July 4, 1972 W. TRACHTENBERG 3,674,353

TONER CONCENTRATION CONTROL APPARATUS

Filed July 1, 1971 2 Sheets-Sheet 1

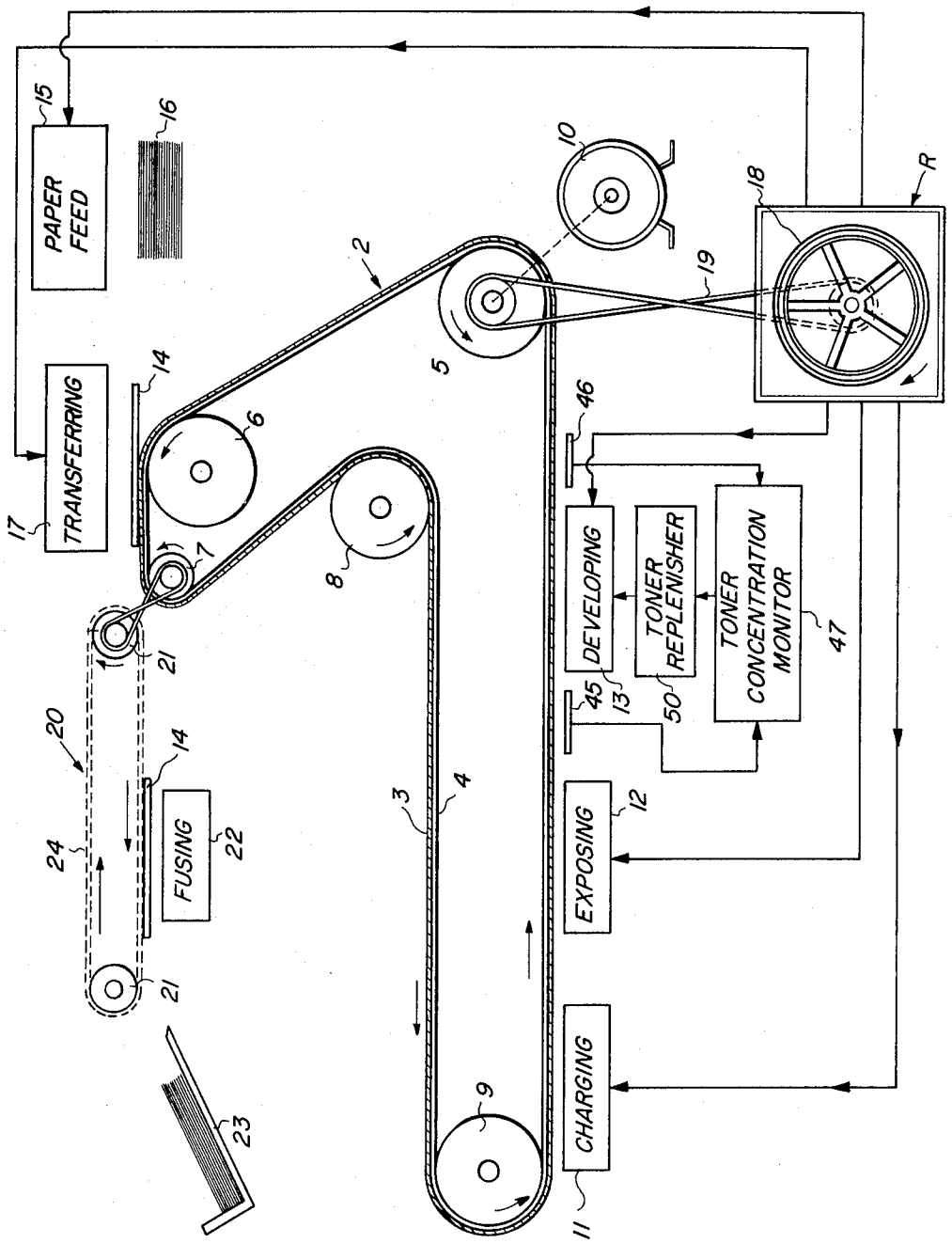



FIG. 1

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TONER CONCENTRATION CONTROL APPARATUS

Filed July 1, 1971 2 Sheets-Sheet 2

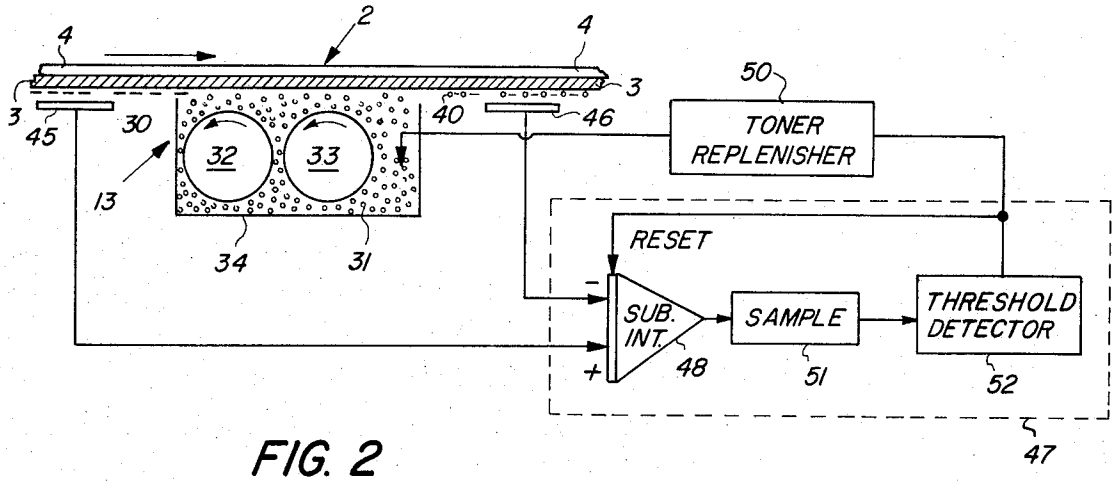



FIG. 2

FIG. 3a

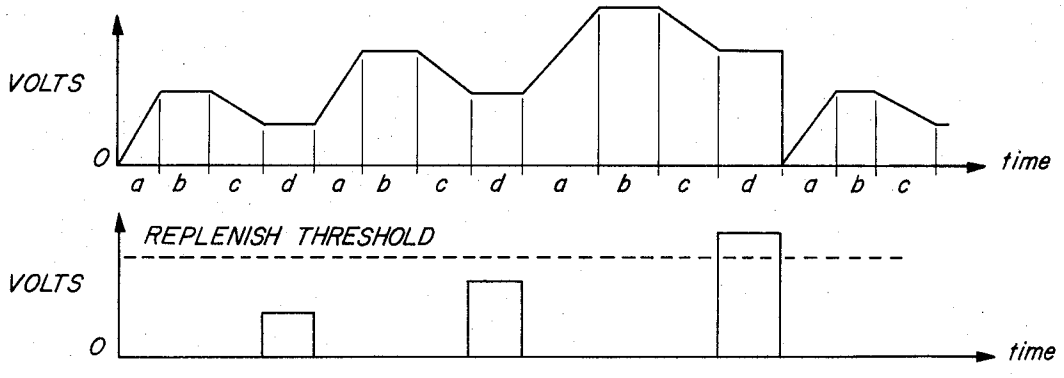



FIG. 3b

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3,674,353

# TONER CONCENTRATION CONTROL APPARATUS

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U.S. Cl. 355—3 5 Claims

## ABSTRACT OF THE DISCLOSURE

An apparatus and method for sensing the quantity of toner depleted from an electrographic developer each time an electrostatic charge pattern is developed and for activating a toner replenisher when the toner depletion exceeds a predetermined value. Toner depletion is sensed by a pair of induction plates arranged on the upstream and downstream sides of the developing station adjacent the path along which a charge pattern-bearing electrographic recording element travels. The difference in charge induced on such plates by the passage of the undeveloped and developed patterns close by is an accurate measure of the quantity of toner applied to the patterns.

This invention relates to electrographic development apparatus and more particularly to an apparatus and method for maintaining the concentration of toner particles in a dry electrographic development mixture at a substantially constant level at which copies of uniformly good density are consistently producible.

Dry electrographic developers commonly comprise a mixture of suitably pigmented or dyed resin-based particles, known as toner, and a granular carrier material which functions to carry toner by generating triboelectric charges thereon. To develop the electrostatic charge patterns produced on the surface of a radiation-sensitive recording element during the electrographic process, it is common to bring such mixture into contact with the image-bearing surface by either cascading the mixture over the surface or, as is becoming increasingly prevalent, contacting the surface with one or more rotating magnetic development brushes, the bristles of which comprise toner-coated metallic carrier particles. Upon contacting the electrostatic image-bearing surface, the toner particles, which are commonly charged to such a potential as to be attracted to the electrostatic charge pattern, are separated from the carrier particles by electrostatic forces and deposited on the surface in accordance with the electrostatic charge pattern. Obviously, as successive electrostatic charge patterns are developed, toner particles are depleted from the development mixture, requiring subsequent replenishment to avoid a grandual reduction in density of the developed or toner images.

Heretofore, it has been common to require the operator of an electrographic copier to observe the reproduction copy quality and replenish the toner particles when the legibility or density of the developed images drops below a subjective acceptable level. While such a toner replenishment system is satisfactory for many applications, such a system has proven highly unsatisfactory when a high throughput application exists. More sophisticated systems have been proposed for automatically replenishing the development mixture with toner particles when the concentration of such particles drops below a predetermined level, but no such system has proven entirely satisfactory to date. Generally, conventional automatic toner control systems have proven unreliable over extended periods of use, insensitive to slight variations in toner concentration of a magnitude adversely affecting image



quality, costly to fabricate, and difficult because of space limitations to incorporate in electrographic copiers.

An object of the present invention then is to improve electrographic development by providing an apparatus for automatically maintaining the toner concentration in an electrographic developer at a substantially constant level at which high quality toner images can be consistently produced.

Another object of the invention is to provide an inexpensive, yet highly accurate and reliable, apparatus for automatically controlling the level of toner concentration in an electrographic developer.

Another object of the invention is to provide an improved automatic toner control apparatus which can be readily incorporated in existing electrographic reproduction apparatus.

Still another object of the invention is to detect the depletion of toner particles from an electrographic developer by sensing in the electric field associated with the electrostatic charge pattern the change resulting from the application of toner particles to such charge pattern during development.

Such objects are achieved by the provision of an apparatus which is capable of sensing the precise amount of toner depleted from the developer each time a copy is produced and activating a toner replenishing apparatus when the level of toner concentration falls below a predetermined threshold value. Briefly, sensing of toner depletion is accomplished by a pair of induction plates or electrometer probes, positioned on the upstream and downstream sides of the development apparatus to sense the electrostatic field associated with the electrostatic charge image before and after development. It has been found that the drop in intensity of such electric field occurring during development is a precise measure of the quantity of toner applied to the charge image. By electronically subtracting the charges induced on the induction plates or probes by the electrostatic charge pattern, a precise measure of the quantity of toner applied to each image is obtained. The resultant signal is used to control the toner replenishing apparatus.

Other objects of the invention and its various advantages will become apparent from the ensuing detailed description of preferred embodiments, reference being made to the accompanying drawings in which like characters denote like parts and in which:

FIG. 1 is a schematic illustration of an automatic electrographic reproduction apparatus embodying the invention;

FIG. 2 is a schematic illustration of an electrographic development apparatus incorporating a preferred embodiment of the invention; and

FIG. 3 illustrates the output signal characteristic of the integrator and sampling circuits depicted in FIG. 2.

For a general understanding of an electrographic reproduction apparatus wherein the invention has particular utility, reference is made to FIG. 1 wherein various components of an electrophotographic copier are schematically illustrated. As in most electrophotographic copiers, an endless photoconductive recording element is advanced along a predetermined path adjacent to which are disposed the various electrophotographic processing stations which serve to form a toner image of the original document on the surface of such recording element. As shown in FIG. 1, the recording element may be in the form of a flexible belt 2 comprising a photoconductive film 3 disposed on a flexible conductive backing 4. The photoconductive film may comprise, for instance, a heterogeneous mixture of a bisphenol A-polycarbonate binder, a triarylmethane organic photoconductor and a pyryllium sensitizing dye. Belt 2 is driven and guided along a path

in the direction indicated by the arrows past the processing stations by rollers **5**, **6**, **7**, **8** and **9**, roller **5** being driven by motor **10**. As belt **2** passes charging station **11**, the surface of photoconductive film **3** receives a uniform electrostatic charge from a corona source or the like. Upon being uniformly charged, the belt is advanced past an exposure station **12** where film **3** is imagewise exposed to actinic radiation in accordance with the indicia on the original document. Such imagewise exposure serves to selectively dissipate the uniform charge on the film to form a developable electrostatic charge pattern thereon corresponding to such indicia. Development of the electrostatic charge pattern is accomplished as belt **2** is advanced past development station **13**. The latter generally comprises a reservoir of electroscopic toner particles having a charge opposite that of the electrostatic charge pattern so as to be attracted thereto, and means for applying the toner particles to the electrostatic charge pattern to render it visible.

To reuse that portion of the photoconductive film bearing the developed or toner image, the toner image may be transferred to a receiving sheet **14** on which it can be subsequently permanently fused. Such a transfer is commonly effected by a sheet feeding device **15** which feeds receiving sheets, usually paper, film or other web material, from a supply station **16** to a transfer station **17** simultaneously with the passage therepast of the toner image-bearing belt **2**. A shift register R serves to control the timing of the electrophotographic operations and to synchronize the feeding of the receiving sheets with the movement of the photoconductive belt. The shift register R includes a rotatable segmented and slotted cylinder **18** which is driven by suitable means, such as belt **19** extending from a pulley around roller **5** so that movement of the shift register is in direct response to movement of the photoconductive belt **2**.

Transfer station **17** commonly comprises means for electrostatically charging the receiving sheet so as to attract the toner particles from the belt thereto. After the toner image is transferred to the receiving sheet, the sheet is peeled away from the belt as the latter passes over small roller **7**. The toner-bearing receiving sheet is then attracted by an endless mesh belt transport **20**, traveling about rollers **21** in a clockwise direction and at the same speed as belt **2**, and is advanced thereby past a fusing station **22** where the toner image is permanentized by heat or the like. The receiving sheet with its toner-bearing surface facing downward is caused to adhere to transport **20** by a source of negative pressure on the rear surface of the lower leg of the transport. After fusing, the receiving sheet is dropped in a receptacle **23**.

Referring now to FIG. 2 and the subject matter of the invention, the photoconductive film **3** of belt **2**, upon being uniformly charged and imagewise exposed, bears a developable electrostatic charge pattern **30** on its outer surface, such pattern being shown as a plurality of negative charges in the drawing. As the electrostatic charge pattern is advanced past the developing station **13**, a developer **31** is applied to the image by a pair of magnetic development brushes **32** and **33** which are mounted for rotation in a reservoir **34** containing the developer. The developer may comprise, for instance, a mixture of iron carrier particles coated with an electrically insulating resin, and electroscopic toner particles comprising a pigmented thermoplastic resin. The particular toner is selected to be triboelectrically charged by the carrier particles to a polarity opposite that of the electrostatic charge pattern so as to be attracted thereto.

As developer is applied to the surface of film **3**, the electroscopic toner particles are separated from the carrier component by the electrostatic forces existing between the charge pattern and toner and are deposited on the film to form a toner image **40**. Such deposition, of course, has the effect of reducing the electric field associated with the charge pattern since the oppositely charged toner particles tend to nullify the charge constituting the charge pattern. As is apparent, as toner images are repeatedly formed, additional toner particles must be applied to the developer in proportion to the amount of toner deposited on the film. Otherwise, the concentration of toner particles in the developer would drop below the level required for copies of good print density.

To maintain the concentration of toner particles in the developer at the optimum level required for high quality copies there is provided, in accordance with the present invention, a pair of induction plates **45** and **46** situated on the upstream and downstream sides of development station **13**, respectively. Such induction plates are fabricated from a highly conductive material such as copper or aluminum, and preferably extend across the entire width of film **3**, closely spaced therefrom to receive an induced charge as the electrostatic charge pattern passes by. The charges induced on plates **45** and **46** serve as the inputs to a conventional subtracting integrator **48**, the output of which serves to activate a toner replenisher **50** upon being processed by conventional sampling and threshold detecting circuits, **51** and **52**, respectively. One of the advantages obtainable with the toner control apparatus is that any conventional toner replenisher mechanism can be actuated by the aforementioned output signal, e.g., that disclosed in U.S. 3,409,901 wherein a hopper is caused to release toner into the developer mechanism.

The operation of the toner control apparatus of the invention can be better understood with reference to FIGS. 3*a* and 3*b* wherein the outputs of the subtracting integrator **48** and sampling circuit **51**, respectively, are shown. As the undeveloped electrostatic charge image **30** passes induction plate **45**, the electric field associated with such charge image induces an electric charge thereon. As shown in FIG. 3*a*, time interval *a*, the charge induced on induction plate **45** is continuously accumulated by the subtracting integrator **48**. After the charge image **30** passes induction plate **45** and enters development station **13**, no additional charge is induced on induction plate **45** and the output of the subtracting integrator, as shown in time interval *b*, remains at a constant level indicative of the total electric field associated with the undeveloped charge image. As electroscopic toner particles are applied to the undeveloped electrostatic charge image **30** to render it visible, the electric field associated with such image is substantially reduced due to the charge cancelling effect produced by the oppositely charged toner particles. Thus, upon leaving development station **13**, the developed or toner image **40** will be capable of inducing a lesser charge on induction plate **46** than the undeveloped pattern **30** induced on induction plate **45**. As shown by the slope of the curve in time interval *c*, of the integrator output, the charge induced on induction plate **46** will increase (shown as a negative-going signal) at a rate slower than that which charge accumulated on induction plate **45**, causing the negative-going output of the subtracting integrator to fall to a level indicative of the difference in electric fields associated with the undeveloped and developed charge, images, as shown in time interval *d*. The output of the integrator will remain at such level until another undeveloped charge image passes induction plate **45**, at which time the output of the integrator will repeat the aforedescribed sequence of events.

The output of subtracting integrator **48** is then fed to a conventional sampling circuit **51** which provides an output similar to that illustrated in FIG. 3*b*, such output being in a form of pulses, the instantaneous amplitudes of which are proportional to the instantaneous amplitudes of the subtracting integrator during time interval *d*. Since the amount of toner applied to the electrostatic charge pattern during development is directly proportional to the change in electric field, the amplitude of the pulses provided by the sampling circuit will be directly proportional

to the amount of toner depleted from the development mixture during development. By passing the output of the sampling circuit through a conventional threshold detector **52**, the toner replenisher is activated whenever the depletion exceeds a predetermined value. In addition to activating the toner replenisher **50**, the output of the threshold detector is used to reset the subtracting integrator output to zero each time toner is added to the development mixture.

Since the aforedescribed toner control apparatus relies on a precise measure of the difference in electric field before and after development, it is necessary to take into account all factors which would produce a decrease in such field during the development process. For instance, some photoconductive films exhibit persistent conductivity for a short period, usually less than one second, following exposure. Thus, in utilizing such film, it is desirable to displace induction plate **45** a sufficient distance from the exposure station so that the effect of such persistent conductivity will have run its course before the undeveloped image arrives at the first induction plate. Otherwise, circuitry would be required to subtract out the reduction in electric field produced by persistent conductivity.

It will be appreciated by those skilled in the art that the subject invention has utility in all electrographic reproduction systems, including xeroprinting, thermoxerography and xerothermography, and in no way is dependent upon the manner or physical form in which the developer is applied to the charge image to render it visible. Moreover, referring to FIG. 2, it should be apparent that, rather than using induction plates to sense the electric field associated with the charge image, other sensing apparatus could be employed, such as for instance electrometer probes.

This invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

I claim:

**1.** In an electrographic reproduction apparatus comprising means for applying electroscopic toner to an electrostatic charge pattern-bearing surface to render such electrostatic charge pattern visible, and means for replenishing such toner applying means with additional toner to compensate for toner depletion resulting from rendering such electrostatic charge patterns visible, an improved toner replenishment control comprising:

means for sensing the difference in electric fields associated with at least a portion of the electrostatic image before and after toner is applied thereto, and for providing an electrical output signal having an amplitude proportional to said difference; and

means operatively coupled with said output signal for activating the replenisher means to add toner to such toner applying means when the amplitude of said output signal exceeds a predetermined value.

**2.** In an electrographic reproduction apparatus comprising means for forming a developable electrostatic charge pattern on an electrographic recording element, means for advancing such image-bearing element along a predetermined path, and means positioned adjacent such path



for applying electroscopic toner to such element to render the electrostatic image visible, the improvement comprising:

means, positioned on the upstream and downstream sides of the toner applying means and adjacent such path, for sensing the electric field strength associated with the electrostatic charge pattern before and after toner is applied thereto, each of said sensing means comprising a conductive member;

means, operatively coupled with said conductive members, for providing an electrical signal having an amplitude proportional to the difference in electric field strength sensed by said conductive members; and

means opeartively coupled with said electrical signal for replenishing the toner applying means with toner when the amplitude of said signal exceeds a predetermined value.

**3.** The invention according to claim **2** wherein said conductive members comprise induction plates whereon a charge is induced as the electrostatic image-bearing element passes thereby.

**4.** The invention according to claim **3** wherein said sensing means further comprises a subtracting integrator circuit having inputs operatively coupled with said conductive members.

**5.** A method of determining the amount of toner depleted from an electrographic development station during a developing operation in which such toner is applied to the surface of an electrostatic charge image-bearing surface to render such image visible, said method comprising the steps of:

sensing the electric field associated with such image before and after such toner is applied thereto;

deriving an electrical signal having an amplitude proportional to the difference in the sensed electric field; and

measuring the amplitude of such signal to determine the quantity of toner depleted from the development station.


**References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 3,376,853 | 4/1968 | Weiler et al. | 118—637 |
| 3,399,652 | 9/1968 | Gawron | 118—637 X |
| 3,453,045 | 7/1969 | Fantuzzo | 355—3 |
| 3,504,968 | 4/1970 | Matkovich et al. | 355—10 |
| 3,527,651 | 9/1970 | Shelffo et al. | 118—637 X |

FOREIGN PATENTS

| | | | |
|---|---|---|---|
| 1,200,986 | 8/1970 | Great Britain | 355—3 |

OTHER REFERENCES

"Controlling toner to carrier concentration in an Electro photographic copier," by H. W. Simpson et al., IBM Technical Disclosure Bulletin, vol. 13, No. 12, May 1971.



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U.S. Cl. X.R.

95—89 R; 118—637; 222—57; 355—10