Oct. 16, 1962 M. L. SUGARMAN, JR., ETAL 3,058,444

APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGE ON ELECTROGRAPHIC SHEET

Filed March 13, 1959 2 Sheets-Sheet 1

Fig. 1

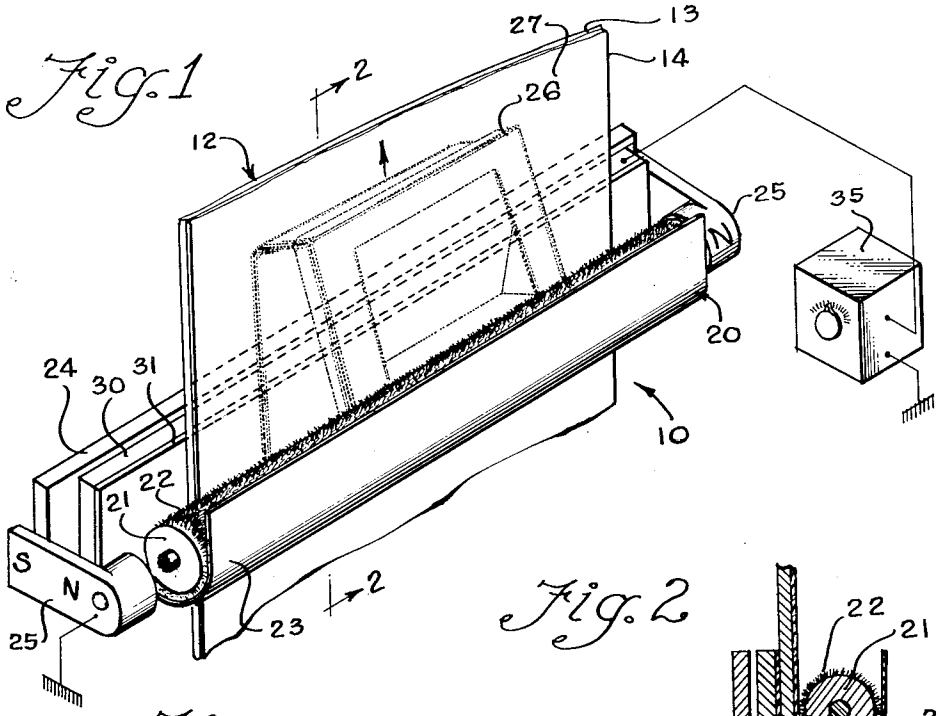


Fig. 2

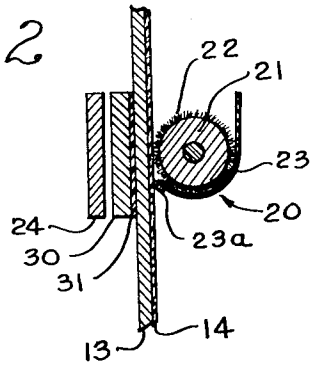


Fig. 3

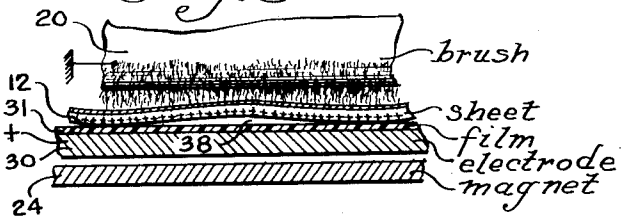
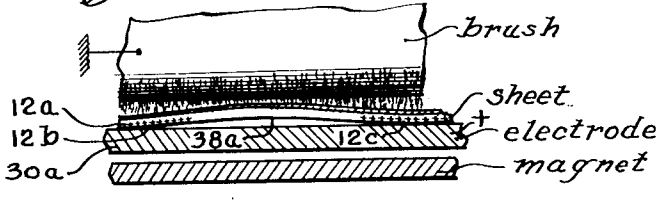


Fig. 4 PRIOR ART



INVENTOR.
Meyer L. Sugarman Jr.
Marvin B. Levine
BY Wolfe, Hubbard, Voit & Osann
ATTYS.

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Fig. 5

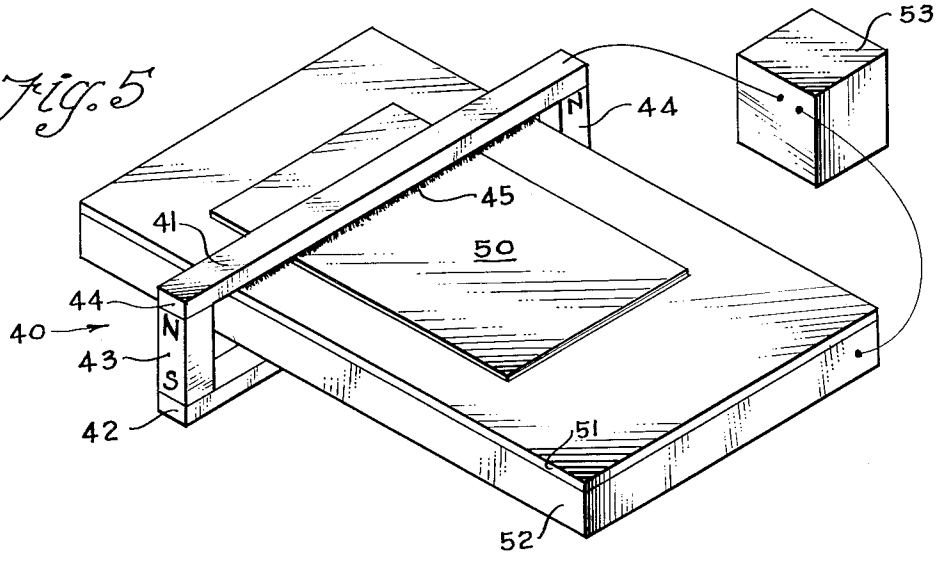
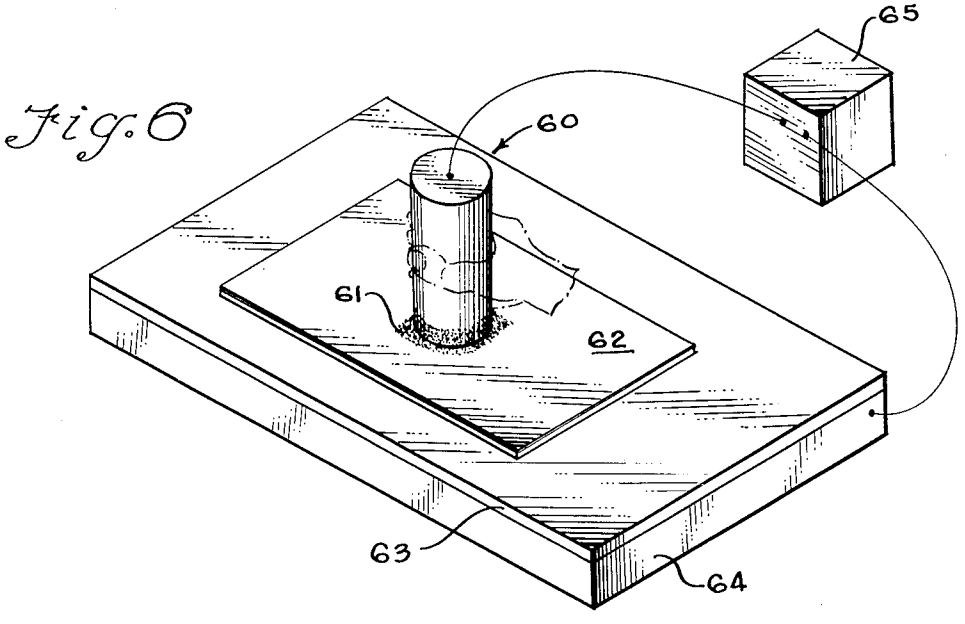


Fig. 6



INVENTOR.
Meyer L. Sugarman Jr.
Marvin B. Levine
BY Wolfe, Hubbard, Voit & Osann
ATTYS.

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APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGE ON ELECTROGRAPHIC SHEET

Meyer L. Sugarman, Jr., Wilmette, and Marvin B. Levine, Evanston, Ill., assignors to American Photocopy Equipment Company, Evanston, Ill., a corporation of Illinois

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The present invention relates to electrophotographic printing and more particularly to means for insuring a clean background in the development of latent electrostatic images.

The electrophotographic printing process employed in office photocopy machines and the like involves the steps of uniformly charging an electrographic sheet, exposing the sheet to produce a latent image thereon with dissipation of charge from the light-struck areas, and development of the image by applying a pigmented powder or toner which tends to adhere selectively to the charged areas. Following this the toner is either fixed in place on the sheet or transferred to a second sheet. One difficulty which has been experienced with this procedure is that the charge is not wholly dissipated from the light-struck areas, usually the background areas, with the result that the background areas have toner spuriously deposited thereon to a degree which makes such background areas grey and "muddied" rather than white and "crisp."

To reduce this unwanted deposit of toner in the background areas, it has been proposed to contact the back of the sheet with an extensive auxiliary electrode and to apply a potential between the electrode and the reservoir of toner particles which is sufficient to neutralize the effect of the residual charge. Practical experience with such an arrangement has shown that the results are often unsatisfactory, with only partial removal of the toner particles, with unwanted variations in density in both the background and printed areas, and with the occurrence of dark stripes across the surface of the developed copy. These effects tend to vary with conditions of humidity and temperature, with the amount of "ripple" in the sheet, and with the mechanical adjustment of the copying machine, particularly the paper tension adjustment in the case of web-fed machines. The final result is unpredictable in the day to day operation of a given machine, or even from sheet to sheet in a sheet fed machine. Moreover, the auxiliary electrode gives rise to complications where it is desired to copy sheets of less than standard width, i.e., less than the width of the electrode. The above has tended to discourage use of auxiliary charged electrodes for clean-up purposes in machines intended for office and commercial use.

Accordingly, it is an object of the present invention to provide an arrangement for developing an electrographic sheet which insures uniform clean-up of background or "white" areas and which is free of the disadvantages normally associated with the use of auxiliary charged electrodes. It is a more specific object to provide a developing arrangement employing an auxiliary charged electrode but which gives uniform clean-up under all ambient conditions and regardless of the condition of the paper. That is to say, uniform results are achieved over wide variations in the resistivity of the paper and independently of the amount of ripple, pucker or other surface irregularities, within the practical variations encountered in normal practice. It is an important object of the invention to provide a developing arrangement producing uniform clean-up in sheet-fed machines where problems of ripple have been aggravated because of inability to tension the paper during development.

It is another object to avoid the stripes and smears over both the background and copy which have been characteristic of conventional electrographic copy machines.

It is a further object of the invention to provide a developing arrangement employing an auxiliary charged electrode but which is capable of accepting sheets of less than "standard" width, which are substantially narrower than the width of the developer brush and electrode without affecting the operation or the quality of the result.

It is a final object of the invention to provide a worthwhile improvement in the developing procedure characterized above, which is universally applicable to various developing setups employing photoconductive sheets, whether manual or automatic, and which may be incorporated in new machines and existing machines at extremely low cost.

Other objects and advantages of the invention will become apparent upon reading the attached detailed description and upon reference to the drawings in which:

FIGURE 1 shows in diagrammatic perspective an embodiment of the invention as applied to either a sheet-fed or a web-fed copying machine.

FIG. 2 is a fragmentary section taken along the line 2—2 of FIG. 1.

FIG. 3 is a diagram showing charging of the sheet by electrostatic induction.

FIG. 4 is a diagram similar to FIG. 3 but absent the insulating film.

FIG. 5 is a diagrammatic perspective of a modified developing arrangement employing the present invention.

FIG. 6 is a diagrammatic perspective showing the invention employed in connection with a hand developing brush.

While the invention has been described herein in connection with several preferred embodiments, it will be understood that we do not intend to limit the invention to the illustrated embodiments but intend to cover such alternative and equivalent arrangements as may be included within the spirit and scope of the appended claims.

Referring now to FIG. 1, a development arrangement **10** is shown which serves to develop a latent image on an electrographic sheet **12**. This sheet, in the present embodiment, includes a paper backing portion **13** and a photoconducting portion **14** in the form of a thin resin-bound layer. The photoconductor may, for example, consist of zinc oxide or selenium, dispersed in a resin binder to create a flexible photoconductive surface. Both of the latter materials have the property of acquiring a uniform electrostatic surface charge when subjected to a high potential field and are capable of dissipating such charge selectively in the light-struck areas when exposed to a photographic image. It will be assumed that the electrographic sheet **12** has been previously charged and exposed to a photographic image so that upon entering the development apparatus the paper includes a latent electrostatic image exhibiting maximum charge in those areas which have not been struck by light.

In carrying out the development, the electrographic sheet is drawn by rollers (not shown) upwardly adjacent a developer brush **20**. The brush arrangement may, for example, be of the construction shown in copending application Serial No. 757,779 filed August 28, 1958, and assigned to a common assignee. Briefly stated, the brush includes a magnetic roller **21** having provision for rotating the same during operation of the machine and having adherent "bristles" **22** formed of a loose, dry mixture of magnetic powder and toner. The roller **21** rotates in a trough **23** which serves as a reservoir for the developing material. A flexible felt strap or other suitable seal **23***a* may be utilized to allow paper to pass into the developing unit while retaining all of the developer mix therein.

As is well known to those skilled in this art, the toner particles tend to adhere triboelectrically to the magnetic particles which act as a carrier but leave the magnetic

particles, due to electrostatic attraction, when brushed against the charged areas of the sheet. In order to insure intimate contact between the brush and the sheet, a closed magnetic circuit is employed, with the return path on the opposite side of the sheet in the form of a bar **24**. The ends of the bar **24** are magnetically coupled to the ends of the magnetic roller **16** through magnetic end pieces **25** so that the roller is of one polarity and the bar of the other, with magnetic lines of force extending between the two.

In operation, as the sheet **12** leaves the developer brush, the toner creates an image thereon consisting of printed areas, for example, as indicated at **26**, surrounded by white or background areas **27** which are, or should be, free of toner. In accordance with the conventional practice, the toner or the surface of the electrographic sheet, or both, may include a thermoplastic binder, with the sheet being subjected to radiant heat as a final step for the purpose of fixing the particles of toner in place, thus producing a permanent copy.

In accordance with the present invention, an extensive auxiliary electrode is employed which is arranged parallel to the back of the sheet, and a dielectric layer, preferably in the form of an insulating film, is interposed between the electrode and the sheet so that, when a high direct potential is applied to the electrode, the sheet is charged, not by contact with the electrode, but purely by electrostatic induction. This charge is applied so as to neutralize undesirable charge in background areas, which may be left after exposure, or may be created by friction of the magnetic brush itself against the coated surface.

In the present embodiment the auxiliary electrode is in the form of a flat conductive plate **30** which preferably extends beyond the lateral edges of the sheet **12**. The dielectric layer indicated at **31** is preferably in the form of a film of plastic or other insulating material having a high specific resistance and a relatively high dielectric constant. The thickness thereof may be from a fraction of a mil to several mils, although thicknesses on the order of $\frac{1}{32}$ of an inch or even greater have been used without affecting successful operation. The nature of the dielectric material is not critical and polystyrene, cellulose acetate and polyester resins, an example of the latter being marketed under the name of Mylar, have been employed with good results. All of these materials have relatively high dielectric constants.

As to the charging circuit, a high voltage source indicated at **35** is used which may be of any desired type capable of producing voltages on the order of several hundred to several thousand volts, but with low current capability and relatively high internal resistance. Assuming that the electrostatic image consists of negative charges, the voltage applied to the auxiliary electrode is of positive polarity. The opposite terminal is formed by the developer brush and toner thereon, the brush assembly and voltage supply having a common ground connection.

According to one of the aspects of the invention, the thickness and dielectric constant of the film **31** is such that the potential drop through the film greatly exceeds the potential drop through the sheet **12** and a potential is used between the electrodes which is many times greater than that which is conventionally employed, absent the insulating film. For example, in a conventional arrangement the potential between the electrode and brush may be on the order of 200 volts, whereas in the present device a potential in excess of 1000 volts is used, preferably a potential on the order of 4000 volts. Voltages of this order may be easily obtained using modern techniques, even in machines small enough for office desk top use, because of the low current drain; moreover, such voltages are safe since the electrode **30** is substantially completely enclosed by the insulating dielectric film **31**.

In analyzing the device for the purpose of explaining the features and advantages, it is desirable to consider the two members **20**, **30** as the electrodes of a capacitor having a plurality of dielectric layers. Referring to the diagrammatic FIG. 3, the first dielectric layer is the film **31** and the second dielectric layer is the sheet **12**, the film **31** preferably having higher dielectric constant than the material, usually paper, which comprises the body of the electrographic sheet, and hence a dielectric constant many times that of air. Thus, employing a dielectric film having the same order of thickness as the sheet itself, most of the potential drop between the plates of the "capacitor" will occur in the dielectric film. For example, where a voltage source is used having a terminal voltage of 4000 volts, a drop of 3800 volts may occur in the dielectric film with the balance of the drop, on the order of 200 volts, occuring in the electrographic sheet.

It is to be noted in connection with FIG. 3, that the electrographic sheet **12** is kept out of contact with the charging electrode **30** and is charged simply by electrostatic induction. This mode of charging has been found to result in a uniform charge being applied to the sheet **12**, as diagrammatically indicated, quite independently of rippling or puckering of the sheet, producing air pockets such as indicated at **38**, and also independently of gross or localized variations in the resistivity of the sheet which may take place under various ambient conditions. Since a uniform charge is thus applied to the sheet, the neutralizing effect will be uniform over the entire area of the sheet. To insure clean-up of the background areas, the voltage of the supply **35** is simply set at a value sufficient to dispose of the residual negative charge existing in the white or background areas. The voltage adjustment may be made at the factory for the conditions of use and thereafter need not be changed.

It is to be particularly noted that substantially uniform charging occurs in spite of the existence of air pockets such as that shown at **38**. Analysis indicates that the reasons for this is that the air, having a relatively low dielectric constant, produces only a minor potential drop as compared to the potential existing across the dielectric film so that even a relatively large air pocket produces only a minor percentage change in the potential assumed by the sheet in the affected area. For purposes of comparison, reference is made to the diagram of FIG. 4 which illustrates a prior art arrangement in which the electrographic sheet indicated at **12*a*** is in direct contact with the charged electrode indicated at **30*a***. The electrode is capable of applying to the sheet a positive charge in those areas of the sheet where direct contact exists as for example at **12*b*** and **12*c***. However, in the presence of a ripple creating a void or air pocket **38*a*** between the electrode and the sheet, and assuming that ambient conditions are such that the sheet is poorly conductive, there will be an absence of charge, and hence of neutralizing effect, in the affected areas of the sheet giving rise to unwanted variations in clean-up and even to stripes and smears across the background and printed areas.

While the present construction produces uniform neutralization of residual charge even in the presence of air pockets resulting from rippling or puckering of the sheet, it is nevertheless desirable to minimize the air pockets in a web-fed machine by causing the sheet to ride in supporting contact directly on the dielectric film, and the rollers (not shown) which carry the sheet may be readily positioned to draw the sheet rather tightly against the film. However, in the case of a sheet-fed machine the present invention is particularly useful since the sheets are largely self-supporting and cannot be flattened by tensioning between rollers or the like.

It is one of the features of the present invention that sheets having different widths may be accommodated, even though the width is less than the width of the charging electrode and brush assembly. Thus, beyond the edges of the sheet the brush idly contacts the surface of the dielectric film but, because of the insulation provided by the film, no current flows. This is to be contrasted with prior devices in which the portions of the

brush lying outside the boundary of the sheet contact the electrode and thus tend to short circuit the voltage supply, resulting in a substantial drop of voltage so that the effect of the auxiliary electrode is lost. Moreover, it is to be noted that the insulation constantly provided by the dielectric film makes it impossible to load the voltage supply **35** so that a light-duty, inexpensive and compact voltage source may be used with perfect reliability. Also, there is no need to divided the electrode into narrow sections with such sections being supplied through independent dropping resistors in an effort to avoid the above mentioned short circuiting effect as has been proposed. In sum, we have devised a developing arrangement which overcomes all of the disadvantages of prior practices but which is nevertheless of inherently low cost.

While the invention has been described in connection with a mechanized, continuous web-fed machine, it will be apparent to one skilled in the art that our teachings are not limited to the construction shown in FIG. 1, but are equally applicable to other developing arrangements as, for example, diagrammatically shown in FIGS. 5 and 6. The arrangement of FIG. 5 differs from that of FIG. 1 primarily in the construction of the developer brush and in the respect that the sheet being acted upon is separate rather than in the form of a continuous web. The developer brush construction indicated at **40** includes a first magnetic bar **41** and a second magnetic bar **42** arranged on opposite sides of the sheet and magnetized by permanent magnets **43**, **44** interconnecting the ends of the bars. A mixture of toner and magnetic particles forms the "bristle" portion **45** of the brush. In contact with the developer brush is an electrographic sheet **50** which corresponds to the electrographic sheet **12** in the previous embodiment. This sheet is supported on a dielectric film **51** covering the charging electrode **52**, the latter being charged by a high voltage supply **53**. In use, means may be provided for moving the sheet on its support relative to the developer brush or for moving the brush, so that the brush is drawn progressively along the sheet **50** to develop the latent image on the latter, following which the deposited toner is fixed by heat just described in the preceding embodiment.

During the development the electrostatic charge induced in the sheet by the electrode **52** serves, as described, to insure clean-up of the background areas.

An even simpler arrangement for employing the present invention in one of its aspects is illustrated in FIG. 6. Here a manual brush **60** is used in the form of a bar magnet having "bristles" **61** which contact the surface of the electrographic sheet **62**. The latter is supported on a dielectric film **63** which covers the charging electrode **64**, with voltage being applied to the charging electrode by a voltage supply **65**. In operation, a sheet **62** having a latent electrostatic image is placed upon the film **63** following which the developer brush **60** is manually passed over the sheet. Electrostatic charging of the sheet occurs simultaneously with development until all of the area has been developed, following which the image is fixed in the usual way. Because of the insulating effect of the film **63**, care need not be exercised to keep the brush within the bounds of the sheet **62**.

We claim as our invention:

1. In an arrangement for developing an electrographic sheet having a previously applied latent electrostatic image on the front surface thereof, said electrostatic image including charged and discharged areas, the latter having residual charges thereon, the combination comprising a developer brush made up of magnetic particles and toner particles, means for magnetizing the brush so that it extends into brushing engagement with said sheet, means for relatively moving the sheet so that toner particles are deposited thereon in the electrostatically charged areas, an extensive auxiliary electrode arranged parallel to the back of the sheet, dielectric means interposed between the electrode and the back of the sheet, said dielectric means being coextensive with the entire surface of the electrode thereby assuring insulation of the electrode from the toner applying brush, means for applying a direct potential between the developer brush and the electrode, the potential being sufficiently high so that a potential gradient is set up in said sheet by electrostatic induction for removing residual charges from the discharged area of the electrographic sheet.

2. In an arrangement for developing an electrographic sheet having a previously applied latent electrostatic image on the front surface thereof, the combination comprising a developer brush made up of magnetic particles and toner particles, means for magnetizing the brush so that it extends into brushing engagement with said sheet, an extensive auxiliary electrode arranged parallel to the back of the sheet, a dielectric film interposed between the electrode and the back of the sheet, said dielectric film being coextensive with the entire surface of the electrode thereby assuring insulation of the electrode from the toner applying brush, means for relatively moving the sheet so that toner particles are deposited thereon in the electrostatically charged areas and with the sheet in contact with the film, means for applying a direct potential between the developer brush and the electrode with the brush maintained at ground potential so that a potential gradient is set up in said sheet by electrostatic induction and maintained independently of electrical contact between the sheet and the electrode.

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