This invention relates generally to improved methods and means for electrostatic printing, and particularly to methods and means for improving electrostatic charging and charge retention on an insulating or photoconductive web or the like on which an electrostatic charge image is to be established.

In the art of electrostatic printing, electrostatic images are produced on the surface of an insulating material. Such images comprise a pattern of electrostatic charges on the surface. Visible images are commonly produced therefrom by applying across the surface a dry mixture of finely-divided developer particles and substantially larger carrier particles. The developer particles deposit in charged areas to produce a visible image in substantial configuration with the pattern of charges. Several methods of producing visible images are described in "Electrostatic Direct Electrophotographic Printing on Paper," by C. J. Young and H. G. Greig, RCA Review, Dec. 1954, vol. XV, No. 4.

The recording element may comprise almost any insulating surface but, preferably, the recording surface is also photoconductive to enable the recording of light images. Recording elements comprising photoconductive selenium coated plates are described in U.S. Patent 2,927,691, issued Oct. 6, 1942, to C. F. Carlson. Recording elements comprising photoconductive coatings such as zinc oxide in an insulating film-forming binder on paper are described in the aforementioned Young and Greig publication.

A so-called liquid process for developing electrostatic images has been proposed in which the solid developer particles are suspended in an insulating carrier liquid. Liquid development methods provide many distinct advantages over the use of dry developer mixtures and other methods of developing electrostatic images for some applications. Basically, the liquid developer consists of finely-divided developer particles dispersed in an insulating liquid. This developer can be flowed over a surface bearing an electrostatic image or the surface can be immersed in a tray of liquid developer. It can also be sprayed or rolled onto the surface. A liquid developer process for charge images is described in greater detail by K. A. Metcalfe and R. J. Wright in a paper entitled "Xerography," published in the Journal of the Oil and Colour Chemists' Association, November 1956, vol. 39, No. 11, London, England and in another paper entitled "Liquid Developers for Xerography," published in the Journal of Scientific Instruments, February 1955, vol. 32.

Although each of the above-mentioned development processes have advantages for particular purposes, it has been found that they entail at least one common problem. The ability of insulators and some photoconductors to retain an electrostatic charge, and in at least some instances to attain a desirable maximum charge voltage, decreases as a function of temperature. For photoconductors such as zinc oxide in an insulating film-forming binder, for example, it has been found that, unexpectedly, charge retention and maximum charge capability deteriorate at a much higher rate at temperatures in excess of about 42°C. As this is only about 20°C above average ambient temperatures, sensitivity and image contrast problems are introduced by the heat generated by the image illuminating source and by the heating element commonly used for fixing the developed electrostatic image. Such problems become especially acute in low-cost electrostatic photocopy apparatus wherein the recording element is subjected to widely varying time intervals of relatively high incident temperatures.

An object of the invention is to provide improved methods and means for electrostatic printing. Another object is to provide novel methods and means for improving electrostatic charging and/or charge retention on an electrostatic recording medium.

A further object is to provide improved methods and means for overcoming deleterious temperature effects in electrostatic recording systems.

Another object is to improve the sensitivity and/or contrast of electrostatic recording systems.

The foregoing and other objects are accomplished in accordance with the invention wherein the electrostatic recording medium and, if desired, the developer medium and apparatus are cooled to maintain the recording medium at a temperature permitting satisfactory electrostatic charge voltage and charge retention.

In a typical embodiment of the invention comprising photocopy apparatus utilizing a recording medium comprising a paper web support coated with photoconductive zinc oxide in an insulating film-forming binder, electrostatic charging, image exposing, image liquid developing and image fixing apparatus, the desired temperature control includes air cooling of the recording medium at the charging and exposing station, as well as cooling of the liquid developer solution and the developer applicator structure.

Such cooling must be accomplished without interference with the charging, exposing, developing and fixing functions. The novel air circulating structure also includes a common air conduit system for simultaneously cooling the developer applicator and for forcing air through the heat fixing structure. In addition, the heat fixing element is programmed to be operated at an intermediate elevated temperature when the recording web is stationary, and operated at a higher temperature when the developed image is fixed as the web passes under the heat-fixing element.

The invention will be described in greater detail by reference to the accompanying drawings wherein:

FIGURE 1 is a front, cross-sectional view taken along the section line 1—1 of FIG. 2 of the interior of an electrostatic printing apparatus made in accordance with this invention;

FIGURE 2 is a side, cross-sectional view of the interior of the apparatus of FIG. 1 taken along the line 2—2 thereof;

FIGURE 3 is a cross-sectional partial rear view of the apparatus, taken along the section line 3—3 of FIG. 2;

FIGURE 4 is a perspective partially cut-away view of the image fixing mechanism of said apparatus;

FIGURE 5 is a partial perspective view of the air flow circulating mechanism included in FIGS. 3 and 4; and

FIGURES 6 and 7 are other detail views showing the air circulating portion of the mechanism of FIGS. 1 through 5.

Similar reference characters are applied to similar elements throughout the drawings.

A compact photocopy apparatus in accordance with this invention is illustrated in FIG. 1. The apparatus is designed with a portion of the photographic print and the housing thereof forming an inverted V-shaped roof. This V-shaped structure is adapted, as shown, to support a book 11 so that a page thereof which is to be copied is in contact with a transparent plate 13. A hinged plate 14 is provided to insure that the page to be copied is firmly held against the transparent plate 13. A single sheet, such as a letter, could be equally well held in place by the hinged plate 14. The page of the book is illuminated through the
transparent plate 13 by means of a light source 15 and a reflector 17.

The light source 15 may comprise one or more pencil shaped horizontal lamps. Well suited for the purpose are lamps such as 500 watt tungsten filament quartz tubes which contain traces of iodine. The iodine in the lamp functions to cathode tungsten particles which evaporate during operation and to return those particles to the filament. Such a lamp is produced by the General Electric Company, catalogue No. 500FT3Q-CL. The reflector 17 conveniently contains a segment of a 6" hollow cylinder, the inside of which is polished to a high degree. Since the distance from the light source 15 to the bottom edge of the plate 13 is much less than the distance from the light source 15 to the top edge of the plate 13, the reflector 17 is positioned to concentrate reflected light toward the upper portion of the transparent plate 13 so that the entire area under the plate is uniformly illuminated. In addition, if required, a properly shaped screen 16 or absorber 18, in the direct or reflected paths respectively of the illumination, may be used to improve illumination uniformity on the page to be copied.

Light reflected from the page of the book 11 is concentrated through a lens system 19 to impinge upon the mirror 21. The light is then reflected from the mirror 21 upwardly and focused on an exposure plane 23. At this point, a shutter 24 is provided in the light path between the mirror 21 and the exposure plane 23 in order to prevent any ambient light from reaching the exposure plane except when exposure is desired.

Further details of the internal structure of the compartment 27 are illustrated in FIG. 2. A supply roll 29 of photosensitive webbing is mounted in the lower portion of the compartment 27. The webbing 30 on the supply roll may comprise, for example, electrophotographic paper such as is described in the aforementioned Young and Greig publication. The paper 30 is fed from the supply roll 29 over an idler roller 31 through a double corona charging apparatus 33 and into the exposure plane 23. The paper is then carried partly around one flexible surface roller 25 of a pair of pressure rollers in a manner so that it reverses its direction and is then brought out from the corona apparatus under a heat fusing mechanism 28.

In the apparatus as shown in FIG. 2, the double corona charging unit 33 may comprise two opposed structures of very fine parallel wires as described in U.S. Patent 2,922,883, issued to E. C. Giaimo, Jr., on Jan. 26, 1960, and the heat fuser 28 one such as is described in U.S. Patent 2,857,682 to R. G. Olden et al. on Oct. 28, 1958.

From the charging apparatus 33 the paper 30 is transported into the exposure plane 23 with its photosensitive surface facing downward. While the paper is maintained stationary in the exposure plane 23, the charging unit is energized and traverses the paper forwards and back to the position shown. After charging is completed, the light source is energized for desired exposure time, and the light image reflected upward from the mirror 21 to substantially reduce or eradicate the charges placed on the paper by the corona unit 33 in those areas on which light impinges. As the paper 30 subsequently passes over one of the pressure rollers 25, liquid developer composition from liquid developer unit 35 is applied to the other pressure roller 26, which in turn applies the liquid developer composition to the paper 30 to produce, in those areas thereof which were not struck by light, a visible image of developer material. This visible image is then fixed to the surface of the paper as it passes under the fuser 28.

The developing unit 35 includes the two pressure rollers 25 and 26 which engage the paper which are driven to pull the paper from the supply roller 29 through the projection plane 23. Liquid developer composition is applied to the upper pressure roller 26 by means of the applicator 41, described in detail hereinafter. The developer composition is supplied to the applicator 41 through a pipe 43 connected to a centrifugal pump 45. As liquid developer composition is carried by the upper pressure roller 26 into contact with the paper, a turbulent nip 46 of the developer composition is formed where the roller 26 contacts the paper. This turbulent nip 46 of developing composition substantially enhances development of images on the paper and also enhances clean-up of developer material which may adhere in unwanted areas on the paper 30. The liquid developer composition not only forms the nip 46 but also flows down the surface of the paper 30 as it is carried over the pressure roller 25. The developer composition is thereby caused to flow in the same direction of the motion of the paper 30 as it is transported over the roller 25.

Developer composition in excess of that used to develop an image on the paper drops therefrom into a tray or sump 47 positioned below the two pressure rollers 25 and 26. The developer composition collected in the sump 47 is returned to the developer container 44 through a pipe 49.

A preferred form of the apparatus 41 includes a metallic head having its upper surface and ends curved to conform to the surface of the upper pressure roller 26 to provide a seal for the liquid developer dispersion. The applicator 41 has a length slightly less than the length of the pressure roller 26. An elongated U-shaped slot 42 extending almost the full length of the applicator 41, and centered therein, opens at the lowest point 43 thereof into the developer supply pipe 43. The applicator 41 is supported in the developer assembly 35 by flat pressure springs, 51 and 53, which press the applicator firmly against the surface of the roller 26. The face 55 of the applicator 41 adjacent the lower edge of the pressure roller 26 is undercut about .005 inch. The precise depth of undercut required is dependent upon developer pump capacity in order to insure that developer continuously fills the slot and undercut openings. Thus, while the upper surface 57 and the ends of the lower adjacent surface in close proximity to the face of the roller 26, the developer is applied extremely uniformly and with the desired pressure to the lower face of the roller 26 along substantially its entire length.

After the developer has been carried by the upper roller 26 to develop the electrostatic image on the paper 30, the developer runs down the surface of the paper, as indicated by the stippling, until it reaches the wiper seal 61. The wiper seal 61 comprises a member, for example, of Teflon, beveled to conform to the surface of the paper carried by the lower pressure roller 25. It is pressed against the lower surface of the paper by one or more flat or coiled springs 63 supported in a bracket 65 attached to the side of the sump 47. Excess developer collected in the bottom of the sump 47 is returned to the developer reservoir 44 through the return pipe 49.

Cooling system

Referring to FIG. 1, a first blower 71 having an air deflectors 73 is included at the lower right side of the compartment 27 to project a relatively slow fan-shaped column of air 75 across the compartment to the opposite and adjacent walls 77 thereof, from which it is deflected slowly across the image plane 23 of the recording medium. After cooling the recording medium the air is vented out of the compartment through the openings 79 at the upper edges thereof. It is essential that the air column from the blower 71 be sufficiently diffused and of sufficiently low velocity to prevent any undue movement or displacement of the recording medium from the image plane.

Referring to FIGS. 1, 3 and 5, a second blower 81 projects a column of air into a conduit 83 which includes a dividing vane 85 to provide separate circulating columns of air for cooling the top plate 87 of the compartment 27 as well as for the developer-cooling and heat-
fixing structures to be described in detail hereinafter. The column of air in the right-hand portion 84 of the conduit 83 also is divided into two air columns. The first passes through a horizontal conduit 89 to cool the top plate 87 of the compartment 27. The resultant cool wall provided by the top plate 87 helps to cool the upper surface of the recording web 30 which is disposed closely below the plate 87.

The second portion of the air column in the right-hand portion 84 of the conduit 83 is projected across the paper web 30 as it emerges from the heat-fixing fuser 28. This helps to cool the fixed recorded image on the web 30 and also is helpful in blowing heat away from the operator as the paper web approaches. The air column in the left-hand portion 86 of the conduit 83 passes through a second horizontal air conduit 91 from which it feeds through openings 93 in the lower wall 95 thereof to the developing and fusing structure. Deflecting vanes 97, 99 (FIG. 6) initially shield the heat fuser 28 from the column of air passing through the aperture 93 and deflect said column around the upper surface of the developer roller 26 to cool the roller before it picks up liquid from the applicator 41. After cooling the developer roller 26 the diffused air column is then caused to pass through the fuser 28 to project a uniformly distributed column of hot air upon the recording web 30 to fix the developed image thereon.

In order to minimize undesired heating of the developer structure by the fuser 28, while permitting the fuser to operate efficiently when desired for fixing the developed images, the fuser is normally operated at an elevated temperature which is below that which would char the recording paper web when it is stationary thereunder. As soon as the paper recording web is caused to travel under the developer roller 26 to the fuser 28, the current through the fuser is increased to provide an operating temperature sufficient to fix the developed image on the web but insufficient to char the moving web.

The air column projected onto the recording web from the fuser 28 normally would travel directly towards the operator. However, the transverse air column blown across the web 30 from the openings 101 near the top of the right-hand portion 84 of the air conduit 83 causes the hot air column to be blown away from the operator and cooled.

Notwithstanding the cooling of the recording web at the exposure station 23 to a temperature of less than 45° C., continuous operation of the photocopy apparatus tends to raise the temperature of the liquid developer solution and developer applicator structure to temperatures which may reach as high as 60° C. Even with the relatively brief time interval required for liquid development, if the developer temperature exceeds about 50° C., the charge image retention may be adversely affected, and poor image contrast and detail may result. Accordingly, it is frequently found desirable to cool the developer reservoir 47 by blowing a vertical column of air against the outer surface thereof. The air column may be provided by a fan 103 (FIGS. 2 and 3) driven by the same motor 105 as drives the developer pump 45. If desired, an additional blower 107 may also project a cooling air stream on the developer tank 44 which may include cooling fins and/or a cooling jacket. Inlets 109 (FIGS. 1 and 2), which may include suitable dust filters if required, are provided for cool air intake to the various air circulating elements.

The developer unit described comprises a substantially closed system for developing images on the paper 30. Such a closed system makes it possible to use developer compositions which include a highly volatile liquid with resulting in excessive evaporation of that liquid. Excessive evaporation would ultimately result in wide variations in the concentration of the developer material in the developer composition.

An example of a suitable, highly volatile developer composition is one where in finely-divided electroscopic developer particles are dispersed in a liquid carrier of trichlorotrifluoroethane.

**EXAMPLE**

A black pigment is prepared by making two solutions:

Solution one comprises:
- 6 grams Iosol black (C.I. solvent black 13).
- 400 grams methanol.

Solution two comprises:
- 9 grams spirith nigrosine (C.I. 50415).
- 400 to 600 grams methanol.

Solution one is poured into solution two with continuous stirring. Once the solutions have been thoroughly mixed and a black, relatively insoluble pigment is precipitated, the mixture is filtered and the filter cake allowed to dry. The dried filter cake is broken up and dispersed in di-methyl polysiloxane liquid having a viscosity of about 2 centistokes. The proportions in this dispersion are about 1 to 10 parts black pigment to about 20 parts of liquid. It is preferred that the liquid content be kept as low as possible but sufficient to provide a uniform dispersion. After ball milling the black pigment is classified as to particles size. Particles having a diameter of 74 microns or less are preferred.

Also prepared is a solution consisting of: 200 grams dimethyl polysiloxane (silicone); 200 grams trichlorotrifluoroethane (Freon). About one part by weight pigment dispersion per 10 parts solution is added to provide a final developer composition.

As images are developed on the paper with the apparatus, the concentration of developer particles in the container 44 may become depleted at a greater rate than will the liquid carrier portion thereof. In order to maintain the proportions of components in the liquid developer at a substantially constant level, means (not shown) may be provided for injecting into the container 44, metered amounts of a concentrated developer composition.

What is claimed is:

1. Electrophotographic recording apparatus of the type wherein heat tends to develop beyond a desired temperature during use, said apparatus comprising:
   a) web feeding means for an insulating photoconductive recording web medium; at a first fixed station for said web;
   b) means for providing a uniform electrostatic charge to the surface of said insulating photoconductive recording medium;
   c) means for projecting an electromagnetic image upon said charged medium to establish a corresponding electrostatic image thereon; and
   d) means for circulating a cooling fluid around opposite sides of said medium for cooling said medium below about 45° C. to improve the electrostatic charge retention characteristics of said medium;
   e) a source of liquid developer;
   f) means for cooling said developer below about 50° C.;
   g) developer roller means at a second station for applying said developer to said electrostatic image to provide a visible recorded image;
   h) heating means located adjacent to said developer roller means for fixing said developed image; and
   i) air circulating means for cooling said developer roller means and for circulating air through said heating means to said recording web.

2. Apparatus as defined in claim 1 wherein said air circulating means comprises:
   a) a conduit providing a source of air under pressure and extending substantially co-linearly and parallel with said developer roller; and
   b) means for guiding the air from said conduit past...
the periphery of said developer roller for cooling said roller and for subsequently guiding said air through said heating means.

3. Apparatus as defined in claim 1 wherein said air circulating means comprises:

(a) a conduit providing a source of air under pressure and extending substantially co-linearly and parallel with said developer roller; and

(b) means including a deflecting shield for said heating means for guiding the air from said conduit past the periphery of said developer roller for cooling said roller and additional air distributing means for subsequently guiding said air through said heating means.

4. Apparatus as claimed in claim 1 including means for operating said heating means at a standby elevated temperature insufficient to char said web when said web is stationary, and means for raising the temperature of said heating means when there is relative movement between said web and said heating means to fix developed images on said web.

5. Electrostatic recording apparatus of the type wherein heat tends to develop beyond a desired temperature during use, said apparatus comprising:

(a) web feeding means for an insulating recording web medium;

(b) means for providing an electrostatic charge image on the surface of said insulating photoconductive recording medium;

(c) means for circulating a cooling fluid around said medium for cooling said medium below about 45° C. to improve the electrostatic charge retention characteristics of said medium;

(d) means for developing said electrostatic image to provide a visible recorded image;

(e) heating means for fixing said developed image;

(f) means for operating said heating means at a standby elevated temperature insufficient to char said recording medium, and means for raising the temperature of said heating means to fix developed images on said medium; and

(g) air circulating means for cooling said developing means below about 50° C. and for circulating air through said heating means to said recording medium.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION


Knut J. Magnusson

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 33, for "recorling" read -- recording --; column 5, line 70, for "volatale" read -- volatile --; column 6, after line 40, insert the following paragraph:

A suitable developer concentrate may be prepared by dispersing developer material such as that described heretofore in a dimethyl polysiloxane in a proportion of about 20 parts by weight of developer material to 80 parts by weight of a dimethyl polysiloxane having a viscosity from 0.6 to about 3 centistokes.

Signed and sealed this 28th day of November 1967.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents