terminal **56**

will, when fed to gate electrode *g* over resistor R19, be sufficient to again trigger SCR Q5 into its on state. The system therefore goes through the exact same toner particle injection step as described above, which step lasts for the same approximately 3 second time period. When transistor Q2 turns on, thus terminating the control signal on lead **50***t*, the injection step is terminated.

The injection steps continue periodically, with additional toner particles being injected into the developer solution from pump outlet **36***e* into sump **28**, on a periodic basis until such time as the minimum tolerance level as detected by device **38** is exceeded. When that point of toner concentration is reached, the resistance of photocell **38***d* is sufficiently large (e.g., >12K ohms) that the base d-c level at terminal **56** will no longer be sufficient to turn on SCR Q5 when the voltage spike of 0.1 volt appears at *g*. Additional document copies can now be made and when the concentration of toner in the developer solution again becomes too low, the injection steps will be initiated. In the meantime, as long as the system is in its Automatic mode, multivibrator **50** continues to operate and provide control pulses to lead **50***t*; no toner injection bursts will occur, however, as long as SCR Q5 is not triggered on.

The Manual Mode

The Automatic mode described above is maintained on a continuing basis, generally throughout the normal operation of the copying machine incorporating the system of the invention. However, either when the machine is turned off (e.g., overnight), or at any other suitable time, the next series of cycles of the machine may be commenced either in the Automatic mode or the Manual mode. Quite often, the Manual mode will be utilized when an operator observes that an initial document copy in any run is grossly illegible, meaning that for some reason, the concentration of toner in the developer solution has fallen below the minimum tolerance level. While it is also true that the Automatic mode of the invention will ultimately compensate for this condition, there are times when it is desired to rectify this situation immediately, without waiting for the Automatic mode to achieve this rectification through the normal detection and timing circuitry described above.

Prior to placing switch **48** in its "Manual" position, the switch will be in the "Off" position, which is that illustrated in FIG. **6**. Thus, switch arm **S1** will be bridging terminals **48***a* and **48***b* and switch arm **S2** will be bridging terminals **48***c* and **48***d*. This "Off" position of switch **48** is significant insofar as it permits multivibrator **50** to be reset (by the discharging of capacitor **C2**, allowing transistor Q1 to turn on prior to transistor Q2), preparatory either to restarting the machine in the Automatic mode or, as will be described hereinafter, in the Manual mode. Specifically, it is important that when the Manual mode is initially selected, the system immediately responds by injecting a toner burst without waiting for the timing circuitry to produce the normal 3 second timing pulse which will ultimately appear on lead **50***t*. Thus, if multivibrator **50** were not reset prior to selecting the Manual mode of operation, as much as 12 seconds of the 15 second period of multivibrator **50** might have to elapse before the system would receive a burst of toner. Moreover, since the "Manual" position of switch **48** can only be maintained by the operator's depressing the switch (e.g., a spring-loaded push button), resetting multivibrator **50** obviates the need for the operator to keep the button depressed against the urging of the spring throughout any "waiting period" — instead, a toner burst will occur as soon as the button is first depressed.

Accordingly, when switch **48** is in its "Off" position (as illustrated in FIG. **6**), capacitor **C2** is permitted to discharge to reset multivibrator **50**. Specifically, whatever charge is present on capacitor C2 leaks off over a path including conductor **60**, terminal **48***a*, switch arm **S1**, terminal **48***b*, jumper lead **52**, terminal **48***c*, switch arm **S2**, terminal **48***d*, jumper **54**, conductor **64** and through a resistance path to ground including resistor **R12**, resistor **R13**, resistor R14 and potentiometer **R15**. (Because of the connection of resistor **R13** in parallel across the output terminals of photocell **38***d*, the discharge path to ground is complete regardless of the energization state of detecting device **38**.) Even assuming that capacitor C2 was fully charged at the moment when switch **48** was placed in its "Off" position, it will only take a few seconds for capacitor C2 to become fully discharged and thus ready for the commencement of the Manual mode of operation. In practice, the system will always be in the "Off" condition for at least that period of time.

Following the discharge of capacitor **C2**, switch **48** is moved from its "Off" position to its right or "Manual" position. Multivibrator **50** is then energized by the +26 volt source across conductors **46** in substantially the same manner as in the Automatic mode. Thus, 26 volt positive potential is applied to bus **B1** over a path including terminal **48***h*, switch arm **S2**, terminal **48***d*, jumper **54**, terminal **48***g*, switch arm **S1**, terminal **48***b*, and lead **62** to resistor RA, which connects to both bus **B1** and to bus **B2**. Accordingly, multivibrator **50** will be activated in the same manner as described above, with transistor Q1 turning on first and transistor Q2 remaining off. Thus, at the outset of operation in the Manual mode, the positive step control signal will appear on lead **50***t* to energize the driving circuit for solenoid coil **34***a* via transistors Q3, Q4.

However, the pulse-forming network and voltage divider (including photocell **38***d*) do not play the same role in the system under the Manual mode as they did in the Automatic mode. Specifically, the pulse or voltage spike which was superimposed on the base d-c voltage level at terminal **56** to energize SCR Q5 via gate electrode *g* in the Automatic mode, is not utilized in the Manual mode. Instead, the application of a higher voltage to SCR Q5 on a direct connection path overrides the "combination" voltage triggering approach used in the Automatic mode. Referring to FIG. **6**, the +26 volt potential is arranged to immediately trigger SCR Q5 by being connected into a reduced portion of the voltage divider circuit. Specifically, the 26 volt positive potential is connected over a path including terminal **48***h*, switch arm **S2**, terminal **48***d*, jumper **54** and lead **64** to the upper terminal of resistor **R12**. This bypasses relatively high magnitude potentiometer **R11**, and establishes a relatively much higher voltage level at terminal **56** than had existed in the Automatic mode. This relatively higher potential at terminal **56** will be present essentially independent of the resistance value of photocell **38***d*, and it is noted that the resistance of the parallel combination of photocell **38***d* and resistor **R13** can never be more than the value of resistor **R13** alone. The circuit is arranged such that connecting the +26 volt

supply to the top of resistor R12 will be sufficient to trigger SCR Q5 regardless of the resistance value of photocell 38*d*.

For example, the values of the relevant components of the voltage divider may be donsidered to be as follows: R12 — 3.3 kilohms; R13 — 10 kilohms; R14 — 220 ohms; R15 —set at 125 ohms. If essentially 26 volts is applied at the top of resistor R12, and the resistance of photocell 38*d* is of the order of 25 K ohms, the voltage level at terminal 56 will be approximately 0.85 volts. When applied to gate electrode *g* of SCR Q5 over resistor R19, this voltage will be sufficient to immediately trigger on SCR Q5. Since terminal 58 will already be highly positive from the positive potential transmitted to that terminal from bus B1 through the collector-emitter path of transistor Q4, an immediate path to ground will be provided for current from terminal 58 through coil 34*a* of solenoid valve 34, the path to ground including the anode-to-cathode path of SCR Q5. A burst of toner particles will therefore be applied to the system in the same manner as previously described, i.e., by the connection of a circulation path from tube 32 to tube 40 resulting from the upward withdrawal of plunger 34*c* in response to the electromagnetic action of coil 34*a*.

The toner burst initiated by placing switch 48 in its "Manual" position will last either until the end of the positive output signal on lead 50*t* (if switch 48 is maintained in its Manual position by the operator, for example, by continuing to press the pushbutton), or until the pushbutton is released by the operator. In the first instance, if the operator continues to press the pushbutton, +26 volts will remain applied to the top of resistor R12 from lead 64 as previously described; multivibrator 50 will time out after approximately 3 seconds, thus terminating the control pulse on lead 50*t*. When transistors Q3 and Q4 thereby turn off, thus depriving SCR Q5 of any current to maintain it on, SCR Q5 turns off and de-energizes coil 34*a*, thus returning plunger 34*c* to its rest position. This blocks the passage of toner particles from tube 32 to tube 40 and ends the toner burst.

The other possibility for terminating the manual toner burst is simply that the operator releases the pushbutton which had placed switch 48 into its "Manual" position. If such release occurs prior to the expiration of 3 seconds, the toner burst will end prematurely when the supply voltage of +26 volts is removed from bus B1. This causes the abrupt end of the positive voltage step on lead 50*t* and also deprives transistor Q4 of the voltage which had been transmitted to terminal 58. Accordingly, transistors Q3 and Q4 and SCE Q5 are de-energized, in turn de-energizing coil 34*a*.

It the operator desires to give the system additional bursts of toner particles, the foregoing procedure is repeated. However, the placing of switch 48 into its "Manual" position must be preceded by having it returned to its "Off" position so that capacitor C2 can discharge as described above. Since this is a very brief time period, the second and successive manual toner bursts can be given almost immediately upon the return of switch 48 to the "Off" position. Generally, however, it does take some time for the toner particles to disperse throughout the developer solution to thereby affect the legibility of a given document copy. Accordingly, the operator will be told to allow sufficient time between manual toner bursts for the toner concentrate to disperse in the developer solution. For example, after the initial manual toner burst, the operator may wish to wait approximately minutes and perhaps run a specimen document copy through the machine to determine if there is now sufficient legibility in such copy to obviate the need for further toner bursts. If this procedure indicates that an additional burst is needed, it can be achieved by repeating the manual burst procedure indicated above.

The system also provides a safeguard against abuse of the Manual mode. For example, even if the operator does not heed the warning that a specified time period should elapse between manual toner bursts (if more than one is required), and instead gives a series of manual bursts with regard for the increasing concentration of the developer solution, nevertheless, this will not severely affect or disturb the system. Each burst of toner particles is arranged, under this invention, to represent only a relatively small quantity of toner and also a relatively small increase in the concentration of the developer solution. Thus, even if the initial unacceptable level concentration is approximately 8 cubic centimeters of toner concentrate per quart of solution, a first manual toner burst will only increase that concentration to approximately 9 cubic centimeters per quart of solution. Accordingly, several bursts of toner will be required in the normal case to properly elevate the toner concentration to an acceptable level. In actual practice, this may also provide for more rapid "toning" by the gradual dispersal of relatively smaller quantities of toner concentrate in the developer solution, rather than having the system attempt to absorb one or two relatively larger bursts of toner particles in a similar time period.

It is to be understood that the above-described arrangements are illustrative of the applications of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A toner replenishing system adapted for use in an electrostatic copying machine comprising a supply of developer solution, a supply of toner, means for monitoring the optical density of said developer solution, valve means for controlling the addition of toner from said toner supply to said supply of developer solution, a switching device connected to said valve means, said switching device having a gate electrode, a timing circuit for providing a periodic timing pulse, a triggering circuit connected to said timing circuit for supplying a periodic voltage spike to the gate electrode of said switching device in response to said periodic timing pulse, said periodic voltage spike being of insufficient voltage level required to trigger said switching device into conduction, a voltage divider for supplying a base voltage to the gate electrode of said switching device, said voltage divider including said monitoring means such that a change in the optical density of said developer solution below a preselected level will increase said base voltage to a sufficient level such that said base voltage in combination with said periodic voltage spike is sufficient to trigger said switching device into conduction and thereby enable said timing circuit to energize said valve means to add toner to said developer solution.

2. A toner replenishing system according to claim 1 wherein said monitoring means includes a light source, a photosensitive element, and means mounting said

light source and said photosensitive element in a spaced relation with developer solution therebetween.

3. A toner replenishing system according to claim 2 wherein the electrical resistance of said photosensitive element of said monitoring means decreases in response to a decrease in the optical density of said developer solution sufficient to trigger said switching device into conduction.

4. A toner replenishing system according to claim 1 wherein said valve means for controlling the addition of toner includes a feed path from said toner supply to said supply of developer solution having a solenoid valve positioned therein for normally blocking said feed path and operative to open said feed path upon energization.

5. A toner replenishing system according to claim 1 wherein said monitoring means includes a light source, a photocell, and a transparent monitoring tube having developer solution flowing therethrough disposed between said light source and said photocell.

6. A toner replenishing system according to claim 1 wherein said switching device includes an SCR.

7. A toner replenishing system according to claim 1 wherein said triggering circuit includes a resistor-capacitor pulse-forming network.

8. A toner replenishing system according to claim 1 wherein said timing circuit includes a free-running multivibrator circuit.

9. A toner replenishing system according to claim 1 including means for effecting actuation of said switching device independent of the optical density of said developer solution.

10. A toner replenishing system according to claim 9 wherein said means for effecting independent actuation of said switching device includes switch means for applying a sufficient voltage directly to said switching device thereby actuating said device and enabling said timing circuit to energize said valve means.

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