

Jan. 16, 1968

R. G. OLDEN

3,363,555

ELECTROSTATIC METHOD OF MAKING MULTIPLE COPIES OF AN IMAGE

Filed March 28, 1966

4 Sheets-Sheet 1

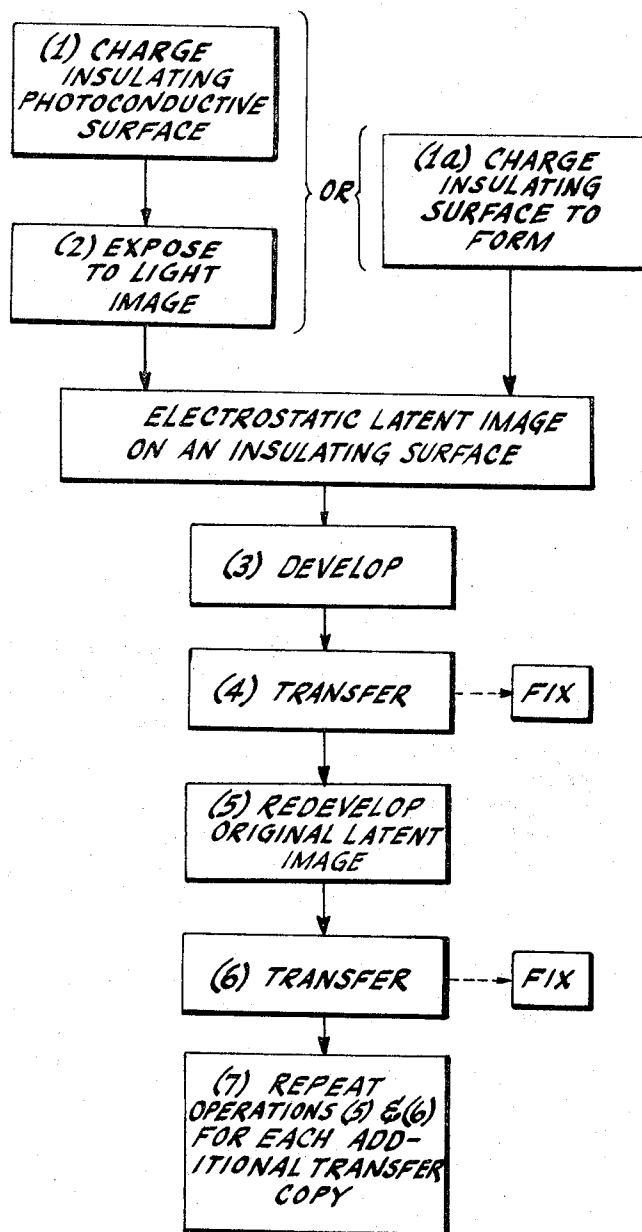


Fig. 1.

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Fig. 2.

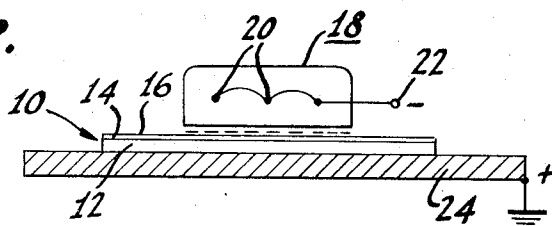


Fig. 3.

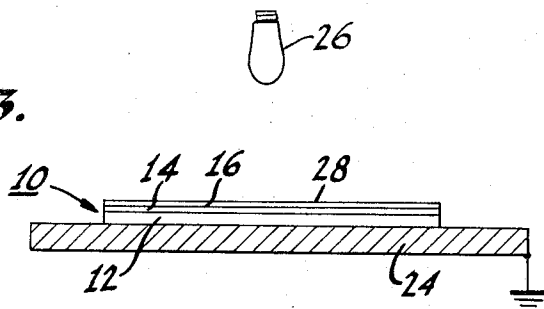


Fig. 4.

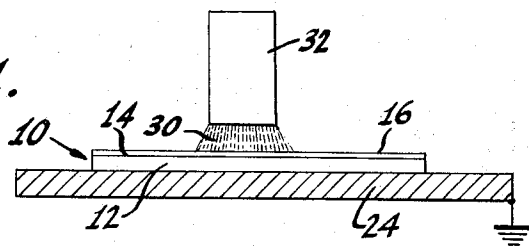
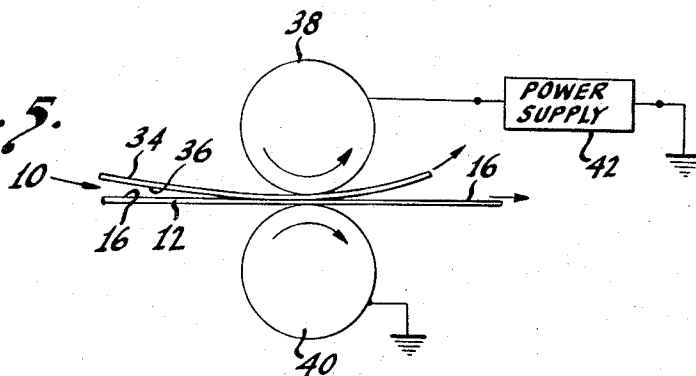


Fig. 5.



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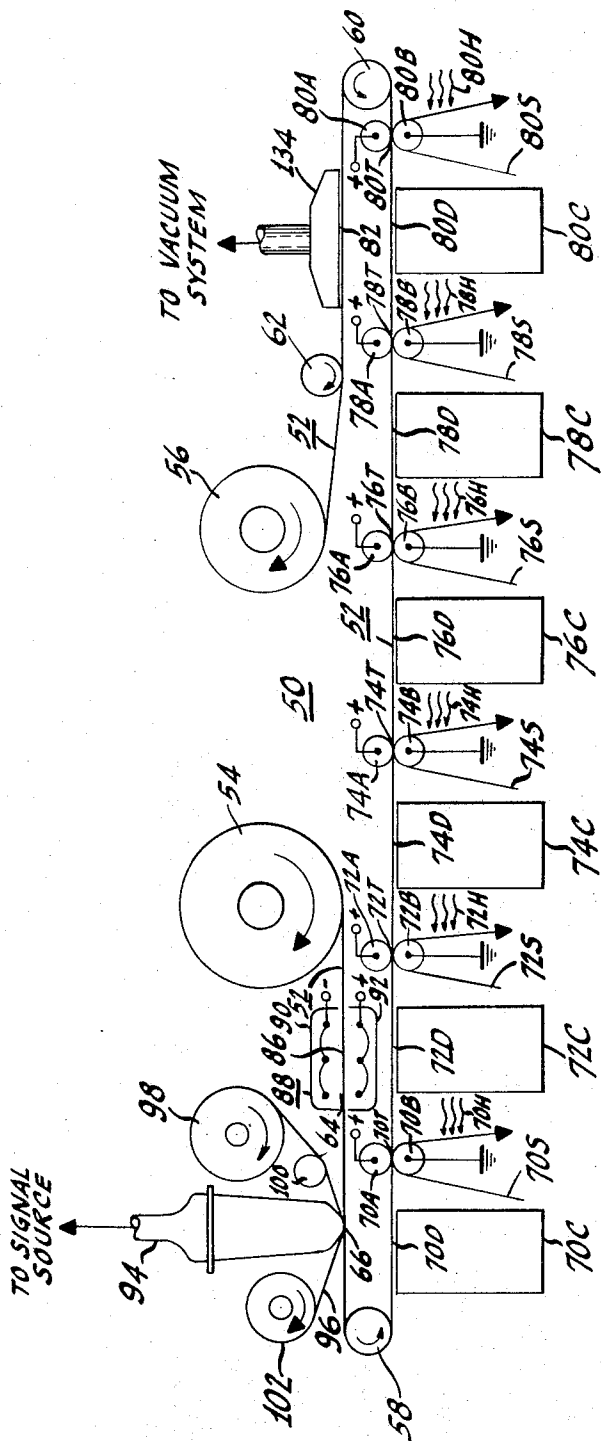
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ELECTROSTATIC METHOD OF MAKING MULTIPLE COPIES OF AN IMAGE

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4 Sheets-Sheet 3



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4 Sheets-Sheet 4

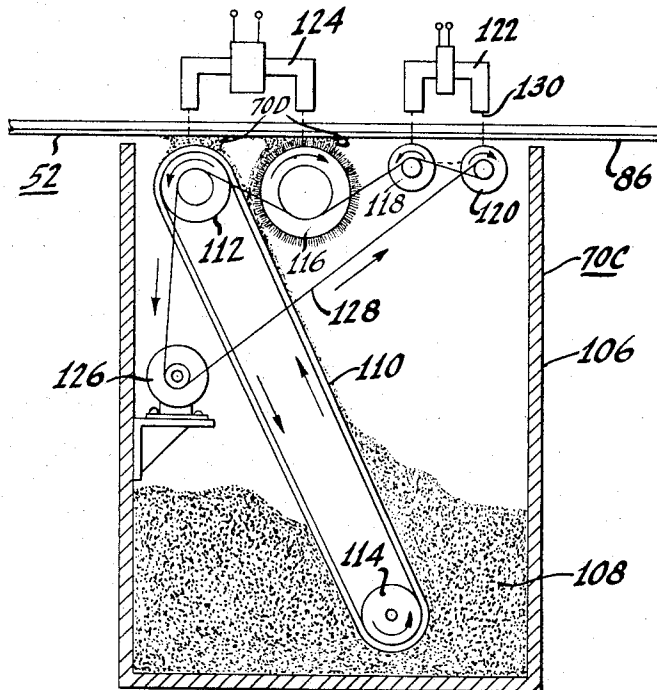


Fig. 7.

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ELECTROSTATIC METHOD OF MAKING MULTIPLE COPIES OF AN IMAGE

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3 Claims. (Cl. 101—426)

ABSTRACT OF THE DISCLOSURE

A method of making a plurality of visible copies from an electrostatic image on an insulating surface (after the first copy is made) comprises the steps of (1) redeveloping the original electrostatic image with a toner for each additional copy desired, and (2) pressing a transfer sheet against the unfixed redeveloped image for each additional copy desired. A transfer voltage may be applied across the insulating surface and the transfer sheet to attract at least a portion of the toner to the transfer sheet. The transfer voltage is preferably increased for each successive transfer copy desired.

This invention relates generally to electrophotography, and more particularly to an improved method of making multiple, visible, transfer copies from an electrostatic charge pattern. The improved method is particularly useful for making a plurality of copies of output data from computers whose outputs can be converted to electrostatic charge patterns.

In an electrophotographic process of the type described in RCA Review, vol. XV, p. 469, December 1954, for example, an electrophotographic recording element, comprising a layer of photoconductive zinc oxide dispersed in a resin binder on a backing of suitable conductivity, is charged negatively so that the photoconductive layer carries a uniform electrostatic charge over its surface. The recording element is exposed to a light image to discharge the surface in accordance with the light intensity falling on it and to leave thereon an electrostatic latent image. The latent image is developed by applying a finely divided electrostatically attractable toner, such as from an electroscopic mixture of fusible toner particles and iron filings, thereon. The developed image may be fixed to the recording element by applying heat to the toner particles to diffuse them into the recording element.

Previously, multiple electrostatic prints of an original have been made by exposing successively a plurality of uniformly charged, electrophotographic recording elements to the same light image of the original and developing each recording element separately. Such a method, however, requires the same light image to be available for each of the multiple exposures. In certain types of apparatus, as, for example, in computers where output data is provided on the face of a cathode ray tube, the data may be presented for a time sufficient to make only one copy thereof, thereby rendering the aforementioned prior-art method useless for providing multiple copies.

Another prior-art method of making multiple copies consists of making a number of transfer copies from a single, unfixed, developed original. Since only the amount of toner used to develop the original is available to produce all of the transfer copies, each succeeding copy usually has less contrast than the former.

It is an object of the present invention to provide an improved method of making a plurality of developed transfer copies of information that can be presented as an electrostatic image on a surface.

Another object of the present invention is to provide an improved continuous method of reproducing copies from only one original exposure.

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Still another object of the invention is to provide an improved method of making a plurality of transfer copies of controllable and/or uniform contrast.

In the improved method of making a plurality of developed transfer copies of an original image, an electrostatic latent image, or electric charge pattern, of the original image is first provided on an insulating surface of a recording element by the aforementioned electrophotographic process or any other suitable process. The latent image is then developed by applying electroscopic toner to it. A transfer material is disposed in contact with the unfixed developed image, and a transfer voltage is applied, if necessary, across both the element and the transfer material to attract toner from the insulating surface of the recording element to the surface of the transfer material. The transfer material is then separated from the recording element, retaining at least a portion of the toner attracted to it from the recording element, thereby providing the first developed transfer copy. Each additional transfer copy is obtained by redeveloping the original latent image on the recording element, disposing another transfer material against the unfixed redeveloped latent image, and applying a transfer voltage, if necessary, across the recording element and the transfer material to attract toner from the recording element to the transfer material. When separated from the recording element, the additional transfer material, with at least a portion of the toner attracted thereto from the recording element, provides an additional transfer copy.

In a preferred embodiment of the invention, the electrostatic charge pattern is provided on an insulating surface of a recording element in the form of a web. The web is moved along a predetermined path along which are disposed a plurality of developing stations. Means are associated with each developing station for moving a separate transfer sheet into contact with the developed latent image, whereby to transfer toner from the developed image on the web to the transfer sheet. A transfer voltage is applied across the web and each transfer sheet. The amplitude of the transfer voltage for each successive image transfer may be increased to compensate for the greater electrostatic force holding the developer particles nearer the charged surface and to attract sufficient developer particles from the redeveloped latent image, whereby to provide multiple transfer copies of controllable and substantially uniform contrast.

The improved method will now be described in detail with reference to the accompanying drawings, in which:

FIG. 1 is a block diagram of the operations in the improved method;

FIGS. 2, 3, 4, and 5 are side elevational views, partly schematic, of apparatus for manually carrying out the steps of charging a recording element, exposing the element to a light image, developing an electrostatic latent image of the light image, and transferring the developed image to a transfer sheet, respectively, in accordance with the improved method;

FIG. 6 is a schematic, side elevational view of apparatus for making a plurality of transfer copies from an original automatically and continuously, in accordance with the improved method;

FIG. 7 is a side, elevational, enlarged view, in vertical cross-section, of a developing station of one of the plurality of developing stations illustrated in FIG. 6, showing details of each of the developing stations.

Referring now to FIG. 1 of the drawings, there is shown a block diagram of the operations whereby an electrostatic latent image of an original image can be formed on an insulating surface, and the sequence of operations of the improved method for making a plurality of visible transfer copies from the single electrostatic latent image. The electrostatic latent image may be

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formed on the surface of a recording element, comprising an insulating layer of photoconductive zinc oxide on a relatively conductive paper backing, for example, by the operation 1 of charging the surface of the layer with a uniform electrostatic charge, as with a corona discharge device, and the operation 2 of exposing the uniformly charged surface to a light image of the original image to be reproduced. Alternatively, the electrostatic latent image can be formed on an insulating surface, such as a sheet of insulating plastic material, for example, by the operation 1a of charging the insulating surface directly with a charge pattern by any means known in the art.

Regardless of the means by which the electrostatic latent image is formed on the insulating surface, a plurality of visible transfer copies of the electrostatic latent image can be formed by the operations 3 to 7 listed in FIG. 1. The first transfer copy is made by the operation 3 of developing the electrostatic latent image with toner particles, and the operation 4 of transferring, both physically and electrically, the unfixed, developed image to a transfer sheet where it may be fixed, if desired. A second transfer copy can be made by performing the operation 5 of redeveloping the original latent image and 6 of transferring, both physically and electrically, the unfixed, redeveloped image to a different transfer sheet which may then be fixed, if desired. Additional copies are made by repeating operations 5 and 6 for each copy desired.

Referring now to FIGS. 2, 3, and 4, there is shown apparatus for manually forming an electrostatic latent image on a recording element 10 of the type comprising a relatively conductive backing 12, such as paper having a moisture content of about 5-6%, and an insulating layer 14 of photoconductive zinc oxide in a suitable resinous binder on the backing 12. The recording element 10 is preferably, but not necessarily, in the form of a sheet.

The insulating surface 16 of the layer 14 can be charged with a uniform electrostatic charge, such as a negative electrostatic charge, by a corona discharge device 18 of any type well known in the art. Corona discharge wires 20 of the discharge device 18 are connected to a negative terminal 22 of a source of unidirectional voltage (not shown) of an amplitude of, e.g., 6000 volts. A positive terminal of the voltage source is grounded to an electrically conductive substrate 24, such as a metal plate. To charge the surface 16 with a uniform negative charge, as shown in FIG. 2, the recording element 10 is disposed with its backing 12 against the substrate 24, and the surface 16 is exposed to the negative corona discharge from the wires 20.

Referring now to FIG. 3, means are shown for forming an electrostatic latent image of an original light image on the insulating surface 16. To this end, the uniformly charged insulating surface 16 is exposed to light, as from a lamp 26, through a slide 28. The slide 28 may be a photographic slide comprising a pattern of opaque and transparent areas forming an image of an original image which is to be reproduced in multiple. The uniformly charged surface 16 is discharged selectively through the photoconductive layer 14 and the conductive backing 12 in accordance with the intensity of light striking the layer 16 through the slide 28, thereby leaving an electrostatic latent image, that is, a charge pattern, on the insulating surface 16.

As shown in FIG. 4, the electrostatic latent image can now be developed by a developer 30 comprising, for example, an electroscopic mixture of particulate toner and iron filings. The particulate toner of the developer 30 may be applied to the electrostatic latent image by means of a magnet 32, as described in U.S. Patent No. 2,874,063, issued on Feb. 17, 1959, for Electromagnetic Printing.

A transfer copy of the unfixed pattern of toner particles constituting the developed latent image on the surface 16 of the recording element 10 can be obtained by means

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of the apparatus shown in FIG. 5. A transfer material, such as a sheet 34 of paper, having a major surface 36, is disposed against the surface 16 of the recording element 10 so that the surface 36 is in direct contact with the unfixed developed latent image on the surface 16 of the recording element 10. Pressure is applied between the transfer sheet 34 and the recording element 10 by passing them between parallel pressure biased rollers 38 and 40. The rollers 38 and 40 are of electrically conductive material, such as steel or conductive rubber, for example, and are pressure biased towards each other by any suitable means (not shown).

The roller 38 is biased electrically with respect to the roller 40, by a means of a unidirectional voltage source 42, as shown in FIG. 5. The roller 38 is either negative or positive with respect to the roller 40, depending upon whether a toner designed to produce a direct copy or a toner designed to produce a reverse copy is used.

Considering an ordinary printed page of dark type on a light background as the original image, a direct copy of the printed page is here defined as one in which the background areas are discharged by the exposing light and the electrostatic latent image (charge pattern) retained is in the printed areas. A reverse copy is one in which the electrostatic charge in the letter or type areas is discharged by the exposing light and the background areas remain charged.

The potential applied by the voltage source 42 across the rollers 38 and 40 may vary from about 50 volts to over a thousand volts. If the electroscopic toner used for developing is positive, the roller 38 would be negative with respect to the roller 40 to produce a direct, developed, latent image and positive to produce a reverse, developed latent image. When the transfer sheet 34 is separated from the recording element 10, a portion of the developer is retained on the surface 36 of the sheet 34 and forms a first copy of the original image. The transferred image may be fixed, as by heating, if desired.

A plurality of additional transfer copies are made from the original latent image on the recording element 10 by redeveloping the latent image, as shown in FIG. 4, and by transferring the unfixed redeveloped image to an additional transfer sheet 34, as shown in FIG. 5. The voltage between the rollers 38 and 40 may be increased incrementally for each additional transfer copy made because the electrostatic force holding the developer particles to the surface 16 increases as the thickness of the layer of developer particles decreases. Also, the electrostatic latent image decays with time and each redeveloped image has progressively less developer particles thereon. Six transfer copies of substantially the same contrast have been made, using steel rollers 38 and 40 and apparatus substantially similar to that shown in FIGS. 2-5, and using transfer voltages:

- 1st copy—600 volts
- 2nd copy—650 volts
- 3rd copy—750 volts
- 4th copy—850 volts
- 5th copy—1000 volts
- 6th copy—1200 volts

If at least one of the rollers 38 or 40 is of conductive rubber, the transfer voltages can be reduced substantially, probably because of the better surface contact provided. Thus, voltages only 10% of those mentioned above have been employed successfully when one of the rollers is of conductive rubber. If only a relatively few transfer copies are desired, say, for example, two or three copies, the transfer voltage may be eliminated altogether.

Referring now to FIG. 6, there is shown apparatus 50 for carrying out the improved method of making multiple transfer copies automatically and continuously. A recording element 52, similar to the recording element 10 and having a photoconductive coating 86 therein is provided in the form of a continuous web and is directed along a

predetermined path from a supply roll 54 to a take up roll 56. The recording element 52 is moved around spaced-apart rollers 58, 60 and 62, and wound up on the take-up roll 56, thereby defining the path of travel of a charge pattern on the recording element 52.

Charging and exposing stations 64 and 66, respectively, are disposed along the path of travel of the recording element 52 between the supply roll 54 and the roller 58. A plurality of developing stations 70D, 72D, 74D, 76D, 78D, and 80D and a plurality of associated image transfer stations 70T, 72T, 74T, 76T, 78T, and 80T are disposed along the path of travel of the recording element 52 between the rollers 58 and 60. An image erasing station 82 is disposed between the rollers 60 and 62.

At the charging station 64, the photoconductive, insulating, zinc oxide surface 86 of the recording element 52 is charged uniformly with a negative charge, as by a double corona discharge device 88, in a manner well known in the art. Thus, one corona discharge device 90 of the double corona discharge device 88 is connected to the negative terminal of a source of suitable voltage (not shown), and an oppositely disposed corona discharge device 92 of the double corona discharge device 88 is connected to the positive terminal of the voltage source, in a manner well known in the art. The insulating surface 86 is, therefore, charged negatively.

The uniformly charged recording element 52 is moved adjacent to the face of a thin window, cathode ray tube 94 to be exposed at the exposure station 66 by a light image to be reproduced. The tube 94 is connected to a source of signals, as, for example, the output of a computer (not shown), for the purpose of presenting output information images to be recorded.

A thin web of transparent plastic material 96, such as "Mylar," is disposed between the recording element 52 and the face of the tube 94, and moved at a much slower rate of speed than the recording element 52, so as to prevent excessive wear on the face of the tube 94 by the recording element 52. The plastic material 96 is moved from a supply roll 98, around a pulley 100 and around the face of the tube 94 to a take-up roll 102 by any suitable means. When the uniformly charged recording element 52 is exposed to the light image on the face of the tube 94, the uniform charge on the insulating, photoconductive surface 86 is discharged in proportion to the intensity of light reaching it, and an electrostatic latent image charge pattern results. The exposure time is relatively fast in comparison to the speed of travel of the recording element 52 so that the recording element can be exposed while in motion.

The electrostatic latent image on the surface 86 of the recording element 52 is developed at the developing station 70D by developing apparatus 70C. The details of the developing apparatus 70C are shown in FIG. 7.

Referring now to FIG. 7 there is shown the developer apparatus 70C comprising a container 106 for holding a quantity of electroscopic developer 108. The developer 108 may comprise particulate toner and magnetic filings. The developer is carried to the electrostatic latent image on the insulating surface 86 of the recording element 52 by a wide belt 110. The belt 110 which may comprise a strip of cloth, such as corduroy, is disposed around rollers 112 and 114 and extends from the developer 108 to the surface 86 of the recording element 52. A roller brush 116, having relatively soft bristles of velour, "nylon," or even flexible metal, is disposed for rotation so that it can contact both the belt 110 and the insulating surface 86 of the recording element 52. A pair of metal rollers 118 and 120 are disposed for rotation beneath the opposite poles, respectively, of an electromagnet 122 for the purpose hereinafter appearing. An electromagnet 124 is also disposed with its opposite poles over the roller 112 and brush 116, respectively, for the purpose hereinafter appearing. A motor 126 has its shaft coupled to pulleys on the roller 112, brush 116, and rollers 118 and 120 by a

belt 128 to rotate them in the direction indicated by the arrows.

In operation, the developer 108 is carried to the recording element 52 by the belt 110. When reaching the surface 86 of the element 52, the magnetic particles in the developer 108 are attracted by the pole pieces of the electromagnet 124 and pressed against the element 52. Some of the toner particles, as well as some of the magnetic particles of the developer 108, adhere to the element 52 and are moved to the roller brush 116. The brush 116, rotating in the direction of the movement of the element 52, but at a slower speed than the element 52, presents additional amounts of the developer 108 to the element 52. This action, due to the difference in the surface velocities of the element 52 and the brush 116, wipes the developer 108 against the surface 86 of the element 52, thus developing the latent electrostatic image thereon. Any magnetic particles that remain on the insulating surface 86, after the latent image has been developed, are removed by the rollers 118 and 120. The electromagnet 122 forms a magnetic circuit with the rollers 118 and 120, shown by the dashed lines 130, which helps to remove the magnetic particles from the insulating surface 86 and to return them to the developer 108 at the bottom of the container 106.

After leaving the developing station 70D, the developed image on the recording element 52 moves to the image transfer station 70T, between two pressure rollers 70A and 70B. The pressure rollers 70A and 70B are substantially similar in operation and function to the pressure rollers 38 and 40, shown in FIG. 5. The rollers 70A and 70B are rotated by any suitable means to move an image transfer sheet 70S, such as a web of paper, at the same speed as the recording element 52, into contact with the developed image. Thus, the rollers 70A and 70B serve as means to press successive portions of the transfer sheet 70S into contact with the developed image so as to transfer a portion of the unfixed developer from the recording element 52 to the transfer sheet 70S. The roller 70A may be biased with a voltage of proper polarity to help transfer the electroscopic developer 108 from the insulating surface 86 of the recording element 52 to the surface of the transfer sheet 70S, whereby to provide a first transfer copy. The transferred image on the transfer sheet 70S may be fixed by heat, as illustrated by wavy lines 70H from any suitable source, after the transfer sheet 70S is moved away from the recording element 52.

Additional transfer copies can be made by redeveloping the original electrostatic latent image on the surface 86 of the recording element 52 and making a transfer copy from the redeveloped image for each transfer copy desired. Thus, the original electrostatic latent image can be redeveloped at the successive developing station 72D-80D, by the developing apparatus 72C-80C, and transferred to transfer sheets 72S-80S between rollers 72A and 72B-80A and 80B, respectively, as explained for the production of the transfer copy on the transfer sheet 70S. The transfer voltages applied between the rollers 72A and 72B-80A and 80B are preferably increased in amplitude for each successive transfer because of the diminution in the charge of the original latent image with each redevelopment. By increasing the successive transfer voltages in suitable increments, as explained, for example, for the production of the multiple transfer copies by the method illustrated in FIGS. 2-5, it is possible to obtain a number of transfer copies with substantially the same contrast, assuming similar developer 108 is used for each transfer copy. Where different developers are desired for different transfer copies, each transfer voltage must be adjusted to provide a suitable transfer of the developer from the recording element 52 to the transfer sheet. For example, electroscopic developing mixtures of different toner particles (as of different colors) and iron filings may acquire different triboelectric charges, requiring different transfer voltages to produce transfer copies of a desired contrast.

After a desired number of transfer copies of the original image is made, any toner remaining on the image is removed at the erasing station 82. A hood 134, attached to a vacuum system, is disposed adjacent to the recording element 52 for sucking toner particles from the latent image. The hood 134 may also be fitted with rotating scrubbing brushes (not shown) to aid in the removing of the toner particles.

From the foregoing description, it will be apparent that there has been provided an improved method of making a plurality of visible transfer copies from a single charge pattern on an insulating surface. While the improved method has been illustrated with a developing operation carried out by electroscopic powder developer, variations in the method and applications thereof, all coming within the spirit of this invention, will, no doubt, suggest themselves to those skilled in the art. For example, a liquid developer may be used instead of the powder developer and applied to the latent electrostatic image by any suitable means known in the art. Hence, it is desired that the foregoing description shall be considered as merely illustrative and not in a limiting sense.

What is claimed is:

1. The method of making a plurality of developed transfer copies from an electrostatic latent image on the surface of an element, said method comprising the steps of:

- (1) applying electroscopic toner to said surface to develop said image,
- (2) disposing the surface of one transfer material in contact with the developed image,
- (3) applying across said element and said one transfer material a given voltage of a polarity to cause said electroscopic toner to be attracted from said surface of said element to said surface of said one transfer material,
- (4) separating said one transfer material, with at least a portion of said toner thereon, from said element, whereby to provide one of said developed transfer copies,
- (5) reapplying electroscopic toner to said latent image on said element to redevelop said image,
- (6) disposing the surface of another transfer material in contact with the redeveloped image,
- (7) applying across said element and said other transfer material a voltage greater than said given voltage and of a polarity to attract said electroscopic toner from the redeveloped image to said surface of said other transfer material, and
- (8) separating said other transfer material, with at least a portion of said toner thereon, from said element, whereby to provide another of said developed transfer copies.

2. In a continuous method of reproducing copies from an original, where said original is an unfixed, developed, toned image of electroscopic toner of an electrostatic latent image on the surface of a web, said method comprising the steps of:

- (1) advancing said web with said toned image thereon along a predetermined path at a predetermined speed,
- (2) advancing a transfer material with the same speed as that of said toned image,
- (3) bringing said toned image and said transfer material into contact with one another while continuously moving them together,

- (4) applying voltage across said web and said transfer material where said web and said sheet are in contact with each other to attract toner from said toned image to said transfer material,
- (5) deviating the paths of travel of said web and said transfer material to separate said transfer material from said web, said transfer material having retained thereon a toned image corresponding to the original,
- (6) redeveloping said electrostatic latent image on said web with electroscopic toner while said web is advancing along said predetermined path,
- (7) advancing another transfer material at the same speed as that of said web,
- (8) bringing said redeveloped toned image and said other transfer material into contact with one another while continuously moving them together,
- (9) applying voltage across said web and said other transfer material where said web and said other transfer material are in contact with each other, to attract toner from the redeveloped toned image to said other transfer material,
- (10) deviating the paths of travel of said web and said other transfer material to separate said other transfer material from said web, said other transfer material retaining thereon at least a portion of the toner from said redeveloped toned image corresponding to the original,
- (11) repeating the steps of (6), (7), (8), (9) and (10) for each additional copy, and
- (12) increasing the amplitude of said voltage for each successive copy.

3. In a method of making a plurality of developed transfer copies of a charge pattern on an insulating surface of an element, wherein a first transfer copy is made by developing said charge pattern with an electroscopic toner, pressing a first transfer material against said developed charge pattern, applying a first transfer voltage across said element and said first transfer material, and then separating said first transfer material from said charge pattern with at least a portion of said toner thereon, the improvement of

- (1) redeveloping said charge pattern on said insulating surface with electroscopic toner,
- (2) pressing an additional transfer material in contact with said redeveloped charge pattern and applying a second transfer voltage of an amplitude greater than that of said first transfer voltage, and
- (3) separating said additional transfer material from said insulating surface with at least a portion of said toner thereon, whereby to provide an additional transfer copy.

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