United States Patent

Mammino

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[54] SELECTIVE REMOVAL OF LIQUID DEVELOPER IN A CYCLICAL ELECTROPHOTOGRAPHIC PROCESS

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[52] **U.S. Cl.** ....**96/1.4,** 96/1 LY, 117/17.5 LY, 134/7.9, 355/15

[51] **Int. Cl.** **G03g 13/22**

[58] **Field of Search** 96/1.4, 1; 134/7.9; 252/410; 15/3; 355/15; 117/17.5, 37

[56] **References Cited**

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[57] **ABSTRACT**

An electrostatographic imaging surface is cleaned of liquid developer by selectively applying to the charged or image areas of the imaging surface a finely divided, dry, absorbent powder. The powder may be selectively applied by charging the powder to a polarity opposite that which the imaging surface bears and presenting a charged powder loaded applicator adjacent the imaging surface such that the charged powder is transferred to the imaging surface with an electrostatic assist from the residual charge on the imaging surface.

14 Claims, 3 Drawing Figures

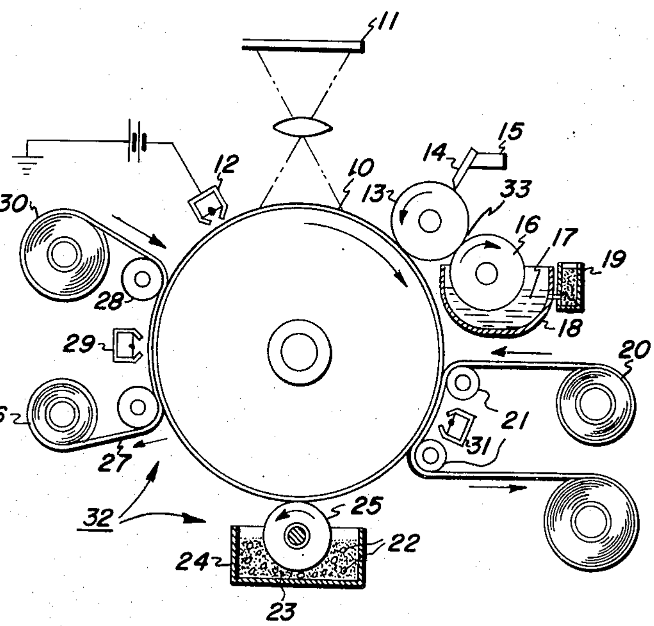
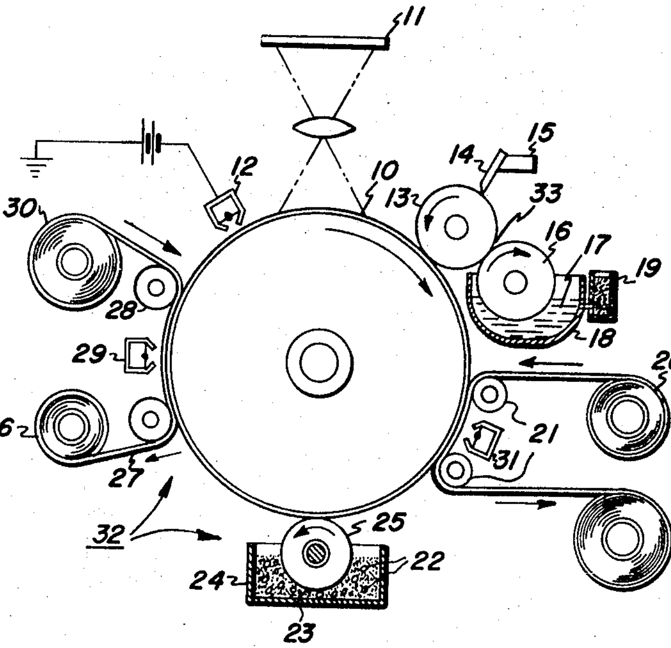


FIG. 1



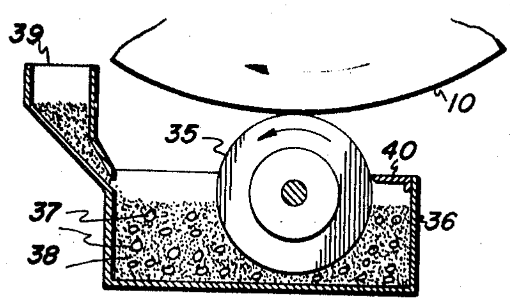


FIG. 2

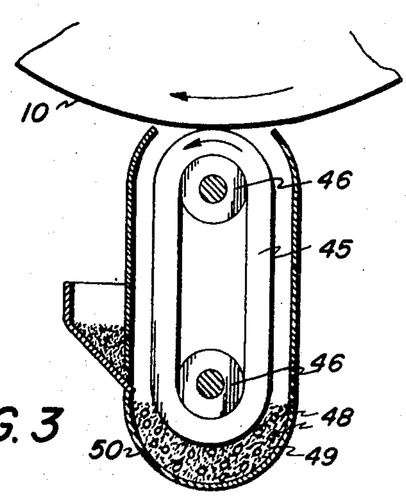


FIG. 3

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SELECTIVE REMOVAL OF LIQUID DEVELOPER IN A CYCLICAL ELECTROPHOTOGRAPHIC PROCESS

BACKGROUND OF THE INVENTION

This invention relates to imaging systems, and more particularly, to improved cleaning systems and techniques.

The formation and development of images on the surface of photoconductive materials by electrostatic means is well known. The basic electrostatographic process, as taught by C. F. Carlson in U.S. Pat. No. 2,297,691 involves placing a uniform electrostatic charge on a photoconductive insulating layer, exposing the layer to a light and shadow image to dissipate the charge on the areas of the layer exposed to the light and developing the resulting electrostatic latent image by depositing on the image a finely divided electroscopic material referred to in the art as "toner". The toner will normally be attracted to those areas of the layer which retain a charge, thereby forming a toner image corresponding to the electrostatic latent image. This powder image may then be transferred to a support surface such as paper. The transferred image may subsequently be permanently affixed to a support surface as by heat. Instead of latent image formation by uniformly charging the photoconductive layer and then exposing the layer to a light and shadow image, one may form the latent image directly by charging the layer in image configuration. The powder image may be fixed to the photoconductive layer if elimination of the powder image transfer step is desired. Other suitable fixing means such as solvent or overcoating treatment may be substituted for the foregoing heat fixing step.

Similar methods are known for applying the electroscopic particles to the electrostatic latent image to be developed. Included within this group are the "cascade" development technique disclosed by E. N. Wise in U.S. Pat. No. 2,618,552; the "powder cloud" technique disclosed by C. F. Carlson in U.S. Pat. No. 2,221,776 and the "magnetic brush" process disclosed, for example, in U.S. Pat. No. 2,874,063.

Development of an electrostatic latent image may also be achieved with liquid rather than dry developer materials. In conventional liquid development, more commonly referred to as electrophoretic development, an insulating liquid vehicle having finely divided solid material dispersed therein contacts the imaging surface in both charged and uncharged areas. Under the influence of the electric field associated with the charged image pattern, the suspended particles migrate toward the charged portions of the imaging surface separating out of the insulating liquid. This electrophoretic migration of charged particles results in the deposition of the charged particles on the imaging surface in image configuration.

A further technique for developing electrostatic latent images is the liquid development process disclosed by R. W. Gundlach in U.S. Pat. No. 3,084,043 hereinafter referred to as polar liquid development. In this method, as electrostatic latent image is developed or made visible by presenting to the imaging surface a liquid developer on the surface of a developer dispensing member having a plurality of raised portions or "lands" defining a substantially regular patterned surface and a plurality of portions depressed below the raised portions or "valleys". The depressed portions of the developer dispensing member contains a layer of conductive liquid developer which is maintained out of contact with the electrostatographic imaging surface. Development is achieved by moving the developer dispensing member loaded with liquid developer in the depressed portions into developing configuration with the imaging surface. The liquid developer is believed to be attracted from the depressed portions of the applicator surface in the charged field or image areas only. The developer liquid may be pigmented or dyed. The development system disclosed in U.S. Pat. No. 3,084,043 differs from electrophoretic development systems where substantial contact between the liquid developer and both the charged and uncharged area of an electrostatic latent image bearing surface occurs. Unlike electrophoretic development systems,

substantial contact between the polar liquid and the areas of the electrostatic latent image bearing surface not to be developed is prevented in the polar liquid development technique. Reduced contact between a liquid developer and the non-image areas of the surface to be developed is desirable because the formation of background deposits is thereby inhibited. Another characteristic which distinguishes the polar liquid development technique from electrophoretic development is the fact that the liquid phase of a polar developer actually takes part in the development of a surface. The liquid phase in electrophoretic developers functions only as a carrier medium for developer particles. In general the developer technique disclosed in U.S. Pat. No. 3,084,043 may provide development with liquid developers having a conductivity of from about 10^{-4} (ohm-cm)$^{-1}$ to about 10^{-14} (ohm-cm)$^{-1}$.

An additional liquid development technique is that referred to as "wetting development" or selective wetting as described in U.S. Pat. No. 3,285,741. In this technique, an aqueous developer uniformly contacts the entire imaging surface and due to the selected wetting and electrical properties of the developer substantially only the charged areas of the imaging surface are wetted by the developer. The developer should be relatively conductive having a resistivity generally from about 10^6 to 10^{10} ohm-cm and having wetting properties such that the wetting angle measured when placed on the imaging surface is smaller than 90° at the charged area and greater than 90° at the uncharged areas.

While capable of producing satisfactory images, these liquid development systems in general, suffer deficiencies in certain areas and are in need of further development and improvement. Particularly troublesome difficulties are encountered in liquid development systems employing reusable or cycling electrostatographic imaging surfaces. In these systems, for example, a photoconductor such as a selenium or selenium alloy drum as the photoconductor surface is charged, exposed to a light and shadow image and developed by bringing the image bearing surface into developing configuration with an applicator containing developing quantities of liquid developer thereon. The liquid developer is transferred according to the appropriate technique from the developer applicator onto the image bearing surface in image configuration. Thereafter, the developer pattern on the electrostatographic imaging surface is transferred to copy paper and the liquid developer may be absorbed by the paper to form a permanent print. During the transfer operation not all the liquid developer is transferred to the copy paper and a considerable quantity remains on the photoconductor surface. In order to recycle the imaging surface, this residual developer must be either removed or its effects immobilized; otherwise it will tend to be present as background in subsequent cycles. If the liquid developer is relatively conductive having, for instance, a resistivity less than about 10^{10} ohm centimeters, any residue remaining on the imaging surface may dissipate any charge subsequently put on it. Furthermore, lateral conductivity of the liquid developer on the imaging surface may become excessive and the resolution of the resulting image will be poor. On repeated cycling, there is also a progressive accumulation of liquid developer on the imaging surface since in each cycle, not all the developer is transferred to the copy paper. This progressive accumulation of developer residue results in an overall loss of density, deterioration of fine detail and contributes to increased background deposits on the final copy particularly since accurate imaging on the imaging surface may by inhibited.

Until recently, the procedures suggested to be employed to remove the developer liquid from the imaging surface have been so severe and complete that there has been a progressive degradation of the imaging surface particularly a photoconductor surface which degradation lessens its useful life span. The severity of the cleaning step is dictated by the fact that on cleaning a film from a surface, the film is progressively split so that on each separate cleaning only about one-half the film is removed. The cleaning solvents that have generally been suggested as adequate cleaning aids frequently chemically attack the imaging surface and are hazardous due to their volatility and toxicity. In some instances, with complete removal of the ink film the electrical properties of a photoconductor are virtually destroyed by the cleaning operation after only a few cycles. In other instances, the solvent employed may also act as a solvent for the resin binder in a binder plate or may induce crystallization of a thin layer of a selenium photoconductor. These problems have, however, to a very large degree, been solved, or at the very least, minimized by the development of the cycling cleaning system described in copending United States application for Letters Patent Ser. No. 873,103 by Joseph Mammino entitled "Cleaning System", and filed Oct. 31, 1969. Therein described is a cleaning system wherein dry, highly absorbent powders are placed on the imaging surface to absorb any residual developer of any particular imaging cycle. After absorbing the developer the fine powders are removed from the imaging surface.

When the technique described in the above U.S. Application for Letters Patent is applied to an automatic machine concept, difficulties are encountered in handling the dry powder. Since in a machine each cycle must be completed within a very short period of time between about 1 to 3 seconds, the powder must be quickly applied and removed from the imaging surface. The rapidity of the technique necessary to provide this result produces a considerable amount of dust during the cleaning. The dust is not only present in the cleaning zone which to some extent minimizes the cleaning efficiency with respect to quantity of cleaning powder employed, but also may be found in other parts of the machine where it may lead to contamination of material supply such as developer liquid and paper or may lead to abrasion or fouling of machine components. Furthermore, the quantity of powder employed in this technique is relatively large in that the powder is applied indiscriminately to the entire imaging surface and removed therefrom. While the cleaning powders may be recycled to some extent, means must be provided to measure the relative remaining absorbent capacity of the powder, and when the capacity is reduced below a certain level, the powder must be removed. To minimize or control these problems, the cleaning mechanism may be extremely cumbersome and complicated. It is therefore clear that there is a continuing need for an improved cleaning technique in a cycling electrostatographic imaging process.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide a developing system which overcomes the above noted deficiencies.

It is another object of this invention to provide a novel cleaning system.

It is another object of this invention to provide a cleaning system which makes more efficient use of cleaning materials.

It is another object of this invention to provide a simple cleaning system capable of cyclical use.

It is another object of this invention to provide a cleaning means for cleaning residual liquid developer from a reusable electrostatographic imaging surface.

It is another object of this invention to provide a simple mechanical means for cyclical cleaning a reusable imaging surface.

It is another object of this invention to provide a liquid development system superior to known systems.

It is another object of this invention to provide a cleaning system superior to known systems.

The above objects and others are accomplished, generally speaking, by providing a cycling electrostatographic imaging system having a cleaning system which enables complete cleaning of residual liquid developer without degradation of the imaging surface. Finely divided dry absorbent cleaning powders are selectively applied to the charged or developed areas of an electrostatographic imaging surface to remove residual liquid developer from the imaging surface in any imaging cycle. More specifically, in a liquid development system employing a cycling or reusable electrostatographic imaging surface the residual developer remaining on the imaging surface in any one cycle is cleaned from the surface by directly placing the highly absorbent dry powders in the areas on the surface to be cleaned. By so applying the cleaning powders to the imaging surface, the residual developer is effectively absorbed by the cleaning powder and with a minimum of mixing removes all residual developer on the imaging surface including that which may be present in the background areas and permits the cleaning powders to be readily removed from the imaging surface.

Any suitable method may be employed to selectively deposit the absorbent cleaning powders on the imaging surface. A particularly preferred technique for ease of operation and simplicity of design involves placing a charge on the powder so that it may be electrostatically pulled from a powder applicator to the image or charged area of the imaging surface. To accomplish this result, the cleaning powders must be charged to a polarity opposite that which the electrostatographic imaging surface bears in the image portions.

Any suitable method may be employed to provide cleaning powders oppositely charged in polarity to the polarity of the image areas of the imaging surface. A particularly preferred technique of great simplicity in design and materials along with excellent functional results is to triboelectrically charge the cleaning powder. The phenomena of triboelectrification is present when two dissimilar materials are brought into contact and rubbed against one another with each material becoming electrically charged to a polarity opposite to that of the other. The polarity obtained from the triboelectric charging may be determined by contacting the two materials, separating them and detecting the sign of the charge on each with an electrometer. By doing this with a variety of different materials, one may arrange the materials in a descending order from positive to negative such that any one material is negative with respect to any other material above it in the series. In such a series, materials above a given one listed will donate electrons to the material and materials below the given one will accept electrons from the material. Therefore, by appropriately selecting materials, the polarity of charge on the cleaning powders may be regulated.

The finely divided dry, absorbent powders may be triboelectrically charged in any suitable manner. They may, for example, be brought into contact with a fur cloth or other solid material. A particularly preferred manner of charging the cleaning powder is by contacting and transporting them by means of a granular carrier. In a typical embodiment, a mass of bead-like solid material and the dry absorbent powders are agitated to provide the desired charge on the cleaning powders. The cleaning powders are then transported to the imaging surface. They may, for example, be pushed, rolled, or cascaded across the imaging surface. A particularly preferred technique providing optimum cleaning while conserving materials, machine space and components is to transfer the charged cleaning powder to an applicator surface which delivers the cleaning powders to the imaging surface.

The invention may be further illustrated by reference to the accompanying drawings in which:

FIG. 1 is a schematic view of an embodiment of an electrostatographic imaging system employing the cleaning technique of this invention.

FIG. 2 is a schematic view of a preferred manner of charging, transporting and applying the charged cleaning powder to the imaging surface.

FIG. 3 is an alternative preferred manner of transporting the charged cleaning powder from a powder reservoir and charging station to the imaging surface.

In the electrostatographic imaging system depicted in FIG. 1, an electrostatic latent image is placed on the imaging surface here illustrated as a rotating cylindrical drum photoconductor **10**, such as a selenium drum by uniformly placing a positive charge on the drum by charging means **12**, exposing the charged imaging surface to a light and shadow image through exposure means **11**, and developing the electrostatic latent image at developing station **33**. Developing station **33** comprises a rotating pattern applicator roll **13** which is loaded with liquid developer **17** by means of feed roller **16** and doctored by doctor blade **14** held in place by positioning member **15** to provide liquid developer in the depressed portions of the applicator surface while the raised portions are substantially free of developer. The liquid developer **17** may be replenished through the developer reservoir **18** by any suitable means such as receptacle **19** with a gravity feed to the developer bath **18**. The developer on the imaging surface in image configuration is transferred to a receiver sheet such as ordinary paper **20**, which is moved through the transfer zone in contact with the drum at the same rate and in the same direction as the periphery of the drum. The paper to which the developed image is transferred is held in transfer position by idlers **21**. Transfer may be electrostatically assisted by means of corotron **31**. The residual liquid developer present on the electrostatographic imaging member is then cleaned from the imaging member at cleaning station **32**. At cleaning station **32**, a porous, resilient roll **25**, containing absorbent charged cleaning powder obtained from bath **24**, containing a mixture of cleaning powder **23**, and carrier beads **22**, delivers the charged cleaning powder to the imaging surface. The residual developer on the drum **10**, may contact the applicator roll containing the charged powder, picking the charged powder out of the applicator in response to the residual charge pattern left on the imaging surface. The residual liquid developer and the charged cleaning powder on the imaging surface next come in contact with a web-type material **27**, which is slowly advanced from a supply reel **30**, through idlers **28**, into a rubbing contact with the imaging surface and finally onto takeup reel **26**. This cleaning web is preferably moving slowly in the direction countercurrent to the direction of the advancing imaging surface so that the cleanest portion of the web contacts the cleanest portion of the imaging surface. In the initial stages of contact between the cleaning web and the imaging surface, the cleaning powder and residual liquid developer are intimately mixed together and the cleaning powder substantially and completely absorbs all the liquid forming a liquid loaded powdery residue. The liquid developer loaded powdery residue is removed from the imaging surface and transferred to the cleaning web. This transfer may be assisted electrostatically by means of a corotron **29**, or any other suitable means such as a biased roll. As a result of the countercurrent motion of the imaging surface and the cleaning web, the powdery residue is removed from the imaging surface by the cleanest portion of the cleaning web. The application of charged dry absorbent powder to an electrostatographic imaging surface and the removal from the surface of the powder with the absorbed liquid developer provides a substantially complete cleaning of the imaging surface such that upon passing the cleanest portion of the web cleaner the imaging surface is prepared for the next imaging cycle.

FIG. **2** is a more descriptive view of the particular cleaning powder applicator station of FIG. **1**. In FIG. **2** the powder applicator device is illustrated as a rotating cylindrical roll which may be independently driven or driven by contact with the moving imaging surface. While this applicator surface may be moved in a direction concurrent or countercurrent with the imaging surface, it is preferred to move it in a direction concurrent with the imaging surface to thereby minimize any possible abrading effect between the powder and the imaging surface and also to minimize any contamination of either the applicator or the powder supply by having the liquid developer pushed into it. In other words, by moving the applicator surface and the imaging surface in countercurrent directions, a nip of liquid developer would form at the line of contact between the two which would be moving in a direction toward the reservoir of cleaning powders. In FIG. **2** the powder applicator here depicted as a cylindrical roll **35**, rotates in powder reservoir **36** containing a mixture of cleaning powders **38**, and carrier beads **37**. An additional supply of cleaning powder is contained within powder supply chamber **39**. A flicker bar **40** is positioned on the reservoir housing so as to serve to contain the carrier beads or composite particles in the powder reservoir.

FIG. **3** is an enlarged view of an alternative cleaning powder supply means in which the powder applicator surface is depicted as a porous resilient belt **45**, driven around support rolls **46**, in powder reservoir **50**, containing finely divided absorbent powder **49**, and carrier beads **48**.

Any suitable absorbent powder may be employed in the practice of this invention. The cleaning aids may generally be described as small sized, highly absorbent, dry powders that function as tiny sponges. To minimize abrasion the dry powders preferably are softer than the surface which they are to clean. For a maximum cleaning effect, the powders are also preferably insoluble in the liquid developer, are adhesive after they have absorbed the developer liquid thereby enabling their ready removal from the surface and further do no introduce anything to contaminate or degrade the imaging surface. The absorbent powders typically have a surface area of from about 30 to about 950 m^2/gm. Preferably, the powders have a surface area of from about 100 to about 800 m^2/gm. The cleaning powders of this invention may be of any suitable size which provides the necessary surface area and absorptive ability. Typically, the particles range in size from about 0.1 to about 20 microns. As the size of the particles increases, they become more abrasive. On the other hand, if their size decreases, greater caution must be exercised in the handling of the powders. For these reasons average particle sizes of from about 1 to about 10 microns are preferred with average sizes of from about 3 microns to about 8 microns providing optimum balance in handling and performance. The particular cleaning powder should in general be selected based on the absorptive capacity of the powder for the particular developer. If the developers are oil base material, the cleaning powder preferably has a high oil absorption, if the developer is a polar liquid, the cleaning powder preferably has high absorptive powers for the polar developer and may have a low oil absorption. Typically, the preferred absorption capacity is from about 40 to about 500 milligrams of developer per 100 milligrams of powder.

Typical absorptive microporous materials useful in the practice of this invention include the finely divided forms of carbon such as furnace black, channel black, lamp black, bone black and charcoal; clays such as kaolin and china clay; diatomaceous earth, pumice, fly ash, infusorial earth; pigments such as titanium dioxide, zinc oxide and silica. Typical organic pigments having adequate absorptive capacity include quinacridones, phthalocyanines, and benzidine yellow.

Especially satisfactory cleaning is obtained with silica gels, kaolin clays, carbon black, titanium dioxide. Particularly preferred materials in handling and cleaning ability are the silica gels having an average particle size of from about 3 microns to about 11 microns, a surface area of from about 200 m^2/gm to about 350 m^2/gm and a liquid absorption of from about 100 to about 315 mg liquid/100 mg powder.

The absorbing cleaning powder may be applied to the surface to be cleaned in any suitable amount. Typically, the absorbing power of the powder is at least sufficient to absorb all the residual liquid on the imaging surface. Preferably the amount of cleaning powder applied provides an absorbing power greater than that necessary to absorb all the residual liquid. Generally the residual developer is present on the imaging surface in an amount up to a maximum of about 2.3 milligrams per square centimeter. For such amounts of liquid from about 1 percent to about 10 percent by weight of the developer of the cleaning powder are generally added.

Any suitable applicator means may be employed to transfer the dry cleaning powder from a powder supply or reservoir to the imaging surface. Typical materials would include rollers, webs and brushes. The applicator preferably is porous, soft and resilient to thereby hold a sufficient amount of dry powder to absorb all the residual developer and to present the dry powder to the imaging surface while minimizing any wear or abrasion due to contact between the two surfaces. A particularly satisfactory group of materials useful as the powder applicator may be described as porous, cellular foams. Typical cellular foams that may be employed as a powder applicator include sponge rubber, foamed polyurethane, polyethylenes, vinyls, polystyrene, cellulose acetate, phenolics, ureas, silicones, epoxies.

The granular carrier material may be of any shape although it is preferred to have them round or nearly round to facilitate their movements in mixing and to provide less friction. Any suitable round granular material may be employed. Typical granular materials include sodium chloride, aluminum potassium chloride, Rochelle salt, granular zircon, granular silicone, methyl methacrylate, phenolics, epoxies, ureas, melamines and other resins; glass, silicone dioxide, flint shot, iron, steel, ferrite, nickel, carborundum and suitable mixtures thereof. In those instances where the particular granular material does not impart the necessary triboelectric properties, the granular material may be covered with or encased in a suitable covering which imparts the necessary triboelectric properties so that it will properly charge the dry cleaning powder when mixed therewith.

To facilitate separation of the dry powder from the granular material, it is preferred that the carrier particles be substantially larger than the cleaning particles. Typically, the granular carrier particles have a particle diameter of between 50 microns to about 600 microns. The granular material should be sufficiently large not to be trapped in the cellular structure of the preferred powder applicator layer but should not be so large that it unduly limits the volume of cleaning powder with which it may be satisfactorily mixed. For these reasons, the particle diameter of the granular material is preferably between about 150 microns and about 450 microns. It is particularly preferred that the granular carrier material be provided with a lubricating coating to prevent the sticking of one particle to another since the entire mass of granular material and dry powders when being agitated should flow like a fluid.

To provide uniform charge on the dry cleaning powders, it is preferred that the granular carrier material and the powder be continuously and uniformly mixed during operation. The granular carrier material and the dry powders may be mixed together in any proportion which will provide sufficient charge on a sufficient amount of the dry powders to be transferred to an applicator surface and on subsequent transfer to the imaging surface remove all liquid developer. Typically, the mixture of granular carrier and dry powder comprises from about 10 to about 50 parts by volume of granular carrier to about 1 part by volume of dry powder. In obtaining uniform charging on the dry powder, there preferably is from about 20 to about 35 parts by volume granular carrier to 1 part dry powder.

The applicator surface should be sufficiently porous to hold an adequate quantity of the dry powder to substantially completely absorb all the liquid developer remaining on the imaging surface when pulled from the applicator to the imaging surface. To assist in transport of the dry powder from the granular carrier to the applicator, it is preferred to provide an applicator which is capable of being charged to a polarity opposite that of the dry powder. A particularly preferred applicator is a cylindrical roll between about 1 inch to 1 ½ inch in diameter comprised of a steel core with an adhesive backed polyurethane sponge cemented around it.

Since the cleaning powders and techniques of this invention provide a substantially complete cleaning of residual developer from the imaging surface on every cycle, no problem of charging and imaging through a residual liquid film exists and developers of both low and high conductivity may be employed. Any suitable developer may be used. Typically, the developers for which the dry absorbent powders of this invention are effective have a conductivity of from about 10^{-4} $(\text{ohm-cm})^{-1}$ to about 10^{-14} $(\text{ohm-cm})^{-1}$. Typical vehicles within this group providing these properties include glycerol, polypropylene glycol, 2,5 hexanediol, mineral oil, the vegetable oils including castor oil, peanut oil, coconut oil, sunflower seed oil, corn oil, rapeseed oil, sesame oil. Also included are mineral spirits, fluorinated hydrocarbon oil such as duPont's Freon solvents and Krytox oils; silicone oils, fatty acid esters, kerosene, decane, toluene and oleic acid. In addition, as is well known in the art, the developers may contain one or more secondary vehicles, dispersants, pigments or dyes, viscosity controlling agents or additives which contribute to fixing the pigment on the copy paper.

Any suitable electrostatographic imaging surface may be cleaned through the technique of this invention. Basically any surface upon which an electrostatic charge pattern may be cyclically formed or developed may be employed. Typical electrostatographic imaging surfaces include dielectrics such as plastic coated papers, xero printing master, photoconductors and overcoated photoconductors. Typical photoconductors that may be employed include selenium and selenium alloys, cadmium sulfide, cadmium sulfoselenide, phthalocyanine binder coatings, polyvinyl carbazole sensitized with 2,4,7 trinitrofluorenone. Typical overcoated photoconductors include those described in U.S. Pat. Nos. 3,234,019 and 3,251,686. A specific example of an overcoated photoconductor is a selenium layer on a conductive aluminum substrate overcoated with a thin film of polyethylene terephthalate. The electrostatographic imaging surface may be employed in any suitable structure including plates, belts, or drums may be employed in the form of a binder layer. For more effective cleaning, it is preferred to provide a surface to be cleaned which has a very smooth surface and which is non-absorbent for the liquid developer since generally the more smooth and uniform the surface, the better will be the cleaning.

After the dry, absorbent powders are applied to the imaging surface, it is generally preferred to distribute the cleaning powder over the imaging surface so that the entire surface is contacted with the dry absorbent powders to thereby insure maximum absorption of all residual liquid developer in the imaging surface including the residual developer in the image or developed areas and those that may be present in the background or undeveloped areas. When the dry absorbent powders employed in this invention have absorbed all the residual liquid developer, they are in the form of a solid powdery residue containing the absorbed developer within the powder and they must be removed from the imaging surface prior to the next imaging cycle. Any suitable cleaning system may be employed. Typical cleaning systems include: wiper blades, brushes, vacuum suction and cleaning webs. Particularly satisfactory distributing of cleaning powder and cleaning is obtained with the use of a fibrous cleaning web moving countercurrent to the direction of movement of the imaging surface such that the cleanest portion of the imaging surface is contacted and finally cleaned by the cleanest portion of the cleaning surface. The cleaning web may be made of any suitable material. Typical fibrous cleaning webs include those made from cheesecloth, flannel, rayon, cotton, and combinations of rayon and cotton, Dacron, polyester and/or polypropylene fibers. Particularly satisfactory cleaning is obtained with those fibrous webs which are substantially homogeneous and thick and have a high absorbent capacity. As indicated in FIG. 1 of the drawing, transfer of the dry powder containing absorbed liquid developer to the absorbent web may be facilitated by electrostatic transfer from the imaging surface to the web. This may be accomplished by the use of a corotron or a biased member disposed on the side of the cleaning web opposite the imaging surface.

In operation, an electrostatic latent image is placed on an electrostatographic imaging surface in a conventional manner. The electrostatic latent image is thereafter developed with a liquid developer according to any of the techniques previously discussed. Development preferably is obtained with the use of a patterned surface applicator roller wherein the liquid developer is present in the depressed portions of the applicator, while the raised portions are substantially free of developer and the developer is pulled from the developer applicator to the imaging surface in image configuration. After transfer of the developer from the imaging surface to receiver sheet in image configuration the residual developer remaining on the imaging surface is removed from the imaging surface according to the technique of this invention. According to this technique, and particularly according to the preferred embodiments illustrated in FIGS. 1 and 2 of the drawing, a mixture of granular carrier material and dry absorbent powder is provided and agitated to apply a charge to the cleaning powder. Thereafter, the powder is separated from the carrier and transferred to a porous resilient applicator which in turn is positioned close to or in contact with the imaging surface where the powder is transferred to the imaging surface in image configuration. Preferably the powder is separated from the granular carrier material by applying a charge of polarity opposite that as the powder to the applicator. In a particular example employing a selenium photoconductor as the electrostatographic imaging surface, the selenium would be positively charged and the image areas would remain positively charged following exposure. To be electrostatically attracted to the image areas of the selenium imaging surface, the dry absorbent powder should be negatively charged. Accordingly, the powder applicator is positively charged to pull the dry powder free from the granular carrier and the granular carrier also has acquired a positive charge due to the triboelectric contact between the granular carrier and dry powder. The polarity of charge placed on the granular carrier by the triboelectric contact and the polarity of any charge placed on the powder applicator must, therefore, be the same as the polarity of charge on the imaging surface. However, to provide the necessary transfer of dry powder from contact with the granular carrier to the imaging surface, the magnitude of potential on the powder applicator preferably is greater than the potential on the granular carrier and the residual potential on the imaging surface is greater than that on the powder applicator. However, while electrostatic transfer may be a principal means of transfer of dry powder from carrier to powder applicator and from a powder applicator to the imaging surface it is not the sole means of transfer. The powder may be transferred to the porous applicator from the carrier by physical scraping during contact. A considerable force acting towards transfer to the imaging surface is the adhesive nature of the liquid residue on the imaging surface. It is the combination of electrostatic transfer and the adhesive nature of this liquid which provide the necessary transfer of the dry cleaning particles to the imaging surface. While the powder applicator and the imaging surface may come in contact, it is preferred that they do not come in contact so that any residual developer on the imaging surface does not offset onto the powder applicator. Residual developer remaining on the imaging surface builds up to a thickness of approximately 3 microns. Therefore, in order to minimize any possible offset to the powder applicator, it is preferred that a layer of dry absorbent powder be provided on the powder applicator in excess of 3 microns and preferably from about 5 to about 10 microns in thickness. Such a relatively thick layer of powder also facilitates adhesive transfer to the imaging surface. Once the dry absorbent powder has been placed on the imaging surface to provide the maximum cleaning efficiency, it is preferred to uniformly distribute the dry powder over the imaging surface to absorb all the liquid developer remaining on that surface. This may be accomplished through any suitable means such as the cleaning web depicted in FIG. 1. With a cleaning web moving in a direction countercurrent to the direction in which the imaging surface is moved the dirtiest portion of the cleaning web would provide this smearing or distributing function in which all of the liquid developer would be absorbed by the absorbent powders. Further upstream in the arch formed by the contact between the cleaning web and the imaging surface, the cleaning web will remove all the absorbent powders which, while they have absorbed the liquid developer, remain powdery and substantially dry. The rate at which a web of cleaning material is consumed is a function of the rate of plate movement and the relative rate of the web required to yield satisfactory cleaning and has been found to vary to some degree dependent upon the particular cleaning material employed. Typically, the cleaning web is found to have a speed on the order of one-fortieth to one four-hundredth of the plate speed.

While the cleaning web and imaging surface may be moved in the same direction, minimum contact length has been found to occur when the web and plate are moved in substantially opposite directions.

The absorbent powder applicator may be independently driven or driven by the imaging surface. Preferably, it will be driven in the same direction as the imaging surface since if driven in a direction opposite to that of the imaging surface, the liquid developer would tend to fill the nip between the two surfaces and serve to contaminate the roll at this nip. When the absorbent powder applicator is frictionally driven by the imaging surface, it is in contact with the imaging surface under the minimal driving pressure necessary to provide adequate motion. If excessive pressure is employed, the absorbent powder may be mechanically pressed onto the entire imaging surface from the powder applicator thus using more powder than necessary and requiring additional cleaning effort later to remove this dry powder. The absorbent powder applicator may be driven at the same speed or a speed slightly slower or faster than the imaging surface provided the abrading effect is minimized and there is no transfer of liquid developer to contaminate the powder applicator.

The agitation of the granular carrier material and the absorbent powders should be sufficient to provide uniform mixing and charging of the absorbent powders and preferably takes place in an area adjacent to and in contact with the powder applicator. Providing this type of mixing in contact with a portion of the powder applicator minimizes any possible clogging of the applicator roller by some wetted powders which may be present on the powder applicator. By providing a sufficient mixing, the wetted powders should be removed from the applicator surface and uniformly distributed throughout the body of the cleaning material. This agitation may be provided simply by the stirring action of a powder applicator roller such as that depicted in FIG. 2. Any suitable means, however, may be employed such as a vibrating or stirring means. Any powder accumulating on the powder applicator that is undesirable may be removed from the applicator surface by positioning a flicking bar or pinch member in contact with the applicator.

DESCRIPTION OF PREFERRED EMBODIMENT

The following preferred example further defines and describes preferred materials, methods, and techniques of the present invention. In the example, all parts and percentages are by weight unless otherwise specified.

EXAMPLE I

An imaging system similar in configuration to that depicted in FIG. 1 is assembled. A photoconductor in the form of a drum comprising a surface layer of selenium about 50 microns thick on a conductive plate is positively charged to about 450 volts and exposed to a light and shadow image in conventional manner. The electrostatic latent image thus formed is developed by moving a patterned surface applicator roll having developing quantities of a developer in the depressed portions thereof past the image bearing surface so that liquid developer is pulled out of the depressed portions to the image bearing surface in image configuration. The speed of development is about 10 inches per second. The developer employed is of the following composition by weight:

Drakeol 9	30 parts by weight
Microlith CT	18 parts by weight
Methyl violet tannate	3 parts by weight
Ganex V216	15 parts by weight

Paraflint RG wax	0.5 parts by weight

Drakeol 9 is a mineral oil manufactured by Pennsylvania Refining Company having a kinematic viscosity of about 15.7 – 18.1 centistokes at 25°C. and a specific gravity of about 0.85. Microlith CT is a resinated predispersed carbon black pigment composed of about 40 percent carbon black pigment and 60 percent ester gum resin, manufactured by CIBA. Paraflint RG is a hard synthetic wax available in flake form from Moore & Munger. Ganex V216 is an alkylated polyvinyl pyrrolidone compound manufactured by GAF Corporation which serves as additional pigment dispersant and may also be regarded as a secondary vehicle.

The developer on the photoconductor is transferred to bond paper in image configuration. A reservoir containing about 5 cubic centimeters of Syloid 308, a silica gel available from Davison Chemical Division, W. R. Grace & Company, and about 175 cubic centimeters of about 450 micron diameter steel spheres. A sponge roll of about 1¼ inches in diameter composed of a polyurethane sponge containing about 80 pores perlinear inch on the surface, available from Scott Paper Company under the name of Scott Industrial Foam, and about one-eighth inch in thickness wrapped around a 1 inch aluminum core is rotated in the reservoir so that the lower portion is below the surface of the mixture of steel spheres and silica gel. The polyurethane powder applicator roll is driven by slight contact with the selenium drum at a speed of about 10 inches per second. A rayon web Miracloth, code 9243 manufactured by Chickapee Mills is advanced in a direction opposite to the rotating selenium drum along an arc of the drum surface of about 5 inches at a speed of about one one-hundredth that of the drum speed. The first print obtained with this apparatus is free of background and has a resolution of about 10 line pairs per millimeter. After repeated cycling of 1000 prints, no significant change in print quality is observed. Very little dusting and no fouling of the mechanical movements by any of the cleaning powder are observed.

The technique provided by the instant invention provides a substantially complete cleaning of all residual liquid developer from an imaging surface without any significant abrasion of the imaging surface and a very fast and efficient manner and employs very few mechanical moving parts. It further provides a cleaning system capable of cyclical use which minimizes dusting and conserves expendable material by applying only sufficient cleaning powder to the areas to be cleaned. In addition, the final material being handled after the cleaning has been accomplished is a substantially powdery residue.

Although specific materials and operational techniques are set forth in the above exemplary embodiments using the cleaning technique of this invention, these are merely intended as illustrations of the present invention. There are other materials and techniques than those listed above, which may be substituted with similar results.

Other modifications of the present invention will occur to those skilled in the art upon a reading of the present disclosure which modifications are intended to be included within the scope of this invention.

What is claimed is:

1. The method of cyclically developing electrostatic latent images on a reusable electrostatographic imaging surface comprising the steps of forming an electrostatic latent image on the imaging surface, developing the image with a liquid developer, transferring the developer from the imaging surface to the receiving surface in image configuration, selectively applying dry absorbent cleaning powder to the image area of said imaging surface to absorb substantially all of the liquid developer on the imaging surface and removing the absorbent powders containing absorbed liquid to prepare the imaging surface for the next imaging cycle and repeating the recited steps of forming, developing, transferring, applying and removing at least one additional time.

2. The method of claim **1** wherein said dry powder has a charge opposite in polarity to the charge in the image areas of the imaging surface.

3. The method of claim **1** wherein said dry absorbent powder is triboelectrically charged by contact with a granular carrier material.

4. The method of claim **1** wherein the imaging member is a reusable photoconductor.

5. The method of claim **1** wherein the photoconductor is selected from the group consisting of selenium and selenium alloys.

6. The method of claim **1** wherein said selective application of absorbent powder is electrostatically assisted.

7. The method of claim **1** wherein the imaging member is treated with an amount of absorbent powder at least sufficient to absorb substantially all the liquid on the imaging member.

8. The method of claim **1** wherein the absorbent powder is substantially insoluble in the liquid developer.

9. The method of claim **1** wherein the powder has a surface area of from about 100 to about 800 m^2/gm.

10. The method of claim **1** wherein the powder has a particle size of from about 1 to about 20 microns.

11. The method of claim **1** wherein said powder is removed from said imaging member by contacting the imaging member with an absorbent fibrous material.

12. The method of claim **1** wherein said absorbent powder is a silica gel.

13. The method of claim **1** wherein said absorbent powder is a finely divided carbonaceous material.

14. The method of claim **1** wherein said carbonaceous material is carbon black.

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