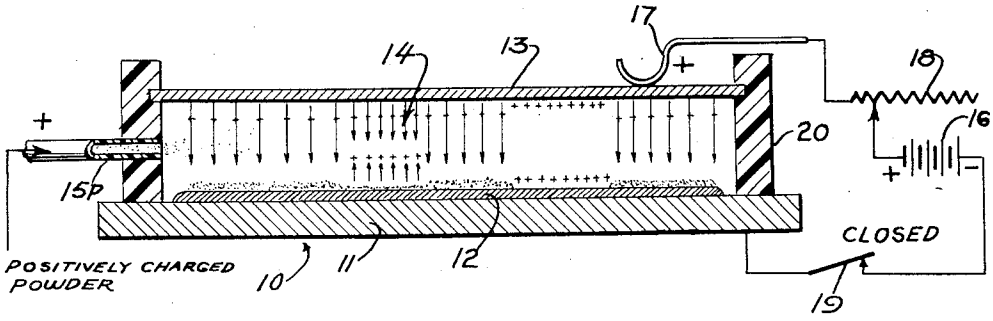
Dec. 24, 1957 R. E. HAYFORD 2,817,598

CONTINUOUS TONE REVERSAL DEVELOPMENT PROCESS

Filed Feb. 1, 1955

Fig. 1.



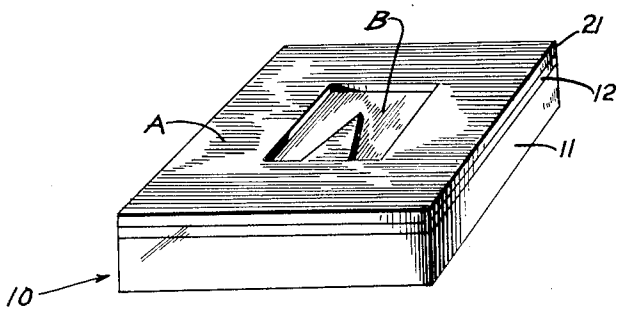
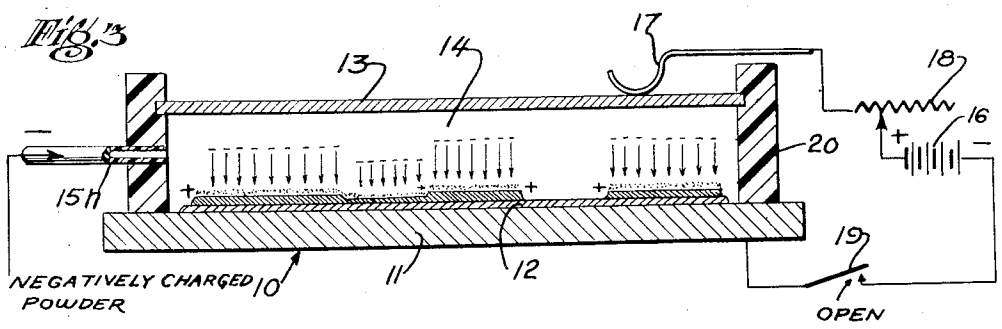




Fig. 2.

Fig. 3



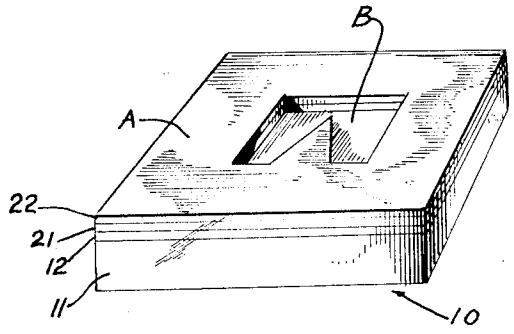




Fig. 4.

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# CONTINUOUS TONE REVERSAL DEVELOPMENT PROCESS

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1 Claim. (Cl. 117—17.5)

This invention relates in general to the process of electrophotography generally known as xerography. and more particularly to methods of development of images on xerographic elements.

In the field of xerography it is usual to form an electrostatic latent image on a suitable surface which may, for example, be a photoconductive insulating layer on a conductive backing member. This electrostatic latent image can then be developed by treating it with a finely divided electroscopic material which is electrostatically attracted to the image surface in conformity with the latent image. Since its inception the xerographic process has been improved to the state in which the photographic results which can be achieved by the process are closely comparable with the results obtained from conventional photography. There is, however, further demand for improved techniques which will produce even better results than those presently obtainable.

In order to obtain fine quality reuslts, particularly in the development of continuous tone images, it is necessary to present to the image layer a finely divided electroscopic material in the form of extremely small uniformly charged particles substantially free from large agglomerates, so that the formation of material deposited on the image surface closely corresponds to the electrostatic charge pattern residing on the surface. It is obvious, of course, that large or non-uniformly charged particles will result in uneven deposition readily apparent to the unaided eye in the form of graininess or improper tone condition. It is likewise obvious that uniform flow must be employed in presenting the electroscopic particles evenly across the entire surface of the image layer so that development in any one area will be on a comparable basis with development in all other areas.

In recent practice, an electroscopic material has been presented to the image bearing surface in the form of an air suspension or cloud of the developer particles, which suspension has been given electrostatic charging prior to being blown across the surface of the image layer. The charge applied to the electroscopic material has been of opposite sign to that on the image bearing surface so that the opposite natures of the charges would increase the attraction and deposition of the powder onto the charged portions of the image surface. The resulting image would be one in which dark objects are recorded directly as dark and light objects directly as light in the developed image.

Occasion frequently arises wherein so-called reversal development is deemed preferable to normal xerographic development. Such reversal development is distinguished from normal xerographic development in that light objects become recorded as black and black objects become recorded as light. This, of course, is directly reverse to normal xerographic methods. Reversal development is in effect akin to photographic negative development but because of the confusion likely to occur



in the use of the term "negative" for this type of development with the use of negative and positive to designate polarities of charges, the term "reversal development" is deemed preferable and will be used hereinafter.

The invention herein contemplates among its objects and features that improvement in continuous tone reversal development which embodies the presentation to an electrostatic image layer of a uniformly charged suspension or cloud of electroscopic particles whose polarity is the same as that of the image on the photoconductive surface while simultaneously applying a potential to a development electrode located in close proximity to the image bearing surface whose polarity likewise is of the same character as that of the image on the surface. In practicing the invention the potential applied to the development electrode is maintained at a figure roughly equivalent to the highest potential on the image surface. In consequence, when the powder of like charge is presented or introduced into the space between the image surface and the development electrode, it will only tend to deposit on those portions of the image bearing surface whose positive charge is lower than the potential or charge of the development electrode. For example, if the highest charge on the image bearing surface is 100 volts and other areas are at varying positive voltages between zero and 100 volts, and if the development electrode is charged to a positive potential of 100 volts, a positively charged powder introduced into the space between them would be driven away from all areas on the image bearing surface except those whose charge is less than 100 volts and will be deposited on such areas in quantities sufficient to neutralize the potential gradient between such areas and the development electrode. The distribution of the deposition will be in accord with the magnitudes of the various positive voltages in various areas of the image bearing surface, being least in those areas whose positive voltages are the same as the positive potential of the development electrode.

Since the image voltages in various areas depend upon the amount of radiation reaching such areas (those most exposed being most discharged and having the lowest charges), such lowest charged areas will receive the larger quantities of deposited powder and in consequence be the darkest. In other words, the powder deposited image created by the presentation of the powder to the surface will have heaviest deposits in those areas which in ordinary development would be the areas most lightly deposited.

The invention further contemplates among its objects and features a further development stage for the image produced as just described which will intensify the contrast and further improve the qualities of the developed image.

In practicing this aspect of the invention the image carrying surface is exposed to light after the completion of the procedure hereinabove outlined and at the same time the potential applied to the development electrode in relationship to the backing plate of the image bearing surface is removed. Developer powder whose charge is opposite to that of the powder particles hereinbefore presented to the image bearing surface is then presented to such surface. Since the newer particles are oppositely charged to those previously deposited on the surface, they are attracted to the latter in proportion to the various degrees of charge thereon until the charges on the particles previously deposited on the image on the surface have been neutralized. The result of this added procedure is an increase in definition and quality of the image developed on the image bearing surface. The explosure of the latter to light between the application of the two powders is advantageous in

that it removes residual charges from the surface of the element on which deposition of material did not occur during the first development step. This elimination further improves the definition and quality of the image on the surface.

Other objects and features of the invention will become apparent from the following specification and the accompanying drawing, wherein:

Fig. 1 is a diagrammatic view illustrative of one mode of practicing the invention;

Fig. 2 is a diagrammatic illustration of a reversely developed xerographic element;

Fig. 3 is a similar diagrammatic view illustrative of a second mode of practicing the invention; and

Fig. 4 is a diagrammatic illustration of the xerographic element after treatment with the mode of Fig. 2.

Referring to the drawing, and first to Fig. 1, a xerographic element **10** comprising a backing member **11** of conductive material and a layer **12** of photoconductive material is adapted to be supported in spaced insulated relationship from a conductive surface **13**, hereinafter called a development electrode. This electrode **13** has an area at least as large as that of the layer **12** and lies in close proximity to the latter. The space **14** between the surface of layer **12** and of electrode **13** is of the order of approximately $\frac{1}{40}$ inch to $\frac{1}{200}$ inch.

An extremely fine hollow member such as a capillary **15***p* connected to a conventional powder cloud generator source (not shown) has its outlet directed into the space **14** so as to deliver a charged electroscopic powder cloud to said space.

The cloud generator in itself forms no part of the instant invention, being any one of the conventional forms of such apparatus commonly used and known. It also includes known arrangements (not shown) for charging the powder cloud delivered into space **14** from the exit end of capillary **15***p* to desired potential and required polarity.

The control electrode **13** is connected to one terminal of a potential source such as battery **16** through a spring contact **17** and variable resistor **18**. The other terminal of the battery **16** is connected through a normally closed switch **19** to the conductive backing plate **11** of xerographic element **10**.

In utilizing this arrangement the xerographic plate or element **10** is charged and then has its layer **12** exposed in any of the usual ways. After such exposure its layer **12** bears a latent electrostatic image in its outer surface. This exposed element **10** is thereupon mounted in spaced insulated relationship from the control electrode **13** as illustrated in Fig. 1, being supported, for example, in this manner by the frame **20** of insulating material. Assuming that the surface charge of the electrostatic image in layer **12** is positive, the control electrode **13** is connected through variable resistance **18** to the positive terminal of the battery B so that the charge on said control electrode **13** is positive. Variable resistor **18** is adjusted so that the positive charge on control electrode **13** is approximately equal to the maximum positive charge of the electrostatic image on the surface of layer **12**. For example, if such maximum positive charge is 100 volts, the resistor **18** is adjusted to provide a like positive charge of 100 volts on control electrode **13**.

In consequence, the potential gradient between the control electrode **13** and any specific image surface area is the difference between the fixed value of the positive charge on the control electrode **13** and the specific value of the positive charge on the surface of the specific image area on the image surface. For example, like image area charge and control electrode charge provide a zero potential gradient between them. A specific image area charge of +10 volts and a control electrode charge of 100 volts produces a potential gradient of 90 volts in such area. Similarly another specific image area charge of +30 volts with respect to the same control electrode charge of +100 volts produces a potential gradient of 70 volts. The potential gradients between the specific areas of latent electrostatic image in the surface of layer **12** and the control electrode **13** are thus distributed in a pattern conforming to that of the electrostatic image in said layer **12**. The electric field in space **14** is distributed in conformity with the potential gradient distribution. Put in another way, in specific image areas of maximum charge, lines of force will all be directed inwardly of the image surface to the backing plate **11**. Specific image areas of zero or minimum charge will have lines of force all outward of the surface **12** toward the control electrode **13**. Specific image areas whose potentials fall between the maximum and minimum will have lines of force directed both outward to the development electrode **13** and inward to the backing plate **11**.

A positively charged cloud of electroscopic powder is now introduced via capillary **15** into space **14**. Because of the potential gradient and line of force distribution in space **14**, the positive charged powder will become deposited on the various image areas on the surface of layer **12** in quantities which are functions of the electric lines of force in space **14** and proportional to the potential gradients between respective of said image areas and said control electrode. The heaviest deposits will occur in those areas where the most lines of force occur in space **14**, i. e. where greatest potential gradient occurs. In other words, heaviest deposits on layer **12** will occur in those image areas thereof which have the least positive charge, namely, those areas which were the lightest of the original image and thus the most exposed areas of the photoconductive layer **12**. Similarly the lightest deposits on layer **12** will occur in those of its areas where the least electric lines of force exist or least potential gradient occurs. In other words, lightest deposits will occur in those image areas of layer **12** which have the maximum positive charge, namely, those areas which were the darkest of the original image and thus the least exposed areas of the photoconductive layer **12**. Since the heaviest deposits occur in the lightest portions of the original image and the lightest deposits occur in the darkest portions of the original image, it is apparent that reverse image development occurs when the polarities of the image surface of the control electrode and of the electroscopic development powder are all alike. This is illustrated diagrammatically in Fig. 2 wherein the shaded areas A on the surface of layer **12** represent a layer **21** of powder deposit covering areas which in the original image exposed were light. The uncovered area B was dark in the original image exposed.

It is to be noted that this manner of reversal development differs from suggestions of simply using oppositely charged electroscopic powder to effect reversal by inducing charges on the surface of the plate, the induced charges acting to hold the developer particles in place. The use in the instant invention of the control electrode **13** charged to the same polarity and to a potential equal to the highest potential on the image bearing surface of layer **12** develop externally extending lines of force between the image bearing surface and the control electrode. The external lines of force provide very effective control and influence on the electroscopic powder of same polarity as that of the control electrode and the image surface when the said powder introduced into the space **14** between the surface and the electrode. The reversely developed continuous tone image has very fine quality and image definition.

When the element **10** bearing the reversal developed image is removed from the frame **20**, the powder deposits A (Fig. 2) forming such reverse image retain their original charge and also cover the various areas of the surface of layer **12** in a layer **21** whose thicknesses in various areas are in reverse proportion to the original image

charges effecting reverse proportional shading of such surface. Exposure now of the powder image carrying layer **12** to light causes discharge of all of its areas which are not covered by any deposited powder. The surface portions A of layer **12** covered by, for example, the layer **21** of positively charged powder, are not, however, affected by the light and the deposited powder particles of said layer **21** retain their positive charge. The quantitative positive charges of powder particles of layer **21** in any particular developed image areas are in proportion to the potential gradients which existed between the development electrode and the corresponding areas of the latent image in said photoconductive layer **12**. For example, if the potential gradient was 90 volts in a specific image area, the deposited powder charge has a positive potential of 90 volts whereas, for example, in another specific image area where the potential gradient was 30 volts, the deposited powder charge has a positive potential of 30 volts.

The plate or element **10** bearing the charged reversal developed powder image after exposure to light to discharge uncovered portions of surface **12** can be developed further with electroscopic powder of the same kind as that used in the stage of reversal development hereinbefore described, charged however to opposite polarity, in this instance negative.

To effect this additional stage of development, the switch **19** (Fig. 3) is opened and the control electrode **13** temporarily removed from the frame **20** to expose the surface **12** carrying the deposited powder image layer **21** to light. Those areas (in this instance B) not covered by the powder layer upon such exposure to light become discharged because of the photoconductive nature of layer **12**.

The capillary **15***n* is connected to a cloud chamber which delivers a powder cloud preferably of the same material as the powder in image layer **21** but of opposite polarity. The switch **19** is maintained in open condition so that when electrode **13** is replaced in frame **20** it has no charge. The powder cloud (in this instance negatively charged) is admitted into space **14**.

The oppositely charged powder particles in space **14** are attracted to the charged powder particles of layer **21** in the image on element **10** in proportion to the distribution of charges in various image areas of layer **21** and are deposited as a second layer **22** in quantities over the layer **21** in the various areas sufficient to neutralize the individual potential differences in said areas. Since preferably the second powder is identical with the first used except for its polarity, the final reversely developed image is a fine quality reverse image of the original latent image in layer **12** consisting of the two layers **21** and **22** with the original reverse image intensified by the second powder deposition. The shading and general quality of this intensified image is a faithful reverse reproduction of the original latent image which is ultra fine in character. It constitutes a most effective way to produce xerographic images resembling the quality of photographic images both as to tonality and color (blackish and whitish) characterisitcs. This second stage of development is not always required and its use is only indicated when the first reversal developement stage does not itself produce the reversal image of desired tonality, quality and intensity.

The electroscopic powders useful in practicing the instant invention and in securing reversal images of highest quality may be those described, for example, in U. S. application Serial No. 353,520, filed May 7, 1950, by Eugene C. Ricker, and include charcoal, carbon blacks, or carbonaceous pigments. In addition, such materials as furnace blacks, channel blacks, various carbon or lamp black materials, or if desired, finely divided materials having added pigment matter may be used. In the latter category are materials such as finely divided resins containing pigments or dyes, compositions of this type being preferred where the exerographic print or picture ultimately is to be made permanent by a fusing process including heat or vapor fusing.

The manner of cloud generation of such electroscopic powders may be that described in said application and the dimensional characteristics of the capillary members **15***p* or **15***n* may be those described for the similar capillary member *o* of said application. Charging of the cloud during its transmission via the capillary member **15***n* or **15***p* to the space between the xerographic element **10** and the control electrode **13** to desired polarity may be effected by selection of the proper material for the capillary member. Thus, if the material thereof is of metal, a negative charge will be imparted to the electroscopic powder particles. On the other hand, the capillary can be constructed of plastic or like material of negative triboelectric properties whereby it is adapted to charge the electroscopic powder particles to positive polarity. A single frame **20** may have two capillaries **15***n* and **15***p*, one of metal and the other of negative triboelectric properties both connected to the cloud generating source and provided with selective controls so that first one and then the other capillary member may be utilized as required for delivering the powder charged to required positive or negative polarity as the case may be. The powders useful, the manner of their charging and presentation to the exposed photoconductive surface **12** and the manner of their cloud generation may be other than those described herein.

While specific methods of practicing the invention have been described, variations in detail within the scope of the claim are possible and are contemplated. There is no intention, therefore, of limitation to the exact details shown and described.

What is claimed is:

A method of reversely developing a xerographic latent image of determined electrical polarity existing on a photo-conductive surface comprising locating a conductive surface in spaced proximity to said photoconductive surface, applying a charge to said conductive surface of the same polarity as the polarity of the latent image and whose magnitude equals approximately the maximum charge of said latent image, presenting electroscopic powdered material charged to the same polarity as that of said latent image and of said conductive surface into the space between the charged conductive surface and the latent image bearing photoconductive surface to effect deposition of powder particles on the photoconductive surface which is a reversal powder image of the said latent image thereon, thereafter exposing the reversal powder image carrying photoconductive surface to light to discharge its uncovered areas and subsequently presenting additional electroscopic powder material to the reversal powder image on said photoconductive surface, the polarity of said additional powder material being opposite to that of the charge on the powder in said powder image to effect an additional powder deposit over the original reversal powder image.

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