

May 8, 1951

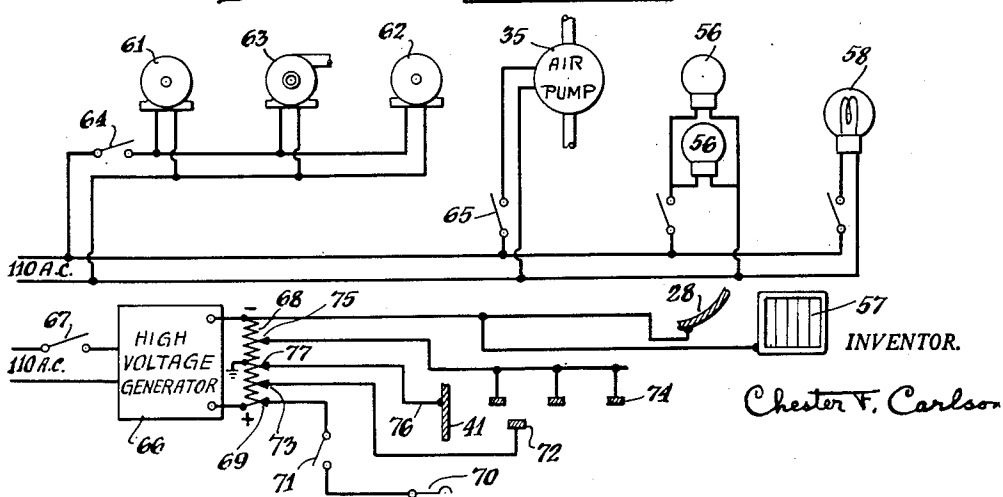
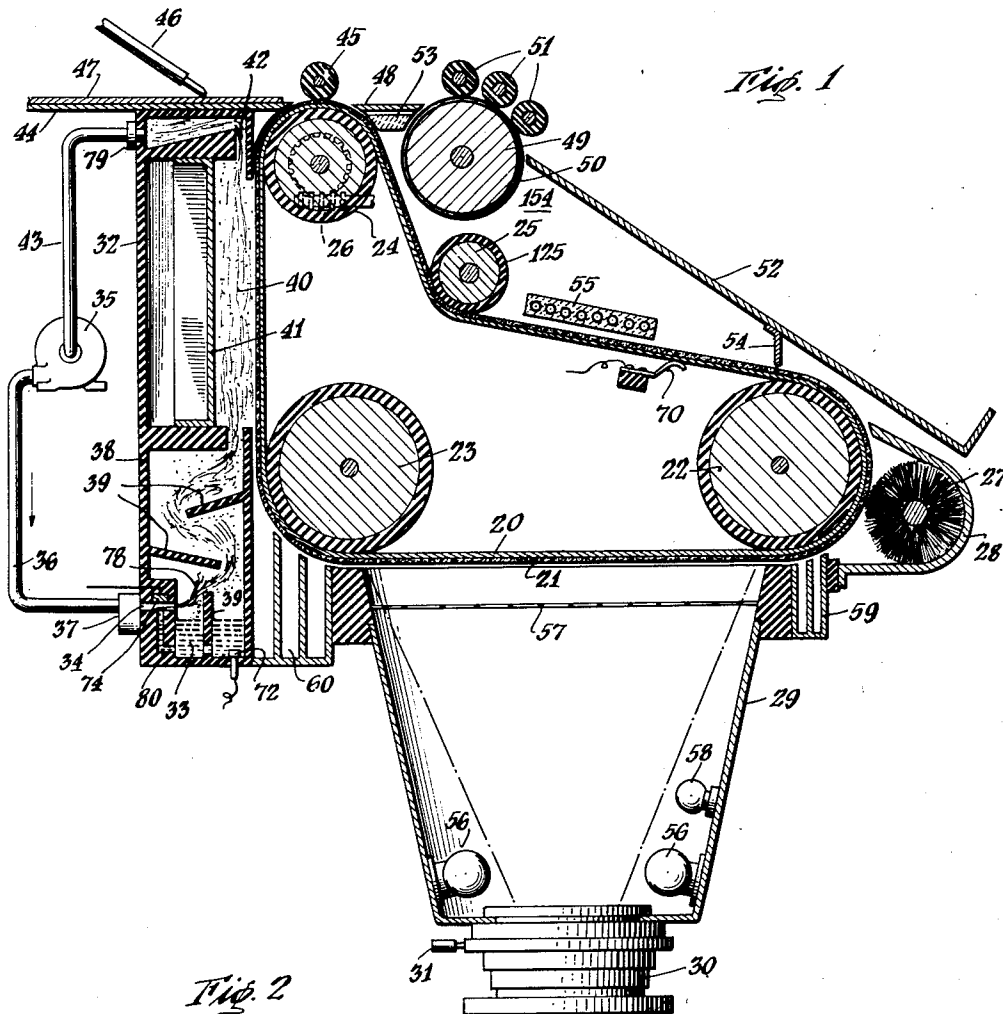
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2,551,582

METHOD OF PRINTING AND DEVELOPING SOLVENT IMAGES

Filed Aug. 27, 1943

2 Sheets-Sheet 1



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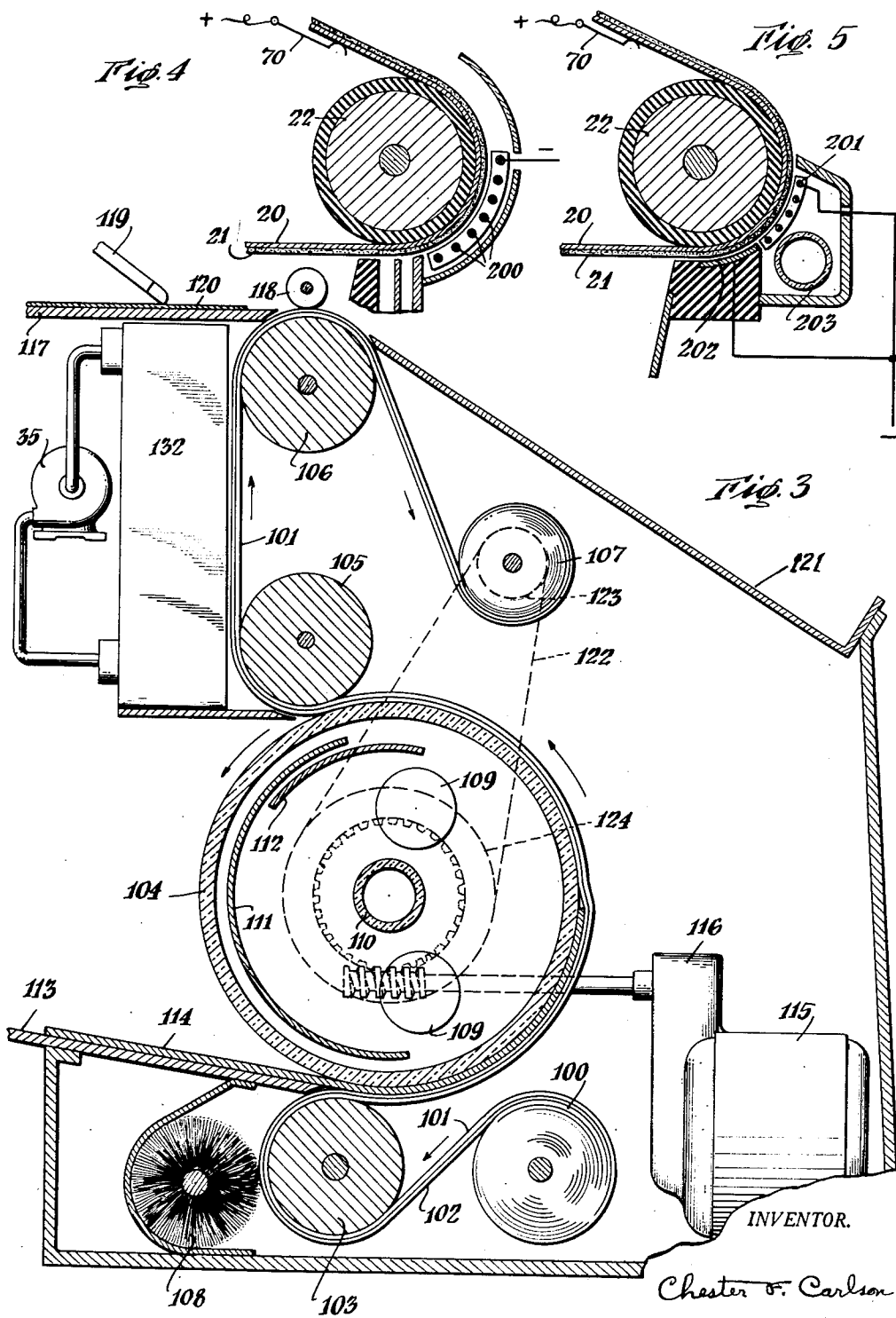
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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,551,582

METHOD OF PRINTING AND DEVELOPING
SOLVENT IMAGES

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11 Claims. (Cl. 101—426)

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This invention relates to electrophotography. An object of the invention is to improve the electrophoto process and the apparatus used therein.

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

In the drawings:

Figure 1 illustrates an electrophoto camera device;

Figure 2 is a circuit diagram therefor;

Figure 3 illustrates a machine for copying transparencies and semi-transparencies; and

Figures 4 and 5 show modified means for charging the plate.

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 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 processes and apparatus including the use of a liquid mist, spray or fog for developing the image. Also contemplated are means for charging the plate and for the reversal of the charge on the plate during exposure. The use of an auxiliary electrode to control development is also a feature. Another feature resides in the methods of transferring the image

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to a sheet of paper or other material and producing a fixed visible copy thereon.

Another feature resides in an improved plate for use in the process. Other aspects and modifications of the invention will also be described.

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 photoconductive 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 end 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 increases 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, Cello-solve, 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 30 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 pro-

duced 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 19 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.

Figure 3 shows a machine suitable for copying transparent or semi-transparent documents or drawings. It also embodies a modified development process.

The construction of the machine will be described in connection with its operation, which is as follows:

A strip of conductive sheet material such as foil 101 having a coating 102 of photoconductive insulating material is unwound from a roll 100 and passed around a roller 103, then around a glass cylinder 104, then over rollers 105 and 106 and finally is wound up in a roll 107.

A rotating brush 108 is mounted adjacent roller 103 to apply a frictional electric charge to coating 102 as the strip passes over roller 103.

Glass cylinder 104 contains lamps mounted in its interior such as incandescent lamps 109 and a tubular fluorescent lamp 110 which give a desirable combination of photo-electrically active wave lengths with infra-red radiation. A pair of adjustable shields 111 and 112 inside the cylinder serve to limit the area of exposure as desired.

A paper feed plate 113 is positioned adjacent the bottom of cylinder 104 where strip 101 begins to wind around it, so that a tracing or other transparent original 114 may be fed between the strip 101 and cylinder 104.

Cylinder 104 is driven at the desired speed by motor 115 through gear train 116 and as the charged strip 101 passes around it the original 114 to be copied is fed between the strip and cylinder to expose the layer 102 to the image on the original. As original 114 emerges at the top of cylinder 104 it may be manually removed or rerouted around the cylinder to produce another copy as desired.

After exposure strip 101 passes around roller 105 and then upward to roller 106 along the face of a mist developing chamber 132 (similar to chamber 32 previously described). However, in this instance, instead of using a pure solvent or solvent mixture an ink or dye solution is used so that the image produced on coating 102 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.

A paper feed plate 117 is mounted adjacent the upper edge of roller 106 and a soft pressure roller 118 is mounted to roll a sheet of paper fed from plate 117 against the coating 102 as it emerges from developing chamber 132. A pusher 119 is provided to advance a sheet of plain paper 120 under roller 118 at the required instant. The dye solution applied by chamber 132 will then be transferred to the paper sheet 120 to produce a finished positive copy of the original 114.

The finished print is received in tray 121 and the used portion of strip 101 is wound upon roll 107 which is driven by belt 122 and slip-pulley 123 from a pulley 124 mounted at one end of cylinder 104.

A certain amount of the dye image will remain on coating 102 after use. When the entire length of strip 101 has been run through the machine and collected on roll 107 the roll is removed from the machine and the coating washed or sponged with a dye solvent after which the strip is ready for reuse. In some instance, especially if sheets 120 are moistened with solvent prior to use, it may be possible to reuse the strip 101 several times before washing.

It is obvious that the development processes of either Figures 1 and 3 may be used interchangeably with both camera and transparency printing processes.

While any paper can be used for sheets 47 and 120, the best results are obtained with paper having a smooth absorbent surface. The paper used for spirit duplicators is very satisfactory. Where the absorbency of the paper is too high or too low for the best results it can be adjusted by applying thin coating of semi-absorbent material such as a mineral filler and a binder, or a material which is itself partly soluble in the solvent, such as zein, ethyl cellulose and combinations of these with other materials.

The conductive backing strips 20 and 101 may

be of metal foil such as plain or etched aluminum or it may be of paper, regenerated cellulose or a plastic coated with a conductive metal layer as described for example in Ruben Patent 2,211,583 or Dorn Patent 2,323,020.

The coatings of photoconductive insulating material 21 and 102 may be applied as described in my Patent 2,297,691. Another method which produces a very thin rapid coating comprises forming a saturated solution of freshly sublimed anthracene in benzene or other solvent and then dissolving ethyl cellulose or other binder in the anthracene solution in proportions of from $\frac{1}{50}$ to $\frac{1}{2}$ the weight of anthracene, preferably about $\frac{1}{2}$ of the weight of anthracene. Any suspended particles are allowed to settle and the clear solution is applied to the conductive backing sheet by passing the sheet through a tank of the solution or painting with a fine brush or by spraying. It dries rapidly forming a thin, smooth adherent layer.

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.

Figure 4 shows an alternative method of charging the surface of coating 21 prior to exposure. This comprises a filament grid 200 of platinum or other filaments having electron emission coatings. The filaments are heated to emission temperature and connected to the negative terminal of the high voltage source while plate 20 is connected to the positive terminal of the source by spring contact 70. The electrons emitted from the filaments are attracted to the surface of the coating where they build up a uniform surface charge.

Figure 5 shows a further charging method. In this arrangement an electrode grid 201 and a metal shield 202 are mounted in spaced relation to the coated surface 21 and a light source 203, such as a mercury or fluorescent lamp, is mounted behind the grid to illuminate the coating through the spaces in the grid. The grid 201 and metal shield 202 are connected to one terminal of the high voltage source and the plate 20 to the other terminal. The illumination from lamp 203 renders the coating 21 conductive to permit the electrodes to induce a charge on the layer. The charge is trapped on the layer when it passes under the shadow of shield 202 and into the camera. With this arrangement the coating may be given a positive charge if plate 20 is connected to the positive terminal of the source, as shown, or a negative charge if the connections are reversed.

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. The process which comprises producing an electrostatic latent image on a layer of insulating material, electrostatically depositing a fine liquid mist consisting of volatile material on said image to produce a liquid image, transferring the liquid image to a copy surface by pressing said surface against the liquid image and then bringing said copy surface into contact with a coloring material to pick up said coloring material on said liquid image.

2. The process which comprises producing an electrostatic latent image on a layer of insulating material, electrostatically depositing a fine solvent liquid mist consisting of volatile material on said image to produce a liquid image, transferring the liquid image to a copy sheet by pressing said sheet against the liquid image and then pressing the surface of said copy sheet against a dye-containing surface to pick up soluble dye in said solvent image.

3. The process which comprises producing an electrostatic latent image on a layer of insulating material, electrostatically depositing a fine solvent liquid mist consisting of volatile material on said image to produce a liquid image, transferring the liquid image to a copy sheet by rolling said sheet against the liquid image and then rolling said copy sheet against a surface carrying a soluble dye to pick up dye in said solvent image.

4. The process which comprises printing a solvent image consisting of volatile material on a paper surface, then pressing the surface against a second surface charged with coloring material to produce an image of said coloring material on said paper.

5. The process which comprises forming a solvent image on a substantially uniform surface, transferring said solvent image to a second surface by pressure contact, and evaporating any remaining solvent on the first-mentioned surface to prepare it to receive a new solvent image.

6. The process which comprises forming a solvent image consisting of volatile material on a substantially uniform surface, transferring said solvent image to a second surface by bringing said surfaces into pressure contact, and then bringing said second surface into pressure contact with a third surface charged with a soluble coloring material to produce an image of said coloring material on said second surface.

7. The process which comprises forming a solvent image consisting of volatile material on a substantially uniform surface, transferring said solvent image to a second surface by bringing said surfaces into pressure contact, evaporating any remaining solvent on the first-mentioned surface to prepare it to receive a new solvent image, and bringing said second surface into contact with a dry soluble coloring material to produce an image from said coloring material on said second surface.

8. The process which comprises producing an

electrostatic latent image on a layer of insulating material, electrostatically depositing a fine solvent liquid mist consisting of volatile material on said image to produce a liquid image, transferring the liquid image to a copy surface, and then bringing the copy surface into contact with a dye soluble in said solvent liquid to produce a dye image.

9. The process which comprises producing an electrostatic latent image on a layer of insulating material, electrostatically depositing a solvent liquid mist consisting of volatile liquid on said image to produce a liquid image, transferring the liquid image to a copy surface and evaporating any remaining solvent from said insulating layer to prepare said layer to receive a new image, bringing said copy surface into contact with a dye soluble in said solvent liquid to produce a dye image and evaporating said solvent from said dye image.

10. The method of developing an electrostatic latent image on a surface which comprises electrostatically depositing thereon a completely volatile liquid to produce a liquid image, transferring said liquid image to a copy surface and bringing against said copy surface a dry dye soluble in said liquid to produce a dye image thereon.

11. The method of developing an exposed electrophotographic plate comprising a layer of photoconductive insulating material carrying an electrostatic latent image which comprises depositing a liquid mist consisting entirely of vola-

tile material on said layer by electrostatic attraction to said latent image to produce a liquid image, transferring said liquid image to a copy surface, and evaporating any remaining solvent on said layer to prepare said plate to receive a new latent image.

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