Sept. 28, 1954 C. F. CARLSON 2,690,394

ELECTROPHOTOGRAPHY

Filed June 6, 1950

Fig. 1

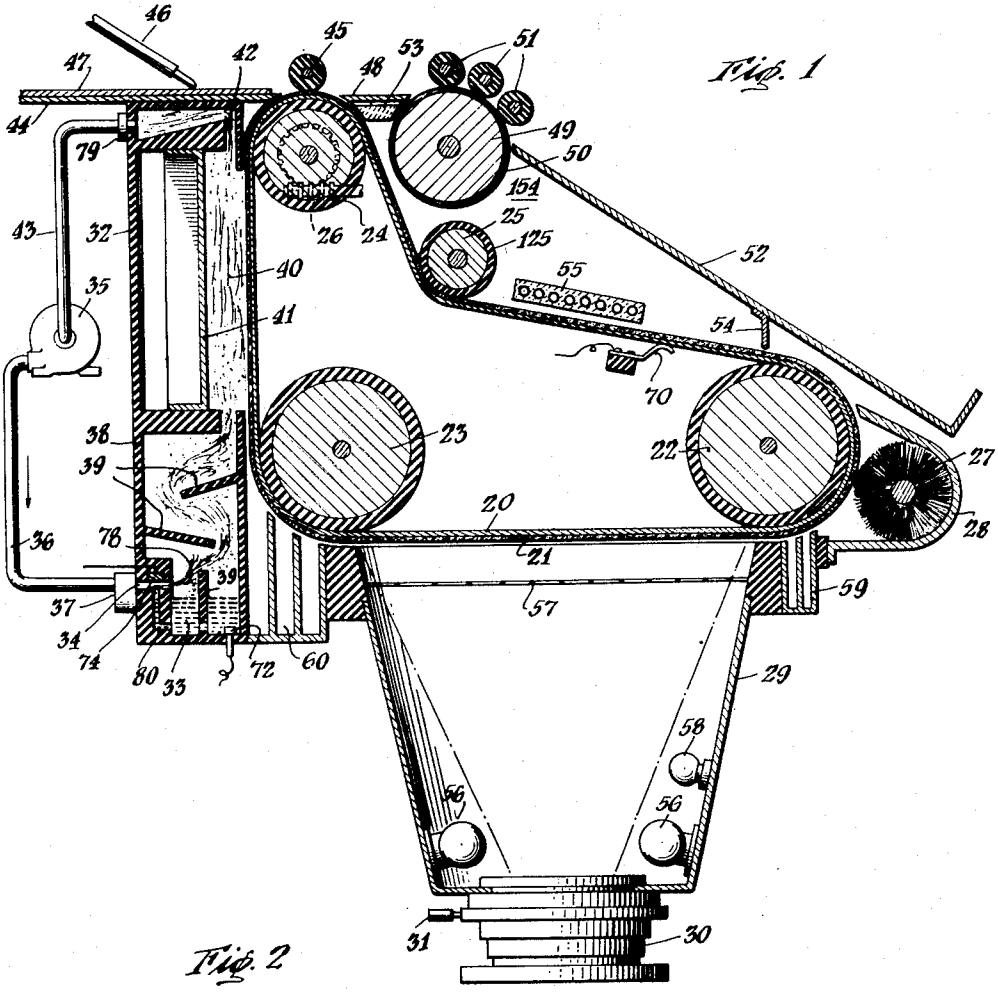
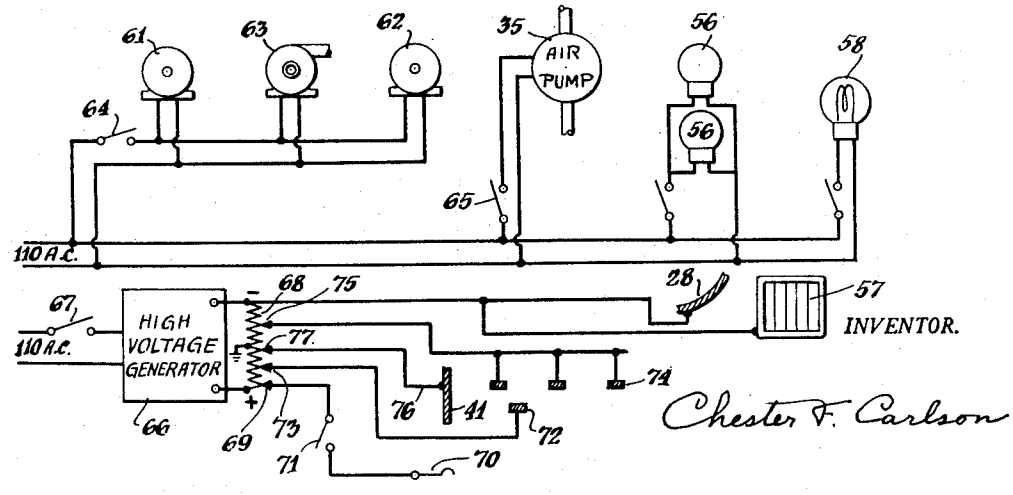


Fig. 2



INVENTOR.

Chester F. Carlson

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ELECTROPHOTOGRAPHY

Chester F. Carlson, Fairport, N. Y.

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10 Claims. (Cl. 95—1.9)

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This invention relates to electrophotography.

This is a division of my copending application Serial No. 500,207, filed August 27, 1943, now Patent Number 2,551,582, granted May 8, 1951.

An object of the invention is to improve the electrophotographic apparatus used therein.

Other objects will appear from the following description and the claims.

In the drawings:

Figure 1 illustrates an electrophoto camera device; and

Figure 2 is a circuit diagram therefor.

Electrophotography is described in my Patent 2,297,691 issued October 6, 1942. The process in its preferred form uses a plate carrying a coating of photoconductive insulating material on its surface. The coating is usually given a uniform electrostatic charge over its surface and the plate is then exposed in a camera or by other means to the picture to be copied.

The light falling on the coating discharges the electrostatic charge in proportion to the quantity of light reaching each part of the plate so that an "electrostatic latent image" is left on the plate. The highest charge will be retained on the areas receiving the least light and vice versa. The image is then developed by depositing a finely divided material on the plate. The material is attracted to the latent image in proportion to the strength of the residual charge. If the finely divided material is a dark colored powder the image is made visible immediately upon dusting the plate. The powder can be transferred and affixed to a sheet of paper to produce the final copy.

In my co-pending application, Serial No. 365,888, filed November 16, 1940, now Patent 2,357,809 issued September 12, 1944, of which this, through Serial No. 500,207, is a continuation-in-part, an electro-photographic apparatus is shown for performing the above process automatically.

Another process of electrical photography is described in my Patent No. 2,221,776, issued November 19, 1940.

The present invention contemplates improvements in the above apparatus including means for producing a liquid mist, spray or fog for developing the image. The combination with an electrostatic image plate of an auxiliary electrode to control development is also a feature.

Figure 1 illustrates an electrophoto camera for producing a complete finished print. The electrophoto plate is an endless belt **20** of conductive material such as metal foil coated on the outer surface with a thin layer **21** of photo-

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conductive insulating material, for example sulfur or anthracene. The belt is mounted to run on four insulating rollers **22**, **23**, **24**, and **25**. Roller **24** is arranged to be driven at relatively slow speed by a worm **26** driven by an electric motor to advance the belt clockwise around its circuit, under control of an electric switch.

A rotary brush **27** is mounted adjacent roller **22** to brush against the surface of coating **21** to apply an electrostatic charge to its surface. The brush is enclosed in a metal shield **28**, which makes contact with the surface of the brush.

A camera **29** comprising the usual lens **30**, shutter **31**, and focussing arrangements is mounted below the under face of the belt to focus the picture to be copied on the coating **21**.

A mist developing chamber **32** is mounted adjacent the face of the belt where the belt passes from roller **23** to **24**. It comprises a liquid reservoir **33** at its bottom and a row of atomizers **34** at spaced intervals along the edge of the reservoir. The atomizers **34** are fed with a liquid from reservoir **33** and air from a pressure pump **35** through tube **36** and header **37**. Immediately above this reservoir is a baffle chamber **38** provided with a series of staggered baffles **39** for removing large droplets from the mist produced by the atomizers. The top of the baffle chamber communicates by a slot, the walls of which serve as feed guides with a vertical passage **40** bounded by the coated side of belt **20** and by a plane metal electrode **41**. The upper end of passage **40** communicates with a receiving slot **42** from which the air is led back to the pump by tube **43**. Pump **35** may be a rotary positive compression pump, a reciprocating piston pump or other type adapted to deliver air under sufficient pressure to the atomizers.

A paper feed plate **44** is mounted above developing chamber **32** and a rubber pressure roller **45** is mounted to roll against the belt **20** where it passes over the roller **24**. A suitable paper feed mechanism, such as a pusher **46**, is provided to introduce the leading edge of a sheet of paper **47** under roller **45** at the appropriate moment.

A paper removal guide plate **48** is supported at the right of roller **24** to remove the sheet **47** as it emerges from under roller **45**. A coated roller **49** is mounted to receive the paper from plate **48**. Roller **49** has a coating **50** of soluble dye which may be integral with the roller or may comprise a separate sheet similar to "carbon" paper, wrapped around the roller. For example: aniline blue, methyl violet, crystal violet,

nigrosene or other dye may be dissolved in alcohol or higher boiling solvents and a sheet of paper may be saturated in the solution and allowed to dry after which it is wrapped around roller 49. Or a binder such as Vinsol resin, zein, ethyl cellulose, other resins and waxes or the like may be added and the solution applied to a sheet of paper as a coating or directly to the roller and allowed to dry. Insoluble pigments may also be added. A series of pressure rollers 51 are mounted adjacent roller 45 to apply pressure to the paper as it passes over the roller. Finally completed copy tray 52 is provided to receive the sheet as it leaves roller 49.

Roller 25 is covered with a cloth or felt layer 125 which engages the coated side of belt 20. A pair of partitions 53 and 54 form a partly enclosed passage 154 through which heated air can be circulated by a blower for drying the excess solvent from belt 20, roller 49 and the finished prints which are deposited in tray 52. A hot plate 55 is mounted adjacent the belt 20 for further drying effect.

A pair of infra-red lamps 56 are mounted inside the camera for infra-red flooding of the plate when required. A fine wire grid electrode 57 is supported inside the camera a sufficient distance in front of belt 20 so that no distinct shadows are produced on the plate by light passing through the lens. A flood lamp 58 is also mounted within the camera to discharge the layer 21 when desired. Baffle channels 59 and 60 are provided at the edges of the camera where the belt 20 enters and leaves, to collect particles of dust or liquid and prevent their entry into the camera.

Figure 2 shows the electrical circuits for the machine. Motor 61 for driving worm 26 and motor 62 for rotating brush 27 and hot air blower 63 for sending drying air through chamber 154 are all connected to the house current supply under control of switch 64. Air pump 35 is separately driven from the electric supply under control of switch 65.

A high voltage generator 66, such as a transformer-rectifier system capable of supplying a small current at a potential of 1000 to several thousand volts is connected to the electric supply through switch 67, and feeds a high resistance voltage divider 68 connected across its output terminals. The mid-point of the resistance is grounded, shield 28 and grid 57 are connected to the negative terminal of the high voltage supply. Metal belt 20 can be connected to a tap 69, normally near the positive end of resistance 68, by contact spring 70 and switch 71. A terminal 72 is in contact with the liquid in reservoir 33 and is connected to a tap 73 normally on the positive side of the center tap of the resistance 68. A terminal 74 is mounted in each atomizer opposite the aperture of the liquid jet and is connected to tap 75 on the negative side of the center tap. Electrode 41 is connected by conductor 76 to tap 77 which will normally be set to a positive potential.

Operation.—In the operation of the camera the belt 20 is first rotated in a clockwise direction by motor 61 while brush 27 is rotated to frictionally apply a uniform charge to the surface of photoconductive insulating layer 21. If the layer is sulfur or anthracene the charge will normally be negative (—) as these materials are near the negative and of the triboelectric series and acquire a negative charge when brought into contact with most materials such as the bristles of the brush. During charging the high voltage generator may be operated to negatively charge shield 28 which thus acts to remove the positive charge received by the brush from layer 21.

When a charged section of the belt has been advanced into the camera the motor 61 is stopped.

The lens 30 of the camera is focussed on the subject, for example a sheet of drawings or documentary material spread on a table below the camera, or a three dimensional object to be photographed. The shutter 31 is opened for the desired exposure period and then closed. The optical image which is focussed on layer 21 renders the layer conductive in proportion to the quantity of light falling on it, so that during the exposure the electrostatic charge will be discharged from the illuminated areas in proportion to the quantity of light they receive. The remaining charge on the layer 21 will then comprise an electrostatic latent image corresponding to the optical image.

Fine wire grid 57 which is charged to a negative voltage accelerates the discharge of the layer by increasing the intensity of the electric field tending to move electrons in the layer toward plate 20. In fact, if exposure is continued long enough a reversal of charge will be produced on the most highly illuminated areas so that they will acquire a positive (+) charge while the darker areas will retain their negative charge. In some cases it is desirable to accentuate the charge reversal still further and for this purpose switch 71 is closed to apply a positive (+) voltage to belt 20.

Some photoconductive materials exhibit a higher photoconductivity when radiated with infra-red radiation simultaneously with exposure to the photoelectrically active wave lengths and for this purpose a pair of infra-red lamps 56 are mounted within the camera to flood the layer 21 with infra-red rays during exposure. This radiation is not itself photoelectrically active but merely increase the photoelectric effect of the optical image entering through the camera lens.

Exposure having been completed motor 61 is started to advance the electrostatic image area past the mist developing chamber 32. At the same time air pump 35 is started to supply a current of liquid mist 78. The liquid in reservoir 33 which creates the mist is a solvent or solvent mixture. A slowly volatile solvent such as one boiling at 100–150° C., is preferred, for example amyl acetate, amyl alcohol, butyl alcohol, Cellosolve, toluene or mixtures, although less volatile materials such as cyclohexanol acetate and more volatile materials such as ethyl alcohol, ethyl acetate, alcohol-water mixtures and mixtures of high and low boiling solvents may be used in some cases.

As the liquid jet in each atomizer emerges from the fine liquid tube 80 into each atomizer air jet positive charges are induced on each droplet by the negatively charged electrode 74. The quantity of this charge on each droplet can be controlled by adjusting taps 73 and 75 on voltage divider resistance. The charged mist 78 produced by atomizers 34 passes up around baffles 39 while the larger droplets are precipitated. A fine mist emerges at the top of the baffle chamber where it passes into the space 40 between belt 20 and electrode 41. The positively charged (+) mist droplets are strongly attracted to the negatively (—) charged parts of the electrostatic latent image and deposit on layer 21 in a configuration corresponding to the image, and substantially in proportion to the degree of charge.

At the top of space 40 the mist enters slot 42

and returns via header 79 and tube 43 to pump 35. Electrode 41 is movable to vary the space 40 between the electrode and plate 20 to adjust the linear velocity of the upwardly moving stream of mist. This velocity should be low enough to permit capture of a substantial number of mist droplets by the electrically charged areas of the image on the coating 21.

By adjusting the position of tap 77 on the voltage divider the positive (+) potential of electrode 41 can be regulated to produce an electric field between the electrode and plate 20 to drive a greater or lesser number of droplets toward the layer 21. It is thus possible to control the intensity and contrast of the developed image.

If exposure has been sufficiently long to give a charge reversal in the brightly illuminated areas so that these are positively (+) charged the positive areas of the image will repel the droplets and permit the contrast to be further improved. Switch 71 may also be left closed during development if desired to repel the particles from the belt except where negative charges remain on the layer.

When the leading edge of the image area approaches roller 45 a sheet of paper 47 is advanced under roller 45 and as the liquid image is rolled against the paper most of the liquid is absorbed by the surface of the paper.

The paper is moved to the right and as it leaves the roller it is fed by plate 48 against the surface of roller 49 which has a surface layer 50 of dye which is soluble in the solvent liquid. Rollers 51 roll the paper firmly against surface 50. The liquid distributed on the paper in the configuration of the photographic image dissolves a small quantity of the dye as it passes over roller 49 to produce a visible dye image on the paper. The finished print is deposited in tray 52 ready for use. The solvent is slowly volatile so as to be retained on the paper until this stage. However, it soon dries leaving the permanent dye image on the sheet. Since the paper absorbs most of the liquid very little is left on layers 21 or 50. Such solvent as remains is volatilized in the air stream flowing through passage 154. The coated belt 20 is thus returned to the camera ready for reuse.

Instead of using a pure solvent or solvent mixture an ink or dye solution may sometimes be used so that the image produced on the plate coating by the electrostatic precipitation of the mist becomes immediately visible. In some cases an ink containing suspended pigment may also be used in place of or supplementary to the dye solution. A dissolved binder can also be added.

While one type of mist generator is shown and described it is contemplated that other atomizers, nebulizers, mist and fog generators can be used to generate the fine mist for development. For example, where an insulating liquid is used the liquid may acquire a charge by friction (contact potential) when issuing from the nozzle. Other suitable atomizers are shown and described in Freeman Patent 2,302,021; Campbell Patent 2,302,185 and Bramston-Cook Patent 2,302,289. It is also contemplated that in some cases an uncharged mist may be used.

By applying a negative or positive charge to the mist 78 produced by the atomizers it is possible to produce a negative or a positive reproduction. In one case the negative mist will deposit on the positively charged parts of the image and in the other case the positive mist deposits on the negative parts.

The walls of developing chamber 32 are of insulating material with the exception of electrode 41, so that any charged mist which deposits on them will produce a charged surface which will repel further charged particles and tend to keep them in suspension in the air stream.

It is obvious that the liquid development methods described herein are also applicable to the development of electrostatic latent images produced on insulating layers by other methods, such as those described in my Patent No. 2,221,776.

While the invention has been described as carried out in specific embodiments it is intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. In electrophotographic apparatus, the combination with an electrophotographic plate consisting of a conductive base and a layer of photoconductive insulating material supported by said base and in contact therewith throughout an image area, of a conductive electrode in spaced parallel relation to the face of said layer in said image area, means to introduce charged particles between said layer and said electrode to develop said electrostatic latent image, and a potential source connected between said conductive base and said electrode.

2. An electrophotographic apparatus comprising, in combination, an electrophotographic plate having a coating of photoconductive insulating material on a conductive backing, an electrode overlying said plate coating in substantially parallel spaced relation thereto, a cloud generator for producing an air suspension of finely-divided charged particles and projecting said air suspension between said electrode and plate coating, and a potential source connected between said electrode and the conductive backing of said electrophotographic plate.

3. An electrophotographic apparatus as claimed in claim 2 in which said cloud generator comprises a liquid atomizer having a liquid passage, means for creating an air stream past the mouth of said passage to detach liquid droplets from a liquid column in said passage, a liquid-charging electrode opposing the mouth of said passage and a second potential source connected to said liquid-charging electrode to induce electric charges on said droplets.

4. An electrophotographic apparatus comprising, in combination, an electrophotographic plate having a coating of photoconductive insulating material on a conductive backing, an electrode overlying said plate coating in substantially parallel spaced relation thereto, a first potential source and means to connect said source between said electrode and conductive backing, a liquid atomizer for projecting a liquid mist between said electrode and said coating, said atomizer comprising a liquid passage means for creating an air stream past the mouth of said passage to detach liquid droplets from a liquid column in said passage, a liquid-charging electrode opposing the mouth of said liquid passage and a second potential source connected to said liquid-charging electrode to induce electric charges on said droplets, and means to adjust the potential of said source to vary the intensity of charge applied to said droplets.

5. Apparatus for producing visible images from electrostatic images, comprising, in combination, a conductive base, an insulating layer overlying said base for holding an electrostatic charge pattern to be developed, a conductive electrode

having a substantially smooth surface spaced parallel to the face of said insulating layer over an area having a width greater than the spacing between said electrode and said layer, means for introducing finely-divided particles between said electrode and said layer, a source of electric potential, a voltage divider connected across said source, and a pair of terminals connected to said voltage divider and to said conductive electrode and said conductive base, respectively, at least one of said terminals being movable to adjust the potential difference between said electrode and said base.

6. In an electrostatic image producing and developing apparatus, the combination with a conductive layer having an insulating coating on at least part of its surface, of moving support means to move said layer from an image-forming station to a position facing an image-developing space, means at said image-forming station for forming an electrostatic image of a first polarity on said insulating coating, an electrode overlying a substantial part of said image developing space, means for injecting a finely-divided electrically charged material into said developing space, and an electric potential source connected between said electrode and said conductive layer and having its terminal of said first polarity connected to said electrode.

7. In electrophotographic apparatus, the combination with an electrophotographic plate of drive means to move said plate from a charging station through an exposure station to a developing position facing a developing space, a charging device at said charging station for applying a charge of a first polarity to the photoconductive coating of said electrophotographic plate, exposure means at said exposure station for exposing said plate to a radiation pattern to be recorded to discharge portions of said plate and leave an electrostatic image thereon, an electrode overlying said developing space and spaced substantially parallel to said plate when said plate is in said developing position, means for injecting finely-divided charged particles into said developing space, and a potential source connected between said electrode and said electrophotographic plate with its terminal which is at said first polarity connected to said electrode, whereby the portions of said plate which are discharged during exposure present a polarity to said developing space opposite from the polarity presented by said latent image.

8. In electrophotographic apparatus, the combination with an electrophotographic plate comprising a conductive base layer and a photoconductive insulating layer overlying said base layer for supporting an electrostatic latent image, of a conductive electrode in closely-spaced parallel relation to said coating and held at a predetermined potential with respect to said conductive base layer, and means to introduce finely-divided electrically charged particles into the space between said electrode and said coating to develop an image on said coating.

9. In electrophotographic apparatus, the combination with an electrophotographic plate comprising a layer of photoconductive insulating material on a conductive base, of means for charging and exposing said layer to produce an electrostatic latent image thereon, means for moving the face of said layer into closely-spaced parallel relation to a conductive electrode, means to introduce finely-divided charged particles into the space between said electrode and said coating to develop an image on said coating, and means to maintain said electrode at a predetermined potential in relation to said conductive base.

10. In electrophotographic apparatus, the combination with an electrophotographic plate of drive means to move said plate from a charging station through an exposure station to a developing position facing a developing space, a charging device at said charging station for applying an electrostatic charge to the photoconductive coating of said electrophotographic plate, exposure means at said exposure station for exposing said plate to a radiation pattern to be recorded to discharge portions of said plate and leave an electrostatic image thereon, a substantially smooth development electrode overlying said developing space in spaced parallel relation to said plate coating when said plate is in developing position, means for injecting finely-divided charged particles into said developing space between said photoconductive coating and said development electrode, and means to maintain said development electrode at a predetermined reference potential in relation to the backing of said electrophotographic plate.

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