

Nov. 4, 1958

R. E. HAYFORD
PROCESS FOR DEVELOPING ELECTROSTATIC
IMAGES AND APPARATUS THEREFOR

2,859,129

Filed Jan. 11, 1956

2 Sheets-Sheet 1

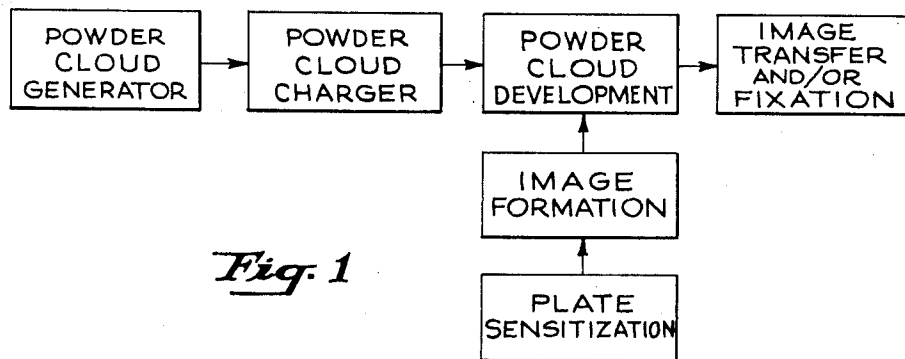


Fig. 1

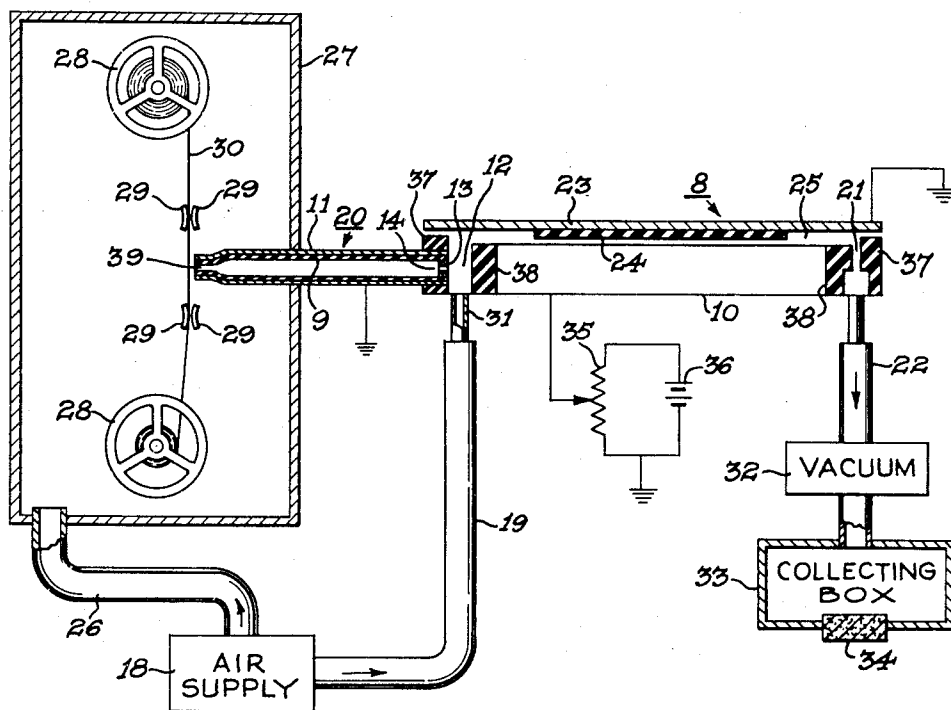


Fig. 2

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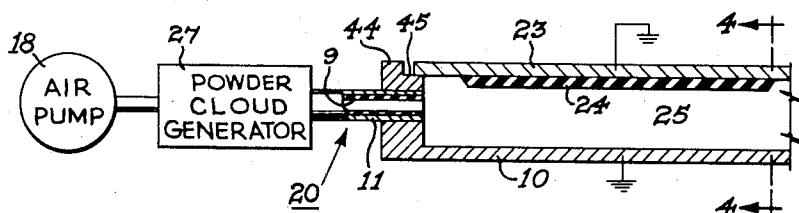


Fig. 3

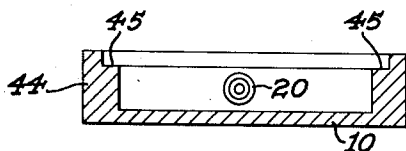


Fig. 4

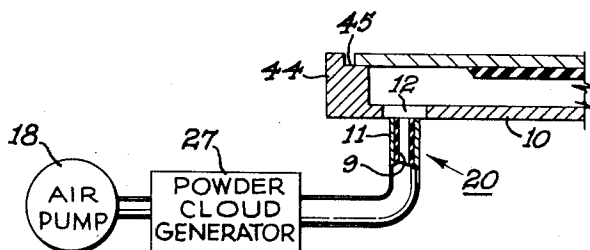


Fig. 5

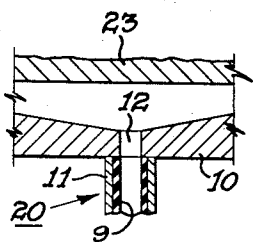


Fig. 6

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2,859,129

PROCESS FOR DEVELOPING ELECTROSTATIC IMAGES AND APPARATUS THEREFOR

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Application January 11, 1956, Serial No. 558,459

11 Claims. (Cl. 117—17.5)

This invention relates to a method and apparatus for the development of electrostatic latent images.

In xerography it is usual to form an electrostatic latent image on a surface. One method of doing this is to charge a photoconductive insulating surface and then dissipate the charge selectively by exposure to a pattern of activating radiation. Other means of forming electrostatic latent images are set forth in U. S. 2,647,464 to James P. Ebert. Whether formed by these means or any other, the resulting electrostatic charge pattern is conventionally utilized by the deposition of an electroscopic material thereon through electrostatic attraction whereby there is formed a visible image of electroscopic particles corresponding to the electrostatic latent image. Alternatively, the electrostatic charge pattern may be transferred to an insulating film and the electroscopic particles deposited thereon to form the visible image. In any case, this visible image, in turn, may be transferred to a second surface to form a xerographic print.

The process of depositing the electroscopic powder on the electrostatic image to render the electrostatic image visible is called the "development step" and is one of the most critical steps of the entire process. It is evident that no picture can be better than the development step permits. About the coarsest type of image reproduced by a xerographic process requires a resolution of at least about 50 lines per inch. Commercial line-copying xerographic machines generally have a resolution power of about 125 to 250 lines per inch. The process used in obtaining this resolution is set forth in U. S. 2,618,552 and involves the use of a finely-divided colored material called a "toner" deposited on a slightly more coarsely-divided material called a "carrier." This two-component developer is cascaded across the electrostatic image areas. The frictional contact between the toner and the carrier charges the particles due to triboelectric contact. Depending on the relative positions of the toner and carrier in the triboelectric series it is possible to place either a positive or negative charge on the toner.

In continuous tone development where resolutions of about 1200 or more lines per inch are often desired, it has been found impossible to obtain this high quality of reproduction using such a system. Accordingly, a system known as "powder cloud development" is preferred. In this system a cloud of colored marking particles is generated as described hereafter, charged, and then contacted with the electrostatic latent image in the development step.

Various means of charging the marking particles have been used. Thus, the two-component developer used in cascade development may be agitated in a closed container to charge the particles triboelectrically and then subjected to an air stream to separate the toner from the carrier entraining the toner in the air stream to thereby form a cloud of colored marking particles. This system suffers from several defects such as lack of uniformity,

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presence of agglomerates rendering a developed print excessively grainy, and the difficulty of maintaining output for appreciable periods of time.

Positioning a corona in the stream of entrained marking particles has also been tried but suffers from difficulties such as inability to impart adequate charge at the high flow rates desired, deflection of the powder stream due to corona wind and the high cost of the separate high voltage power supply rendering the equipment bulky and expensive.

The system which has proven most effective in practice has been to pass the entrained developer particles through a narrow tube in turbulent flow whereby the particles are in repeated contact with the walls of the tube. Thus, the powder cloud is passed through a capillary whereby it is charged through triboelectric contact with the walls of the capillary. This eliminates the necessity for a separate power supply and makes possible small, compact and highly effective charging of the powder cloud. A drawback of capillary charging has been that the material most suitable for powder cloud development, namely finely-divided charcoal, was charged negatively when used in this device. Even constructing capillaries from materials imparting a positive charge to resin toners when used as carriers in the two-component development process was not effective to positively charge finely-divided charcoal. For several years there has been a demand for a material having this property. Thus, zinc oxide binder plates, such as described in U. S. patent application Serial No. 311,546, filed September 25, 1952, by Middleton and Reynolds, are charged negatively to obtain positive prints. Because of this zinc oxide plates have been developed by either cascade or with a magnetic brush with consequent limitations on the quality of reproduction obtained. Although selenium plates are generally charged positively, in several processes for obtaining positive prints from negative originals: i. e. reversal development, a negatively charged image is formed on the surface of the selenium. Hence, there has long been a need for a material which could accept electrons from finely-divided charcoal rather than merely donate electrons to it.

Applicant has now found that if a capillary is constructed from a material selected from a special group of poorly conducting or semiconducting minerals, it is possible to impart a positive charge to finely-divided charcoal while at the same time avoiding the problem of excessive sparking or deposition on the walls of the capillary which might be expected from relatively non-conductive properties of these unusual materials.

In the drawings:

Fig. 1 is a block diagram showing the position of the development step in an over-all development process which results in a visible image;

Fig. 2 is a semi-diagrammatic illustration of apparatus according to one embodiment of the invention;

Fig. 3 is a side elevation of a developing zone with an image-bearing member thereon, according to one embodiment of the invention;

Fig. 4 is an end elevation in cross section of the structure shown in Fig. 3 with the image-bearing member removed therefrom;

Fig. 5 is a side elevation of a developing zone with an image-bearing member thereon, according to one embodiment of the invention; and

Fig. 6 is a fragmentary end elevation in cross section of the structure shown in Fig. 5.

As shown in Fig. 1 the general xerographic process involves the formation of an electrostatic latent image. This is generally, although not always, preceded by a treatment to sensitize, i. e. electrically charge, the surface

on which the electrostatic image is to be formed. The electrostatic latent image, to be useful, must then be rendered visible which is done in a development step. This is accomplished by depositing electroscopic particles either on the surface on which the image was formed or on an insulating surface to which the electrostatic latent image has been transferred. The method shown in Fig. 1 for doing this is termed powder cloud development. In this process a powder cloud is generated, charged and then contacted with the electrostatic latent image in the development step. The visible image so produced may be used as such, permanently affixed to the plate or may be transferred to another material as a sheet of paper or plastic as is well known to those skilled in the xerographic art.

The instant invention relates to a process which represents a substantial improvement in the art of powder cloud development. The process of the instant invention makes possible compact and highly effective charging of finely-divided charcoal to a positive polarity. In general, the present invention accomplishes this object by flowing the finely-divided charcoal suspended in a gas stream through a narrow tube of soapstone, montmorillonite, halloysite, bentonite, spodumene, red sandstone, pyrophyllite, oligoclase, gray sandstone or flagstone in turbulent flow. The process of the invention and apparatus for its accomplishment will now be set forth in more detail.

Referring to Fig. 2 there is illustrated semi-diagrammatically an apparatus suitable for use in the instant invention. According to this embodiment an air or gas supply 18 is provided from which a tube or conduit 26 leads to an air tight housing 27. Within this housing are positioned reels 28 carrying a powder impregnated ribbon 30. The reels 28 are so mounted that the ribbon 30 passes over guides 29 which lead the ribbon past nozzle 39 of tube 20. The reels are spring or motor driven in order to move the ribbon at a controlled rate. In practice the nozzle 39 and the ribbon 30 are relatively close together. The air supply 18 maintains the housing 27 at a pressure greater than ambient whereby a jet of gas is forced through the nozzle 39 bearing with it a supply of powder-in-gas suspension from the powder impregnated ribbon 30 into the tube 20. The gas suspension of powder particles passes through tube 20 into manifold 14 where it spreads out to pass through jets 13 into the entrance chamber 12. The liner 9 of tube 20, the nozzle 39, the manifold 14 and the jets 13 are constructed of soapstone jacketed on the outside with conductive material 11 which in turn is grounded. A suitable material for the ribbon 30 is napped cotton flannel.

The air supply 18 also supplies air through tube or conduit 19 to jets 31 which feed additional air into the entrance chamber 12 where it combines with the powder cloud. The powder cloud passes through entrance chamber 12 into development zone 25 formed by positioning a xerographic plate 8 consisting of a conductive backing 23 having coated thereon a photoconductive insulating layer 24. This plate rests on insulating spacers 37. Means are provided to ground the conductive backing of the xerographic plate.

The development electrode 10 is positioned at a distance of no more than about $\frac{1}{8}$ inch from the photoconductive insulating layer 24 and, desirably, for good photographic quality of the developed image, no more than $\frac{1}{40}$ inch. The development electrode 10 is insulated from the rest of the assembly by means of insulating spacers 38. The insulating spacers 37 position the xerographic plate 8 at the correct distance from the development electrode and act as dust seals at the ends of the xerographic plates. Similarly, insulating spacers, not shown, serve the same purpose for the sides of the assembly.

Means are provided for applying an electric potential difference between the backing member 23 of the xerographic plate 8 and the development electrode 10. These

means may include, for example, a battery 36 or similar D. C. power source connected through a potentiometer 35 to one or the other of the xerographic plate or the development electrode. In the embodiment shown, it is connected to the development electrode.

Many variations of the apparatus will instantly be apparent. Thus, in the placing of the insulating spacers 37 at each end of the assembly there may be substituted therefor conductive spacers which will position the xerographic plate at the correct distance from the development electrode 10 and serve as dust seals. With this change the ground on the powder cloud supplying means, here shown connected to the metal jacket 11 on tube 20, will ground the spacers 37 and the conductive backing 23 of the xerographic plate when placed thereon. This eliminates the necessity of a separate ground for conductive backing 23. Insulating means 38 will suffice along with the insulating dust seals, not shown, along the sides of the assembly to keep the development electrode 10 electrically insulated from the rest of the assembly.

In operation a xerographic plate is charged and exposed by any of the means known to those skilled in the art to place thereon an electrostatic charge pattern corresponding to a pattern of light and shadow to be reproduced. The image-bearing surface is then scanned with a vibrating probe electrometer, in the dark, to determine the maximum potential on the image-bearing surface. The plate is then positioned on the spacers 37 as shown in Fig. 2. Potentiometer 35 is then adjusted to place on the development electrode 10 a potential approximately equal to the highest potential found on the image-bearing surface. The gas supply 18 and vacuum means 32 and drive means for reels 38 are now actuated. The gas supply 18 maintains enclosed chamber 27 at a pressure greater than atmospheric. This causes a stream of gas to pass into nozzle 39 which entrains charcoal powder particles from ribbon 30 thereby creating a suspension of powder particles in gas. The powder cloud is carried along by the air stream through tube 20 into manifold 14 where it expands and passes through jets 13 into the entrance chamber 12. The tube 20 has a restricted cross section so that the powder is in turbulent flow while passing therethrough and by repeated triboelectric contact with the walls 9 thereof gives up electrons to the tube to become itself positively charged. The additional air flow from air supply 18 through tube 19 enters the entrance chamber 12 through jets 31 where the extra air mingles with the powder cloud. The thus augmented cloud now enters the development zone 25 where it passes over the photoconductive insulating layer 24 depositing electroscopic particles in accordance with the charge pattern produced thereon by the action of the potential applied to the development electrode 10 on the electrostatic latent image on the photoconductive layer 24. The powder cloud then leaves the development zone 25 through means 21 whereby it is fed into exhaust means 22. A slight negative pressure is kept on the exhaust means by suitable means 32. The powder passes through means 32 into a collecting box 33 wherein the powder is separated from the gas suspension by a filter 34.

When operated in this means using soapstone for the tube liner 9, the nozzle 39 and the jets 13 a highly efficient positive charge was imparted to the finely-divided charcoal powders. By this means there was obtained a high quality, continuous tone, reversal print of the original to be reproduced without any trouble due to agglomeration, undue deposition in unwanted areas or objectional sparking or arcing.

In Figs. 3 and 4, there is shown a development apparatus according to another embodiment of this invention.

According to this device one or more capillary or like ducts 20 feed to an image support member 10 which preferably has an extremely smooth upper surface extend-

ing in a horizontal plane. According to the preferred embodiment of this invention, this support member desirably is electrically grounded or may be held at some suitable bias potential thus acting as a development electrode. The back and sides of the support member 10 have walls 44 with supporting ledges or shoulders 45 which are adapted to receive and support an image-bearing member 8 with the image-bearing surface extremely closely spaced in parallel relationship to the smooth upper surface of the support member 10. According to the usual practices of xerography, the image member 8 comprises a conductive backing member 23 for a photoconductive insulating layer 24 on at least one surface thereof and when such an image-bearing member is used in conjunction with this support, the photoconductive insulating layer 24 is faced toward member 10 thereby defining a development zone 25 and the conductive backing member 23 is preferably electrically grounded. Capillary or duct 20 is preferably constructed of soapstone 9 and jacketed with metal 11 which is grounded.

In operation, the gas supply 18, such as an air pump, is activated causing the powder cloud generator 27 to supply a suspension of finely-divided charcoal in gas through duct 20 in turbulent flow, whereby the finely-divided charcoal repeatedly contacts the soapstone walls 9 of duct 20 giving up electrons thereto and becoming itself positively charged.

Where the photoconductive insulating layer is zinc oxide in a binder, the electrostatic latent image thereon is composed of negative electrostatic charges. This device causes powder particles to deposit thereon in faithful conformity with the image to be reproduced.

Fig. 5 is a side elevation of a modification showing an alternative developing zone. In this variation, there is a delta-shaped expansion chamber 12 where the powder cloud from the capillary or duct 20 impinges normally on a deflecting surface which may, if desired, be an edge or border portion of the image member 8 on image member support 10. In this manner, the suspension of finely-divided charcoal in gas is directed outwardly as illustrated by the arrows 42 and is caused to flow substantially straight across the surface of the member 8. Otherwise, the construction and operation of the apparatus is as shown in Figs. 3 and 4.

Using soapstone for the tube liner 9 in the apparatus of Figs. 5 and 6 over 100 reversal prints were made consecutively by placing a suitable bias on support 10 as set forth in connection with Fig. 2. Even after this continuous use, the pictures were all high quality, continuous tone, reversal prints without any trouble due to agglomeration, undue deposition of charcoal in unwanted areas or objectionable sparking or arcing. The process was repeated using each of the following materials for liner 9: gray sandstone, quartzose sandstone of the argillaceous type, pyrophyllite, serpentine, oligoclase, spodumene, halloysite, montmorillonite and bentonite. In each case a high degree of positive charge was imparted to the particles of finely-divided charcoal making possible the obtaining of a high quality reversal print of the electrostatic charge pattern originally occurring on photoconductive selenium layers. While all of the materials named gave excellent results in positively charging finely-divided charcoal particles, soapstone, montmorillonite and bentonite were particularly outstanding in ease of fabrication and handling.

I claim:

1. A process for electrically charging finely-divided charcoal to a positive polarity comprising entraining said charcoal in a stream of air and then passing said entrained charcoal in turbulent flow through a narrow conduit the interior walls of which consist of a mineral selected from the group consisting of soapstone, montmorillonite, halloysite, bentonite, spodumene, red sandstone, serpentine, pyrophyllite, oligoclase, grey sandstone, and quartzose sandstone of the argillaceous type.

2. A process according to claim 1 wherein the interior walls of the conduit consist of montmorillonite.

3. A process according to claim 1 wherein the interior walls of the conduit consist of soapstone.

4. A process according to claim 1 wherein the interior walls of the conduit consist of bentonite.

5. An improved xerographic developing method wherein a positively charged suspension of finely-divided charcoal powder particles is presented to an electrostatic latent image-bearing surface, said method comprising forming a gas suspension of said finely-divided charcoal, forcing said gas suspension through a capillary turbulence zone at a rate of flow therethrough sufficient to achieve turbulent flow in contradistinction to laminar flow whereby the suspended charcoal particles are deagglomerated and are electrostatically charged to a positive polarity by contact with the walls of the capillary zone, said walls consisting of a mineral selected from the group consisting of soapstone, montmorillonite, halloysite, bentonite, spodumene, red sandstone, serpentine, pyrophyllite, oligoclase, grey sandstone, and quartzose sandstone of the argillaceous type and presenting the suspension of said positively charged charcoal particles from said turbulent zone to the electrostatic latent image-bearing surface.

6. A process according to claim 5 wherein the walls of the capillary zone consist of montmorillonite.

7. A process according to claim 5 wherein the walls of the capillary zone consist of soapstone.

8. A process according to claim 5 wherein the walls of the capillary zone consist of bentonite.

9. Apparatus for making visible an electrostatic latent image on an image-bearing member comprising means to create a suspension of cloud particles in gas, support means for an image-bearing member having an electrostatic latent image thereon, an elongated zone of turbulent flow comprising a tubular member of restrictive cross section between said means to create a suspension of powder particles in gas and said support, and means to flow said suspension into said tubular member whereby the gas suspension of particles flowing through the tubular member from said means to create a suspension of powder particles in gas is caused to be in turbulent flow thus bringing the suspended particles into repeated triboelectrically charging contact with the walls of said member during passage therethrough, the walls of said member being a mineral selected from the group consisting of soapstone, montmorillonite, halloysite, bentonite, spodumene, red sandstone, serpentine, pyrophyllite, oligoclase, gray sandstone, and quartzose sandstone of the argillaceous type.

10. Apparatus for making visible an electrostatic latent image on an image-bearing member comprising means to create a suspension of powder particles in gas, support means for an image-bearing member having an electrostatic latent image thereon, at least one capillary tube between said means to create a suspension of powder particles in gas and said support, and means to flow said suspension into said tube whereby the gas suspension of particles flowing through said tube from said means to create a suspension of powder particles in gas is caused to be in turbulent flow thus bringing the suspended particles into repeated triboelectrically charging contact with the walls of said tube during passage therethrough, said walls being a mineral selected from the group consisting of soapstone, montmorillonite, halloysite, bentonite, spodumene, red sandstone, serpentine, pyrophyllite, oligoclase, gray sandstone, and quartzose sandstone of the argillaceous type.

11. Apparatus for making visible an electrostatic latent image on an image-bearing member comprising a source of gas under pressure feeding into a cloud generator, said cloud generator being adapted to create a suspension of powder particles in gas suspension, means for supporting an image-bearing member having an electrostatic latent

image thereon and at least one capillary tube between said cloud generator and said support means whereby the gas suspension of particles flowing into the tube from the cloud generator is caused to be in turbulent flow thus bringing the suspended particles into repeated triboelectrically charging contact with the walls of said tube during passage therethrough, the walls of said tube being a mineral selected from the group consisting of soapstone, montmorillonite, halloysite, bentonite, spodumene, red sandstone, serpentine, pyrophyllite, oligoclase, grey sandstone, and quartzose sandstone of the argillaceous type, said tube further being adapted to convey the suspension of particles into the space between the image-bearing member and a closely spaced conductive electrode.

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