

[54] **METHOD AND APPARATUS FOR
MEASURING AND CONTROLLING THE
TONER CONCENTRATION IN
ELECTROPHOTOGRAPHIC
REPRODUCTION MACHINES**

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[52] **U.S. Cl.**..... 250/272; 250/273; 250/308;
250/359; 118/637

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[58] **Field of Search**..... 250/272, 273, 277, 308,
250/359, 360; 118/637; 222/57, DIG. 1

[56] **References Cited**

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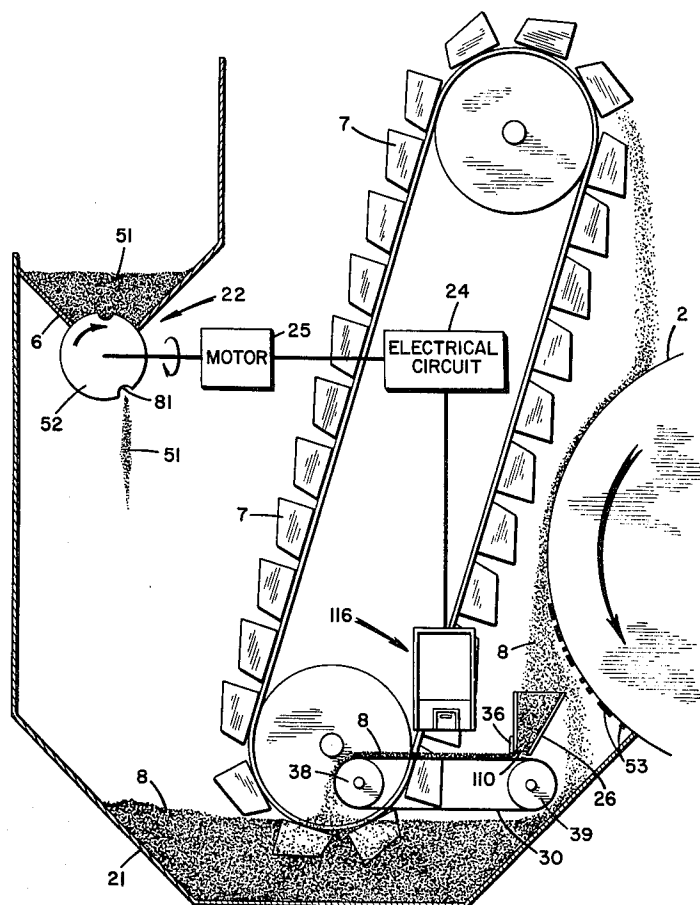
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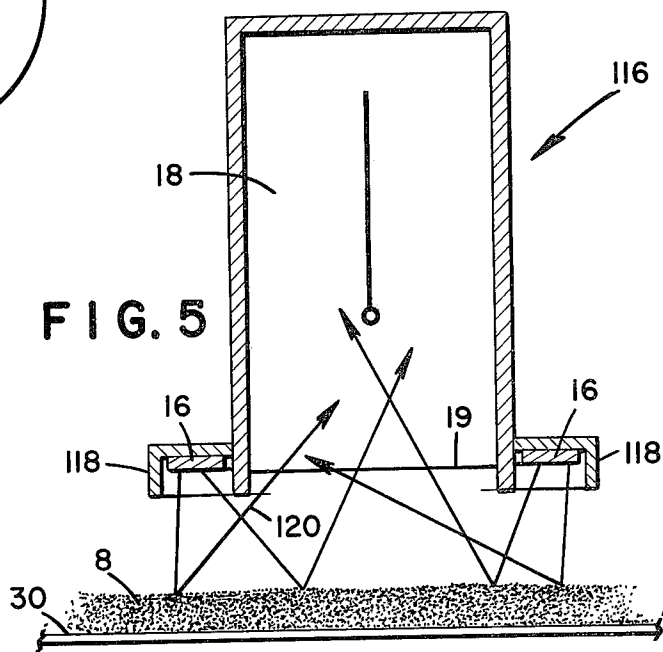
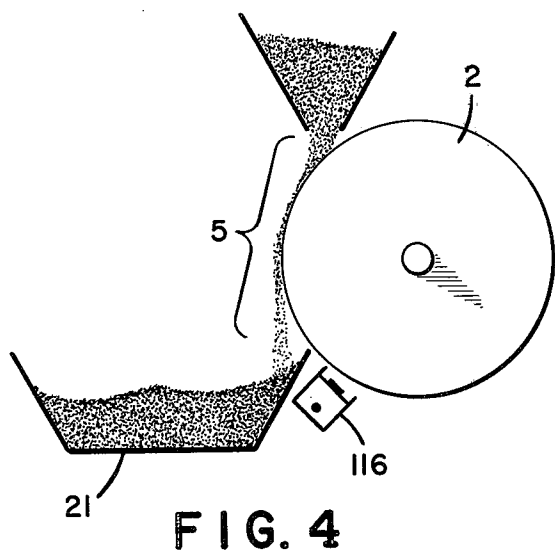
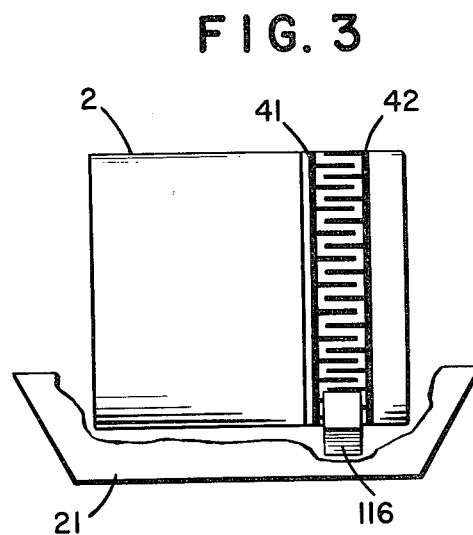
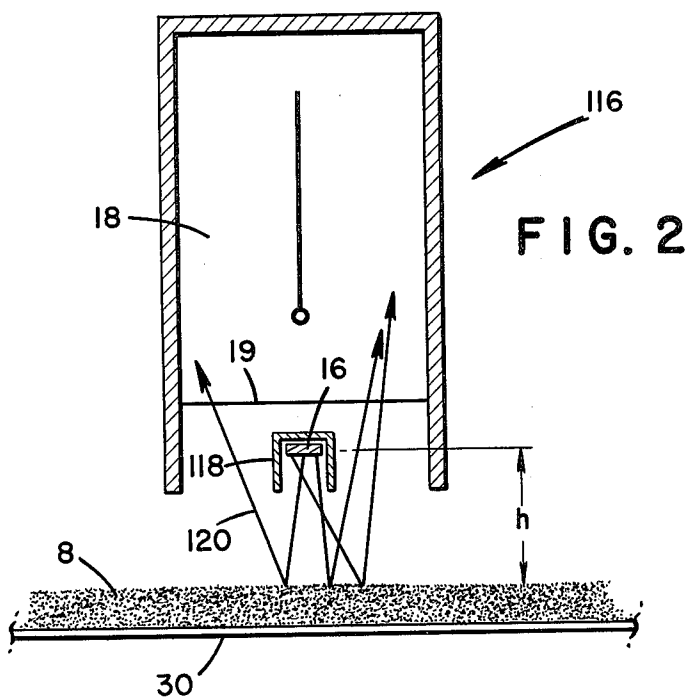
Primary Examiner—Archie R. Borchelt
Attorney, Agent, or Firm—Stevens, Davis, Miller &
Mosher

[57] **ABSTRACT**

A method of measuring the toner concentration of a developer containing toner circulating in an electrophotographic reproduction machine including preparing a sample from the developer for measurement, arranging the sample so that the toner can be estimated as a proportion of the required toner concentration of the developer, irradiating the sample by β -rays that are effected by the toner and measuring the β -rays being scattered back from the irradiation. An apparatus for measuring the toner concentration of a developer including an endless belt mounted for movement with part of its surface horizontal for forming a uniform layer of developer thereon for measurement, a measuring head as a source of β -rays positioned to irradiate the uniform layer of developer, a detector for measuring the effect of the irradiation, an electronic unit responsive to the measured radiation and a toner supply device operable by the electronic unit to replenish toner in the developer when needed. In lieu of the endless belt the photoconductive surface of the electrophotographic reproduction machine may be provided with one or more electrodes to which an electrical potential may be applied.

11 Claims, 5 Drawing Figures





METHOD AND APPARATUS FOR MEASURING AND CONTROLLING THE TONER CONCENTRATION IN ELECTROPHOTOGRAPHIC REPRODUCTION MACHINES

The present invention relates to a method of and apparatus for measuring or measuring and controlling the toner concentration of a developer circulating in an electrophotographic reproduction machine. Such apparatus is particularly suitable for use in automatic high-speed reproduction machines.

In electrophotographic reproduction machines the images are developed with developers which generally consist of two components, known as the toner and the carrier. The toner may, for example, be a colored synthetic resin powder and the carrier a granular material consisting of glass, or iron coated with synthetic resin. The carrier is used for carrying the toner and in charging it triboelectrically. The toner is used for inking the copies. In the case of liquid developers, finely-divided toner materials (e.g. droplets of an adhesive liquid) are contained in a liquid carrier. During development, the toner is used up at a rate dependent upon the nature and number of the copies produced. Further amounts of toner must be added in order to maintain the density of the copies at the correct level. For the purpose of controlling the toner concentration in the developer, it is necessary to use measuring apparatus, the signals from which can be used to adjust the rate of replenishment of the toner.

Various methods are known for measuring the toner concentration. U.S. Pat. No. 2,956,487 and German Pat. No. 1,926,198, for example, deal with the determination of the optical density of a toner-treated charge image or of the developer liquid. German Pat. Nos. 1,936,815 and 2,014,430 disclose methods of determining the permeability of the developer mixture in cases where the toner or the carrier is ferromagnetic.

The optical methods are relatively complicated and therefore prone to breakdown.

The determination of the permeability of dry mixtures having a customary composition of ferromagnetic carrier and non-ferromagnetic toner has the disadvantage of falling sensitivity with rising toner concentration. This results from the fact that the first toner particles force the carrier granules relatively widely apart, and further toner is preferentially deposited in the gaps thus created. Furthermore, these methods are limited to very specific developer substances, i.e., those containing ferromagnetic carrier materials.

One object of this invention is to provide a method of measuring toner concentration that possesses a high degree of sensitivity even where high concentrations of toner are concerned, and is relatively simple and thus not very prone to breakdown.

The present invention accordingly provides a method of measuring or measuring and controlling the toner concentration of a developer circulating in an electrophotographic reproduction machine. In this method, in a sampling step, there is prepared from the circulating developer a sample for measurement, which sample consists either of the said developer itself or of a material composed of or enriched in the toner component of the said developer. The sample is so arranged that the toner therein can be estimated as a proportion of the required toner concentration of the developer. In a measurement step the prepared sample is irradiated by

β -radiations from a radioactive preparation which are caused to impinge on the sample and to be back-scattered therefrom and a measurement is made of the back-scattered radiation.

It has been found that this method, known per se in radiation measurement techniques, is particularly suitable, in measuring toner concentration, for detecting small proportions of components which differ from one another as regards atomic number. The sensitivity of this back-scatter method is just as great as the through irradiation method described in copending application Ser. No. 276,307. Compared with through irradiation, however, the use of back-scatter offers the advantage that the determination of the toner concentration is not dependent upon the degree of compacting of the developer mixture prior to carrying out the measurement. Also, the measured intensity is less dependent upon the geometry of the arrangement.

Furthermore, the back-scatter method offers the advantage that considerably lower strengths of preparation (smaller activity quantity of the preparation) can be used. When a suitable measuring arrangement is used, the activity quantity of the radioactive preparation can be kept within the limits permitted by anti-radiation regulations, so that in an arrangement of this kind it is possible to dispense entirely with radiation screening even of the simple kind required in the case of β -radiation. Finally, the cost involved in measuring back-scatter radiation is lower, since the β -radiation used in the back-scatter measurement is preferably measured with a Geiger counter, whereas a scintillation counter is necessary for detecting γ -radiation. With a Geiger counter the number of counts in the case of γ -radiation is 100 times less than with β -radiation. The counter and the measuring apparatus occupy less space and are cheaper in the case of a Geiger counter.

According to the present invention, preference is given to a method in which a layer of developer is continuously produced and passed in a uniform manner between and at a constant distance from the radiation source and the detector. It is possible with this continuous method to operate an electrophotographic copying apparatus fully automatically, the measured change in the impulse rate being used to control means for adding toner. It is of course necessary to realize that when the counting rate is above its normal level, the toner concentration is below its normal level. Thus, replenishment of the toner material is always to be carried out when the counting rate has exceeded a certain level.

Instead of using the developer mixture itself as the sample for measurement, it is possible, by the method of the present invention, to use, as this sample, a surface of material which provides strong back-scatter of β -radiation and on which varying amounts of toner, depending upon its concentration in the developer, have been deposited. In this case, as a thin strip of material there can be used a charged photoconductor layer on a thin support of plastic material, or a thin support of plastic material which carries thereon an electrode which is constituted in particular by a vapor-deposited metal layer and to which a constant voltage can be applied. The surface may, for example, take the form of an electrode made of copper or iron or a heavy metal (gold in particular), a certain electrical potential being applied to the electrode which is used to assess the developer under investigation. Varying quantities of toner are deposited on the heavy-metal electrode depending upon the toner concentration, and with

increase in the quantity of toner there is a reduced intensity of the back-scattered β -radiation. The use of heavy-metal electrodes is preferred, since the change in back-scatter intensity is particularly high with these.

The method has been found particularly reliable when a C14 preparation is used as the β -preparation. Other nuclides such as Sr 90/Y 90, Pm 147 or Tl 204 are suitable radiation sources. The C 14 preparation is, however, preferred for the back-scatter method.

According to the present invention, apparatus for performing this method may include an endless circulating belt, of which at least part of the surface faces upwards, in an electrophotographic reproduction machine, located at a point where the developer circulates, means for forming a layer of developer of constant thickness on the upwardly facing portion of the surface of the belt, a β -preparation, so located as to be presented to the free surface of the layer of developer mixture, and a detector for the β -radiation back-scattered by the developer mixture, located on the same side of the layer of developer mixture as the radiation source but so arranged that it is screened from the direct β -radiation of the radiation source.

Apparatus for performing the method of the present invention in which the back-scatter measurement is made by means of an electrode on which toner has been deposited includes a metal surface so formed and disposed in an electrophotographic reproduction machine that it is developed by the developer circulating in the reproduction machine, and a measuring head, including a β -radiation source and a detector, presented to this metal surface, a certain electrical potential being applied to this metal surface during the developing.

In this arrangement, it is preferred to provide, laterally of a repeatedly usable photoconductor of an electrophotographic reproduction machine, one or more electrodes which can be moved with the photoconductor through the developing and cleaning zones, and to locate a stationary measuring head in a position in which it is presented to the moving electrode or electrodes.

The present invention is illustrated by way of example in the accompanying drawings, in which:

FIG. 1 is a diagrammatic view of an embodiment employing the back-scatter method of measurement of toner concentration,

FIG. 2 is a diagrammatic section through the measuring head of the apparatus of FIG. 1,

FIG. 3 shows a front elevation view of a further embodiment of the device for use in the method of the present invention, and

FIG. 4 is a side elevation view of the device of FIG. 3, and

FIG. 5 is a diagrammatic section through a measuring head the radiation source of which is arranged on a ring around a counting tube.

For each copy produced in an electrophotographic reproduction machine, a certain quantity of toner is drawn from the stock of developer. In the case of the machine of FIG. 1, using a dry two-component developer with toner image transfer, impoverished developer mixture 8 falls from a photoconductive surface 2. A toner image 53 on this surface is transferred to a copying material, for example paper, by a transfer device, not illustrated.

In order to determine the extent of the diminution of the toner content in the developer mixture 8 with sub-

sequent addition of further toner 51 to the mixture by means of a replenishing device 22, the following method is used.

The replenishing device 22, as shown, comprises a container for the toner 51 at the base of which is mounted a rotatable roller 52. This roller contains longitudinal grooves 81. When the roller 52 rotates, toner 51 is carried around in the grooves 81 and falls into the developer trough 21. From there the developer mixture containing fresh toner is carried, as shown, by a bucket conveyor system 7, to the photoconductive surface 2.

The apparatus of FIG. 1 makes use of a back-scatter radioactivity method for determining the extent of the reduction of the toner content in the developer mixture 8. The developer to be examined trickles from the developer device into a collector-hopper 26. Below the delivery end 110 of the hopper 26 is an endless belt 30 which circulates around two rollers 38 and 39. As the belt 30 moves round, it carries with it a layer of developer mixture of a thickness governed by a levelling device 36. Above the layer of developer mixture 8 is located a measuring head designated generally by the numeral 116. The measuring head will now be described in detail by reference to FIG. 2.

The measuring head 116 consists of a counting tube 18, in front of the window 19 of which a radio-active β -ray preparation 16 is so positioned that no direct β -rays but only back-scattered rays are able to pass through the window of the counting tube 18. This is achieved, as shown, with the aid of a screen 118. The paths 120 followed by the β -rays and indicated by lines and arrows, thus extend from the preparation 16 to the developer mixture 8 under examination, and after back-scatter (i.e., after reversal caused by multiple scatter at the atomic nucleus of the developer substance) the rays pass through the window 19 of the counting tube 18.

The distance (h) of the preparation from the surface of the layer under investigation is adjusted depending upon the form of the measuring head. In the arrangement here described this distance is a few millimeters.

With a suitable arrangement, the intensity of back-scatter is directly proportional to the atomic number of the substance causing the back-scatter. The determination of the toner concentration by the back-scatter method is thus based upon the fact that the β -rays are back-scattered to a less pronounced extent in the layer of toner, consisting mainly of carbon, hydrogen and oxygen atoms, than in the thin coatings of plastic material and the iron cores of the particles constituting the carrier. The thicker the layer of toner, the lower the intensity of the β -rays back-scattered by the developer mixture becomes.

When use is made of β -rays that are not too hard, back-scatter occurs only on the uppermost layers of carrier particles contained in the developer mixture. The back-scatter method is thus independent of the density of compacting caused by shaking down the material. Conversely, in the through radiation method the change in the density of the developer mixture with change of toner concentration constitutes the basis on which the toner concentration is determined (increase in intensity of the rays passing through, with increasing thickness of the layer of toner and with correspondingly decreasing density).

Back-scatter measurements using carbon 14 as the β -radiation source have indicated a change in back-

scatter intensity of 20% with a change in the concentration of toner of from 1 to 2% by weight. Since a 2% change in intensity can be measured on a reproducible basis, a change in toner concentration of up to 0.1% by weight (e.g. a change of from 1.6 to 1.5%) can be determined by the back-scatter method.

It thus becomes possible to replenish the toner in a very accurate manner and to maintain the toner concentration very accurately.

Incorrect measurements resulting from deposition of dust (particularly dust from the toner) upon the window 19 of the counting tube or upon the radiation source can be avoided if one of the following precautions is taken: (i) a stream of air is branched off from one of the blowers always present in electrophotographic reproduction machines and used to prevent the deposition of any dust layer, or (ii) a thin foil or film is arranged between the measuring device and the developer sample, which foil or film either bounds the developer mixture and is maintained clean by it, or is periodically set in motion. As an example, an 8 μ m thick film sold under the Registered Trade Mark "Hostaphan" reduces the sensitivity of the device to about one-half, but the latter still operates satisfactorily.

It will be seen from the figures given above that the toner always has to be replenished when the counting rate has risen above a predetermined level. The toner concentration will then have fallen below the required value. For the purpose of such replenishment, there is provided an electronic circuit which is indicated generally by the numeral 24 (FIG. 1) and which, with the aid of a motor 25, causes the roller 52 of the toner replenishing device to execute a certain number of revolutions when the counting rate has risen above a predetermined level. Electronic circuits of this kind are known in metrological techniques employing radioactive materials, so that there is no need for detailed description.

In FIGS. 3 and 4 the photoconductor 2 is developed in the cascade developing device 5. Located laterally of the photoconductor 2 and on the same belt of plastic material as the photoconductor is a strip electrode consisting of two interlocking strips 41 and 42. These strips are made of gold applied by a vapor-deposition method. For clarity, the width of these strips is exaggerated in the drawing. These electrode strips can be connected to a fixed voltage source by means of wiper contacts, or insulated strips can be used which can be brought to a predetermined potential, according to the level of charge taken up and the capacity, by a corona charging device (not illustrated in FIG. 3).

The strips 41 and 42 are developed with the photoconductor 2 at the device 5. A layer of toner, the thickness of which is dependent upon the toner concentration, is deposited on the strips.

The intensity of the β -rays back-scattered by the toner-covered strips 41 and 42 is measured by the measuring head 116. It has been found that the intensity of the back-scatter from a bright iron surface not covered with toner is reduced by at least 30% by 0.5 mg/cm² of organic material. This demonstrates that the back-scatter method is also eminently suitable for this form of measurement.

What is claimed is:

1. A method of measuring the toner concentration of a developer containing toner circulating in an electrophotographic reproduction machine, comprising forming a horizontal layer of developer of constant thickness from the circulating developer for measurement, passing said layer past a source of β -rays that are effected by the toner, irradiating the layer by β -rays and measuring the β -rays being scattered back from said irradiation to determine the amount of toner present.

2. The method as claimed in claim 1, in which the sample constituted by the developer itself is at a constant distance at its closest point from the radiation source and measuring device, whereby irradiation and back-scatter are from the same side of the sample.

3. The method as claimed in claim 1, in which the radiation source is a C 14 preparation.

4. The method as claimed in claim 1, in which the radiation source is a Sr 90/Y 90, a Pm 147 or a Tl 204 preparation.

5. An apparatus for measuring the toner concentration of a developer containing toner circulating in an electrophotographic reproduction machine including means for preparing and arranging a sample from the developer for irradiation comprising an endless belt mounted for circulation with part of its outer surface horizontal and facing upwards and means for forming a layer of developer of constant thickness on this part of the belt, a measuring head as a source of β -rays located for irradiation of the sample being located to irradiate developer on this part of the belt and a detector for measuring the effect of the sample on the said radiation.

6. The apparatus as claimed in claim 5, further including electronic means arranged to be responsive to the received radiation and a toner supply device operable by said electronic means to replenish the toner in the developer in accordance with the amount of the resulting radiation.

7. The apparatus as claimed in claim 5, in which the means for forming the layer of developer comprises a collector-hopper for delivering developer to the belt, a layer thickness determining means, and lateral confining walls at least in the zone of irradiation.

8. The apparatus as claimed in claim 5, in which the means for preparing and arranging the sample for measurement include the charging device and developing device of the electrophotographic machine.

9. The apparatus as claimed in claim 5, in which as radiation source a β -ray source is located to face the free surface of the layer of developer and the detector is a detector for detecting β -rays back-scattered by the developer, the detector being screened from direct radiation from the said source.

10. The apparatus as claimed in claim 9, in which the detector is of circular section and the β -ray source is a counting tube positioned in the center of this circle between the detector and the developer, said detector being screened from said source.

11. The apparatus as claimed in claim 9, in which the detector is a counting tube and the radiation source is located on a ring around it.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,928,764
DATED : December 23, 1975
INVENTOR(S) : Hartmut BOCK et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Claim 10, lines 2 and 3, (Column 6, lines 57 and 58) should read, -- detector is a counting tube of circular section and the β -ray source is positioned in the center of this circle --

Signed and Sealed this

Twenty-first **Day of** *November 1978*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

DONALD W. BANNER
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