

Sept. 8, 1959

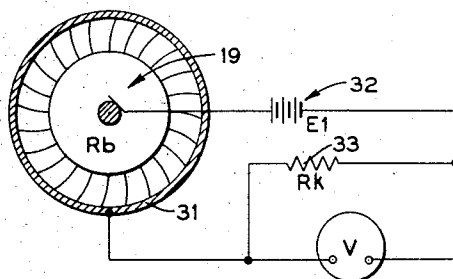
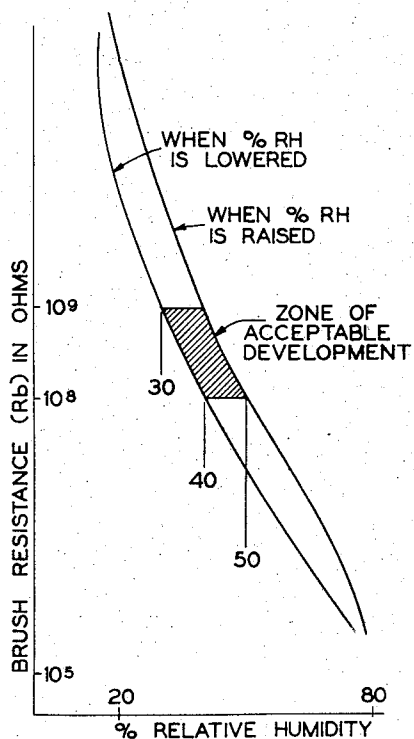
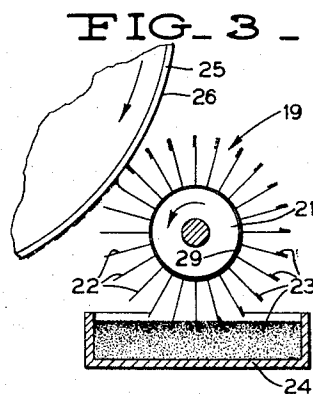
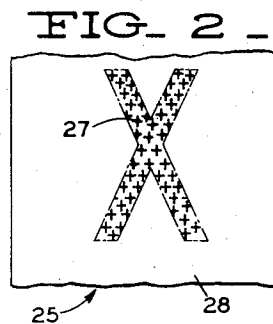
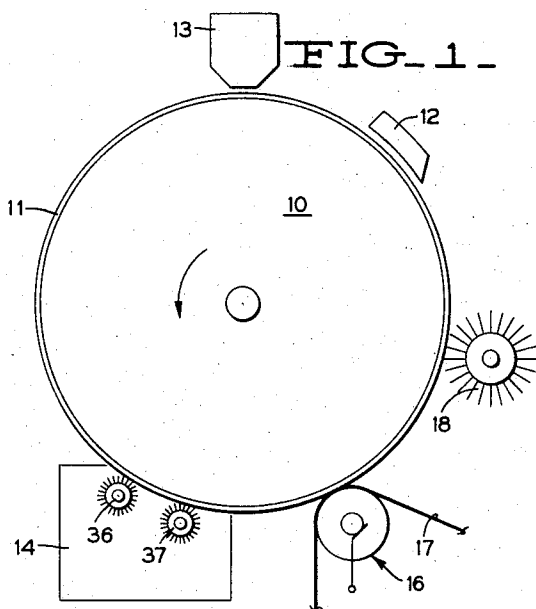
R. W. GREAVES

2,902,974

LATENT ELECTROSTATIC IMAGE DEVELOPING APPARATUS

Filed June 14, 1956

2 Sheets-Sheet 1



INVENTOR.
ROBERT W. GREAVES

BY

J. Janin Jr.

ATTORNEY

Sept. 8, 1959

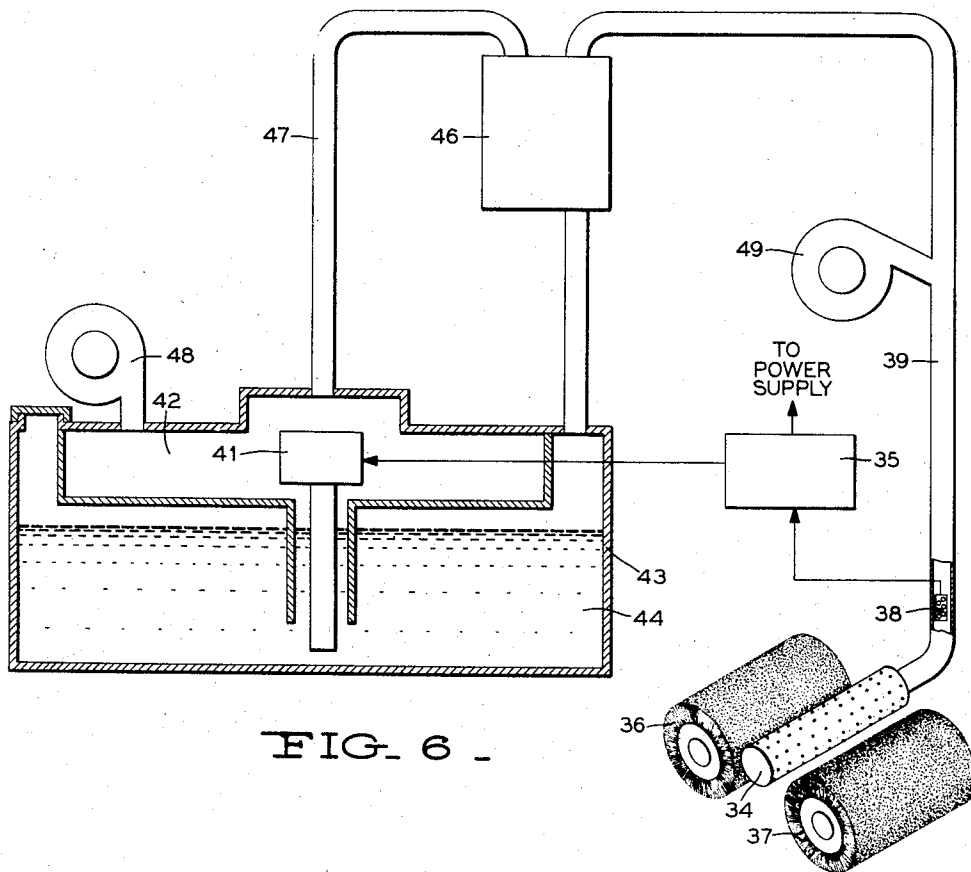
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2 Sheets-Sheet 2



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LATENT ELECTROSTATIC IMAGE DEVELOPING
APPARATUS

Robert W. Greaves, Endwell, N.Y., assignor to International Business Machines Corporation, New York, N.Y., a corporation of New York

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2 Claims. (Cl. 118—637)

This invention relates to electrographic printers in general, and in particular to the apparatus thereof for developing latent electrostatic images of the subject matter to be printed. Accordingly, the present invention has for its broad object the provision of an improved latent electrostatic image developing apparatus.

It is well recognized that xerography, or "dry printing" as it is so often called, requires the application of a pigmented powder onto the surface of a charged plate in order to develop the latent electrostatic images thereon. A preferred latent electrostatic image developing apparatus which is disclosed and claimed in the copending U.S. patent application, Serial No. 554,515, filed by W. D. Bolton et al. on December 21, 1955, utilizes a soft fur brush for transferring electroscopic toner particles from a suitable source thereof onto the charged plate surface. As is brought out in this copending application, in addition to transferring the toner particles, the soft fur brush causes an electrostatic triboelectric charge to be imparted to these particles which are actually brought into physical contact with the brush hairs or fibers. It might be well to bring out at this time that the triboelectric effect is one of contact electrification; that is, an exchange of electrons takes place between two triboelectrically dissimilar materials when these materials are initially brought into physical contact so that one material gains electrons lost by the other material. Thus, in the case of the afore-mentioned fur brush and toner particles, the brush fibers are charged positive whereas the toner particles are charged negative. Furthermore, since the fur fibers as well as the toner particles are for the most part good insulators, the triboelectric charges imparted thereto are retained upon the physical separation of these two materials.

Another object of this invention is to provide an improved brush type developing unit for consistently producing good printing results, by maintaining the electrical resistance of the brush fibers at a substantially steady, optimum printing value.

Another object of this invention is to provide a relative humidity governing apparatus for use with a brush type developing unit so as to maintain the resistance of the brush fibers at a substantially steady, optimum printing value by controlling the amount of moisture content of the said brush fibers.

In line with the foregoing, another object of this invention is to provide a brush type latent electrostatic image developing unit having an apparatus therein for maintaining the moisture content of the brush fibers within the aforesaid unit at a level commensurate with optimum printing results.

Still another object of this invention is to provide a latent electrostatic image developing apparatus for use in continuously operating high speed xerographic printers.

Other objects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings, which disclose, by way of examples, the principle of the invention and the best

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mode, which has been contemplated, of applying that principle.

In the drawings:

Fig. 1 is a diagrammatic view of a continuously operating xerographic printer employing brush development.

Fig. 2 is a view of a portion of the surface of an electroplate having a latent electrostatic image thereon.

Fig. 3 is a schematic showing of a brush developer apparatus.

Fig. 4 is a circuit diagram for measuring the bulk resistance of the brush fibers.

Fig. 5 depicts brush fiber resistance versus percent relative humidity curves.

Fig. 6 is a diagrammatic view of apparatus for maintaining the relative humidity within a brush type developing unit at a steady, optimum printing value.

Xerographic printer—General description

Referring to Fig. 1, xerographic drum 10 having a photoconductive insulating layer 11 thereon, would be driven in a counterclockwise direction by conventional means (not shown) so that the incremental surface areas of the photoconductive insulator layer 11 would be acted upon in the following sequence:

(1) These surface areas would initially be charged positive by corona unit 12.

(2) Charged surface areas corresponding to the light image projected from optical apparatus 13, would be discharged so as to form a latent electrostatic image on layer 11.

(3) Those surface areas depicting the latent electrostatic image would have applied thereto, toner particles by the brush type developing unit 14.

(4) The developed image as depicted by the toner particles on the surface of photoconductive insulator layer 11, would be transferred at station 16 onto a print receiving material 17.

(5) Any residual toner remaining on the surface of the xerographic drum after the afore-mentioned transfer operation, would be removed by the cleaning brush 18.

The electroscopic toner applied to the surface of xerographic drum 10 by the brush type developer unit 14 may be a powder composition comprising one or more resins which are preferably thermoplastic in character, a plastisizer which is a solvent that can act upon the resin at a temperature below the melting point of the resin, and a pigment for imparting a desired color to the toner material. Several electroscopic toner compositions are described in the U.S. Patents Nos. 2,618,551 and 2,618,552, which issued to Walkup and to Wise, respectively, on November 18, 1952.

Brush developing description

General.—As is brought out in detail in the afore-mentioned copending Bolton et al. application, there is used in a brush development apparatus a soft fur brush to impart the required triboelectric charge to the toner particles. As stated previously, it is by the physical contact of the soft fur brush fibers with respect to the electroscopic toner particles that opposite triboelectric charges are imparted to these fibers and the toner particles.

Referring to Fig. 3, the principle of brush developing as it is now understood in its simplest form may be explained. A suitable brush 19, such as beaver for example, is secured to a rotatable drum or cylinder 21 which, in turn, is so positioned that the brush fibers 22 move through a mass of electroscopic toner material 23 in a source reservoir 24, and also in physical contact with the charged surface of an insulating layer 26 of an electroplate 25. Before proceeding any further it would be well to distinguish an electrophotoplate from an electroplate. The former is a member comprising a photoconductive

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insulating layer 11 (Fig. 1) on a conductive backing, whereas the electroplate is a member comprising an insulating layer, photoelectric or otherwise, on a conductive backing. Accordingly, it should be clear that the expression electroplate includes an electrophotoplate. Furthermore, insofar as the present invention is concerned, it should be clear that it is of no consequence how a latent electrostatic image is formed nor is it of any significance in what type of material this image is stored.

Referring once again to Fig. 3, the afore-stated physical contact between the brush fibers 22 and the toner particles 23 causes a triboelectric charge to be imparted to the toner particles so acted upon. The use of a fur such as beaver referred to hereinabove, as well as the use of a thermoplastic electroscopic toner such as described previously, causes a negative triboelectric charge to be imparted to the toner particles and a positive triboelectric charge to be imparted to the brush fibers. Thus, as incremental areas of the insulating layer 26 having positively charged latent electrostatic images stored thereon are subjected to the negatively charged toner particles 23, the charged particles will be caused to adhere to the positively charged surface areas so long as this force of attraction is great enough to overcome the force of attraction between the positive brush fibers and negative toner particles. As a result, the latent electrostatic images will be visibly defined by the pigmented toner particles.

"Wet" developing brush when relative humidity is high.—Referring to Fig. 2, the latent electrostatic image 27 is shown to be defined by a positive electrical charge of approximately +600 volts. The background area 28 of the electroplate 25 could be at a +150 volt residual level. Thus, the various electrical charges produced must be such that the force of attraction between the negative toner particles and the positive fur fibers must be large enough to prevent toner transfer to the background area 28 and yet small enough to enable the latent electrostatic image area 27 to capture and hold a sufficient amount of toner so as to cause the said image to be developed. It has been discovered, however, that when the relative humidity within the brush type developing unit is excessively high so as to bring about a so-called "wet" brush, the resistance of the brush fibers 22 (Fig. 3) is lowered considerably. It is believed that this is due to a conductive surface film of moisture on the said fibers which is brought about by adsorption. Thus, when the brush fiber resistance is so decreased, the positive triboelectric charges produced on the brush fibers are able to leak off rapidly through the brush hide 29, the brush support, etc. Accordingly, it should be clear that the force of attraction between the now less positively charged brush fibers 22 and the negatively charged toner particles 23, will be decreased. If the brush fiber resistance is low enough, the aforesaid force of attraction between the fibers and toner particles will be decreased to a point where even the residual charge appearing on the background area 28 (see also Fig. 2) will be of sufficient magnitude to remove the toner particles from the brush fibers. This, of course, will produce a very poor, dark background since the positive residual charge defining the background area 28 will have a so much greater effect on the negatively charged toner particles than will the brush fibers 22 (Fig. 3) themselves. In addition to the foregoing, it is believed that the decreased resistance of the brush fibers as brought about by the high relative humidity within the brush type developing unit, will provide a convenient path for the latent electrostatic image defining charges, whereupon these charges can leak off so that the image-background contrast is very poor.

In summation, a so-called "wet" developing brush will produce a developed toner image which has a dark background and very poor image-background contrast.

"Dry" developing brush when relative humidity is low.—When the relative humidity within the brush type

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developing unit 14 (Fig. 1) is too low, a so-called dry brush results. It is believed that the resistance of the dry brush fibers is caused to increase due to the reduction of the aforementioned conductive surface film on the fibers.

Thus, it should be clear that if the fiber resistance is high enough, the positive triboelectric charge formed on the fibers will leak off very slowly through the brush hide 29 (Fig. 3). Thus, if the brush fiber positive charge is maintained at a very high level due to the high resistance of the fibers per se, the force of attraction between these positively charged fibers and the negatively charged toner particles, may well be so high that very little, if any, toner transfer onto the surface of the electroplate 25 (see also Fig. 2) may result. Thus, there will be produced on the surface of the electroplate a very poor, light image because only those poorly charged toner particles which are remote from the brush fibers 22, will be transferred to the surface of the electroplate 25. Such toner particles are those not held to the brush fibers 22 directly, for example those particles which are held only onto other toner particles due to toner agglomeration and the like.

In summation, a dry brush brought about by a low relative humidity within the developing unit, will produce a very light image, if one at all, and one which will have very poor image-background contrast even though there will not be any toner transfer to the background area, because of the limited amount of toner transfer to the latent electrostatic image area.

Normal brush for producing good printing results by maintaining the brush fiber resistance at an optimum printing value.—By employing the circuit and apparatus shown in Fig. 4, the bulk fiber resistance of a great variety of natural and synthetic fur brushes has been determined at different values of relative humidity. In these tests, the particular brush 19 to be tested is secured to a cylindrical form 3.75 inches in diameter and 6.0 inches long, said brush having fibers approximately 0.875 inch long. A conductive cylinder 31 which is 5.125 inches in diameter is placed over brush 19, thereby causing a 0.375 inch interference with the brush fibers. Thus, by connecting a known source 32 of voltage E_1 , e.g., 100 volts, in series circuit with the aforesaid brush-cylinder arrangement and a known resistance 33 (R_k), the bulk brush fiber resistance (R_b) may be calculated by the equation

$$R_b = R_k \left(\frac{E_1 - V}{E_1} \right)$$

where V is the voltage drop across resistor 33.

By varying the relative humidity within the brush developing unit in increasing and decreasing steps for a beaver brush, the curves shown in Fig. 5 are realized. It must be pointed out here that the relative humidity is maintained constant at each step until a point of equilibrium resistance is reached. It is interesting to observe that each of the brushes actually tested, produces a looped curve which is very similar to those shown in Fig. 5. That is when the relative humidity with respect to the test equipment shown in Fig. 4, is descending, the resistance of the brush fibers is considerably less for a given value of relative humidity than when the relative humidity is being raised. Thus, the lower curve depicts the brush fiber resistance as the relative humidity is being lowered, whereas the upper curve depicts the brush fiber resistance as the relative humidity is being raised, thereby exhibiting a hysteresis effect.

As stated previously, a great variety of natural and synthetic fur brushes were tested in accordance with the setup shown in Fig. 4, and for each of these tests, a looped curve similar to that shown in Fig. 5, resulted. Furthermore, these tests clearly indicate that good printing results may be had when the brush fiber resistance is in the magnitude of 10^8 – 10^9 ohms. That is, the zone of acceptable developing is defined by an area within the looped curve shown in Fig. 5, which area may be ap-

proximated to be between the two limits 10^8 ohms and 10^9 ohms. It should be recognized that the brush fiber resistance referred to throughout this entire specification, is not intended to be construed as the actual resistance of the brush fibers. The resistance values referred to throughout this specification, are those bulk fiber resistance values obtainable by an arrangement similar to that shown in Fig. 4. It is recognized that there are other known ways and means for measuring brush fiber resistance, which other methods will result in fiber resistance values considerably apart from those referred to herein. However, it is intended that all fiber resistance values obtained by any other test arrangement but yet which correspond to the values indicated in this specification, be included.

Referring once again to Fig. 5, it may be seen that the zone of acceptable development lies pretty much between a 30% and 50% relative humidity range. It appears that most natural furs acceptable for brush developing, such as beaver, racoon, skunk, for example, have a similar zone of acceptable development. Thus, it would appear that a safe optimum relative humidity condition at which good printing is obtained, would be approximately 40%.

Moisture governing apparatus for developing brush

Referring to Fig. 6, an air distribution manifold 34 is positioned in between two developing brushes 36—37 (see also Fig. 1). A conventional humidity control sensing element 38 is positioned in the air line 39 used to feed the manifold 34, said humidity sensing element 38 being used to control the operation of the relative humidity controller 35 which, in turn, governs the operation of an atomizer device 41. When the device 41 is operated, a water vapor is formed within the chamber 42 which is a part of the reservoir 43 for holding a water supply 44. This moisture laden air within chamber 42 is carried to a liquid separator 46 via a line 47 by the action of a blower 48. The moist air within separator 46 is then further advanced into the distribution manifold 34 by the action of another blower 49. Thus, as the developing brushes 36—37 are caused to rotate in order to deposit electroscopic toner particles on the surface of an electroplate whereon a latent electrostatic image is stored, moist air is forced through small openings within manifold 34 onto the aforesaid developing brush fibers. When the humidity sensing element 38 detects the fact that the relative humidity of the air within manifold 34 exceeds the relative humidity for which element 38 is set, the atomizer device 41 is caused to be disabled. As a result, there will be a drop in the moisture content of the air within chamber 42, so that air at ambient temperature and ambient relative humidity is forced through the afore-mentioned openings within distribution manifold 34. The operation of humidity sensing element 38 is such as to render atomizer device 41 operated and disabled a number times per second, whereupon the relative humidity of the air being forced through line 39 to distribution manifold 34 is kept to within very close limits of the humidity setting of this device 38.

In accordance with what has been stated hereinbefore, the optimum relative humidity setting of device 38 for most developing brushes such as beaver, for example, would be 40% (see also Fig. 5). Thus, the "off-on" spray of regulated moist air on the fibers of developing brushes 36—37, would maintain the bulk resistance thereof at a value in the neighborhood of 10^8 – 10^9 ohms. This, of course, would be within the zone of acceptable development (see also Fig. 5), whereby optimum printing results could be obtained.

Summary

With the recognition of the fact that brush fiber resistance varies inversely with the percent relative humidity of the atmosphere surrounding the brush fibers, 75

and with the discovery that good quality printing can be had only by maintaining the bulk brush fiber resistance at a predetermined level, it is the purpose of the present invention to improve the brush type developing unit by maintaining the relative humidity within the unit at a value commensurate with a fiber resistance value for producing good printing results. By preventing the relative humidity within the brush type developing unit from becoming too low, extremely light and indistinct images are avoided. On the other hand, by preventing the relative humidity within the brush type developing unit from becoming too high, extremely dark background and poor image-background contrast printing results are prevented.

Thus, should the ambient atmosphere relative humidity be low, the apparatus shown in Fig. 6 hereof will increase the relative humidity within the developing unit to the optimum printing point. Should the ambient relative humidity be too high prior to the time that an electrostatic printer is initially operated, the relative humidity within the brush type developing unit may be equally too high. However, the relative humidity of the air within the developing unit will within a very short period of time after the printer is initially operated, be decreased to a value lower than the optimum printing relative humidity point, due to the heat generated by the printer. Of course, an external heat source may be used even when the printer is disabled so as to keep the temperature within the developing unit considerably above the ambient temperature.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to a preferred embodiment, it will be understood that various omissions and substitutions and changes in the form and details of the device illustrated and in its operation may be made by those skilled in the art, without departing from the spirit of the invention. Accordingly, since the apparatus for maintaining the resistance of the brush fibers within predetermined limits, is not per se a part of the present invention, any suitable means for accomplishing such a result is intended to be covered. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. In a xerographic printer of the class described having an electroplate for storing a latent electrostatic image thereon, the combination of apparatus within an image developing station for depositing electroscopic toner solid particles onto the surface of said electroplate whereon the latent electrostatic image is stored, comprising a rotatable cylinder; an image developing fur brush secured to said cylinder for rotation therewith, said brush having brush fibers extending therefrom for contacting said electroplate surface; an electroscopic toner compartment positioned relative said cylinder so that said brush fibers are caused to move through the electroscopic toner solid particles within said compartment, whereupon electroscopic toner particles are deposited on said brush fibers and thereby caused to be triboelectrically charged opposite to the charge imparted to said brush fibers; humidifying means for maintaining the bulk brush fiber resistance at a value between 10^8 – 10^9 ohms; and means for simultaneously moving said electroplate relative said cylinder and for rotating said cylinder at a velocity such as to effect a continuous wiping action in the direction of movement of said electroplate relative said cylinder, whereby the latent electrostatic image is developed by the adherence of said electroscopic toner particles onto said electroplate surface.

2. In a xerographic printer of the class described having an electroplate for storing a latent electrostatic image thereon, the combination of apparatus within an image developing station for depositing electroscopic toner solid particles onto the surface of said electroplate, comprising a rotatable cylinder; an image developing fur brush secured to said cylinder for rotation therewith having

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fibers extending therefrom for contacting said electroplate surface; an electroscopic toner compartment positioned relative said cylinder so that said brush fibers are caused to move through the electroscopic toner within said compartment, whereupon electroscopic toner solid particles are deposited on said brush fibers and thereby caused to be triboelectrically charged opposite to the charge imparted to said brush fibers; means for applying moisture laden air onto said brush fibers, whereby electrically conductive moisture films are formed on said brush fibers by adsorption; means for governing said moisture laden air applying means so that the resistance of said brush fibers is maintained at a value between 10^8 - 10^9 ohms; and means for simultaneously moving said electroplate relative said cylinder and for rotating

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said cylinder at a velocity such as to effect a continuous wiping action in the direction of the movement of said electroplate with respect to said cylinder, whereby the latent electrostatic image is developed by the adherence of said electroscopic toner particles onto said electroplate surface.

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