# United States Patent [19]

**Mutschler et al.**

[11] **3,714,665**

[45] **Jan. 30, 1973**


[54] **ELECTROSTATIC RECORDING WITH IMPROVED ELECTROSTATIC CHARGE RETENTION**


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[73] Assignee: **Xerox Corporation,** Rochester, N.Y.



[22] Filed: **Jan. 28, 1970**

[21] Appl. No.: **6,633**

**Related U.S. Application Data**

[63] Continuation-in-part of Ser. No. 693,893, Dec. 27, 1967, abandoned.

[52] **U.S. Cl.** .....**346/74 ES,** 117/37 LE, 118/DIG. 23

[51] **Int. Cl.**.....**G01d 15/06,** B41f 23/06, B41l 23/20

[58] **Field of Search** .....346/74 ES; 101/DIG. 13; 118/637; 117/37 LE, 17.5



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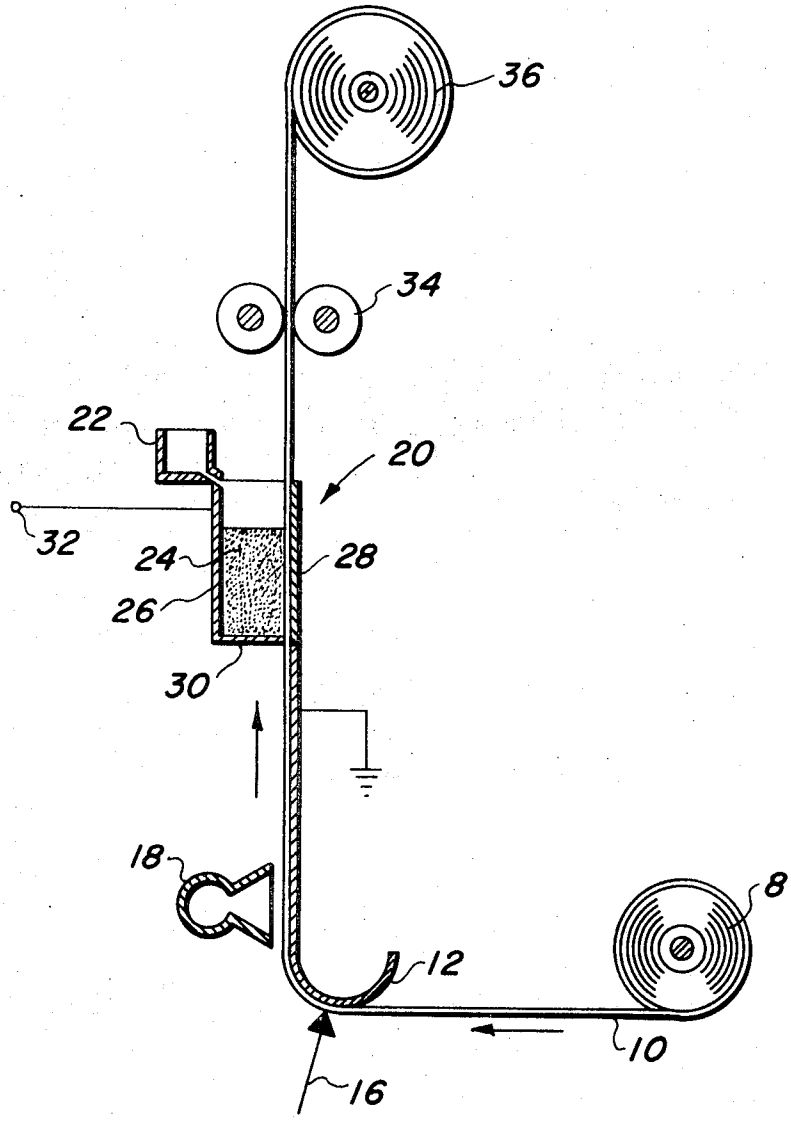
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[57] **ABSTRACT**

Method and apparatus for electrostatic recording on ordinary paper. An electrostatic latent charge pattern to be developed is deposited on dry ordinary paper. A conductive member is positioned in contact with the other surface of the paper from the point of charge deposition to the development area. The electrostatic latent charge pattern is then developed in the development area.


**13 Claims, 6 Drawing Figures**



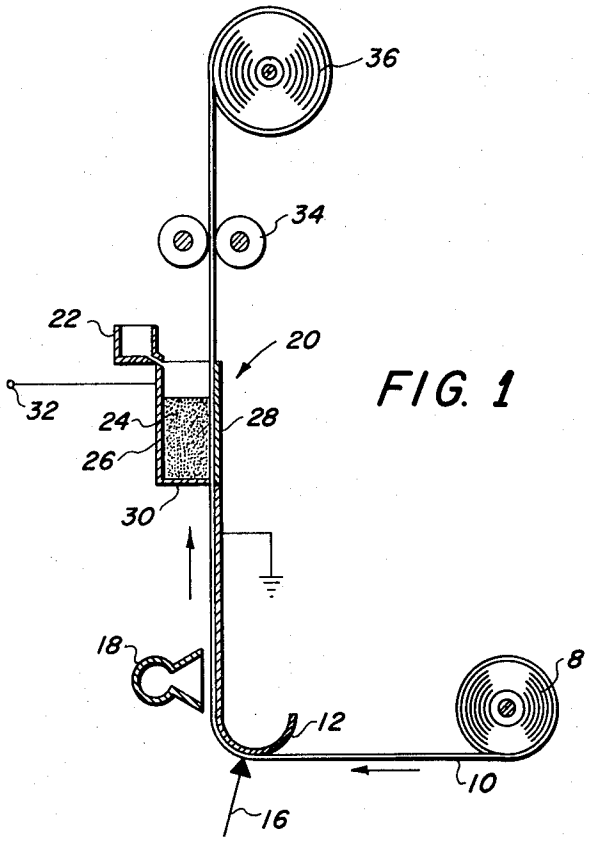



FIG. 1

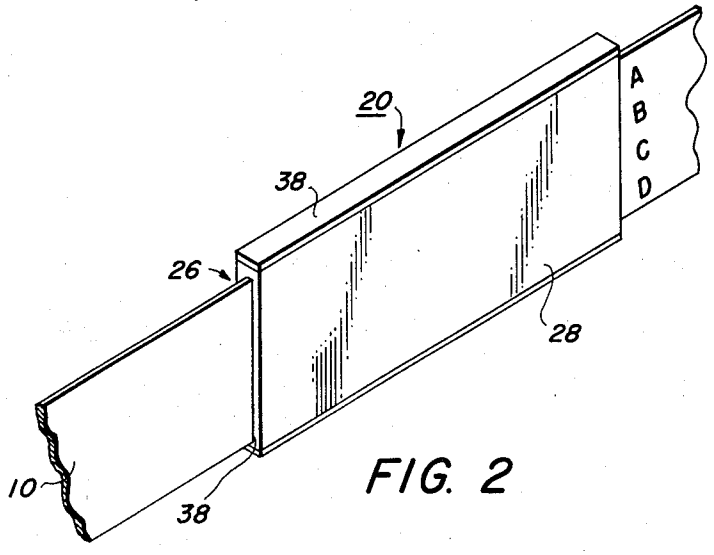



FIG. 2

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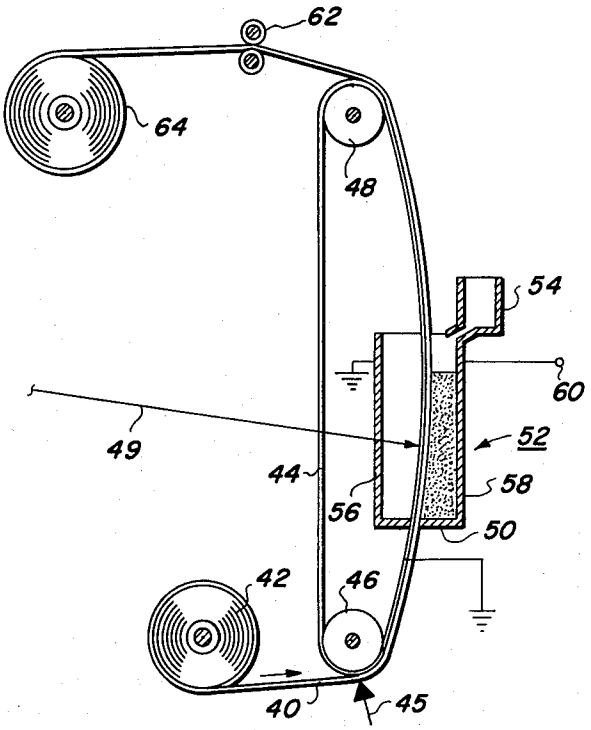



FIG. 3

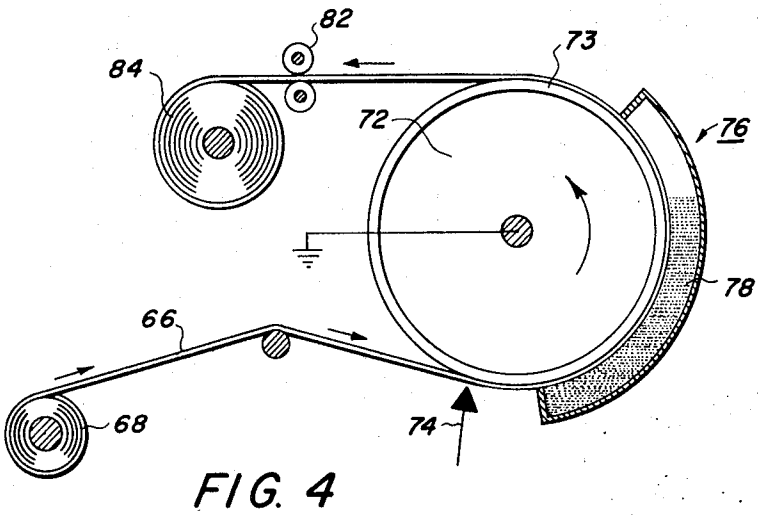



FIG. 4

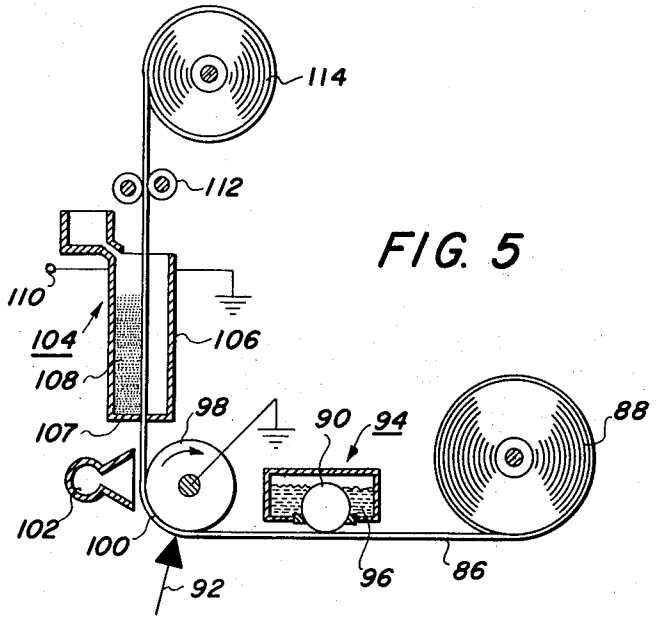

114
112
110
104
108
107
106
98
90
94
88
102
100
92
96
86

FIG. 5

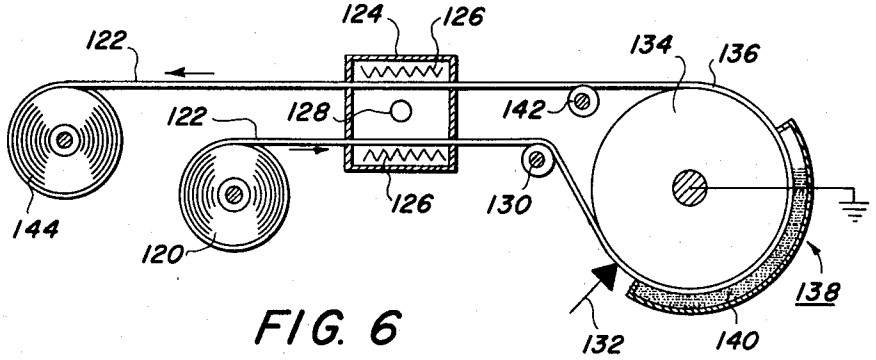

124
126
122
134
136
122
128
142
144
120
126
130
138
132
140

FIG. 6

# ELECTROSTATIC RECORDING WITH IMPROVED ELECTROSTATIC CHARGE RETENTION

## CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. application, Ser. No. 693,893, filed Dec. 27, 1967 now abandoned.

## BACKGROUND OF THE INVENTION

Prior art electrostatic recording systems produce a latent electrostatic image on a dielectric recording surface. In general, the electrostatic image pattern is produced by virtue of an electrical discharge from electrodes directed to an electrode located behind the dielectric recording media. A wide variety of techniques, utilizing contact styli, sheet transfer of electrostatic charge, and transfer from shaped electrodes have all been employed in this area. The electrostatic recording process consists broadly of three steps. The first step comprises establishing or printing electrically charged areas on selective portions of a recording media which are representative of information in the form of letters, lines, dots, etc. The second step consists of developing these charged areas on the recording media by means of a developing powder generally referred to as toner, which makes them visible. The third step, which is optional, consists in fixing or rendering the developed areas substantially permanent.

The prior art in this area contains occasional references to the use of pre-dried paper as the recording medium. In general, the paper is pre-baked to high temperatures on the order of 300° F and then kept in an environment of relative humidity on an order of less than 10 percent by being held in a container containing a desiccant until immediately before its use. However, any charge deposited on such pre-dried paper tends to be dispersed both laterally and through the paper resulting in a loss of charge with attendant loss of resolution and clarity of the image within a few seconds after deposition of the initial charge. A large part of this difficulty apparently arises from the fact that the charge disperses laterally even on extremely dry paper within a few seconds of its deposition. There has therefore never been a particularly practical or effective system which could employ the use of ordinary paper in its uncoated form to receive electrostatic images.

It has thus been a major problem in the prior art that shortly after charging the charge is lost and the image effectively destroyed, in many cases long before the development could take place in the system in which it was desired to use ordinary paper.

## SUMMARY OF THE INVENTION

The present invention provides novel method and apparatus for developing electrostatic images. In particular, the present invention provides a technique for developing electrostatic images formed on ordinary paper, the paper being in contact with a conductive electrode from the charging station into the developing area.

It is an object of the present invention to provide novel method and apparatus for recording electrostatic images on a substrate.

It is a further object of the present invention to provide novel method and apparatus for recording electrostatic images on ordinary paper.



It is an object of the present invention to provide novel method and apparatus for recording electrostatic images on ordinary paper wherein an electrically conductive member is maintained in contact with said paper from the charging station into the development area.

It is still a further object of the present invention to provide novel method and apparatus for recording electrostatic images on ordinary paper wherein an electrically conductive member is maintained in contact with said paper from the charging station into the development area and wherein the paper between the charging station and the development area is enclosed by a chamber containing a desiccant.

## DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention as well as other objects and further features thereof, reference is made to the following description which is to be read in conjunction with the accompanying drawings wherein:

FIG. **1** is a cross-sectional representation of a first embodiment of the present invention;

FIG. **2** is a perspective view of development apparatus which may be utilized in the present invention;

FIG. **3** is a cross-sectional representation of a second embodiment of the present invention;

FIG. **4** is a cross-sectional representation of a third embodiment of the present invention;

FIG. **5** is a cross-sectional representation of a fourth embodiment of the present invention; and

FIG. **6** is a cross-sectional representation of a fifth embodiment of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the present invention illustrating the operative principles of the present invention is shown in FIG. **1**. A roll of pre-dried paper **8** for deposition of electrostatic charge thereon is provided. The pre-dried paper is normally packaged in sealed packages containing a desiccant to keep the moisture content of the paper low. A paper moisture content of less than three percent is preferred. Suitable drive means (not shown) feeds the paper **10** from the paper roll **8** to a backing electrode **12** which is grounded. The paper contacts the surface of the backing electrode **12** as it move thereacross. The backing electrode **12** extends into the development apparatus **20**. A charging station **16** is provided to deposit electrostatic charge on the paper in the area where paper **10** initially contacts backing electrode **12**. Any suitable means of depositing electrostatic charge may be employed at charging station **16**; however, a contact stylus array is preferred. Typical contact stylus arrays suitable for use in the present invention are 5 × 7 pin matrices operated at approximately 750 volts or 13 pin stylus matrices operated at approximately 600 volts. At slow speeds somewhat lower potentials may be employed. In general for typical operating speeds and pressure voltages ranging from 600 to 1000 volts may be utilized.

In the alternative, an array of ion guns may be utilized at the charging station in lieu of a contact stylus array. Any other suitable electrode arrangment as disclosed in the prior art may also be utilized at charging station **16**.

For slow operating speeds (paper flow rate of approximately 0.1 to approximately 1 inches per second) a blower **18** may be provided between the charging station **16** and the development apparatus **20** to direct a desiccant, such as dry air or gas, across the surface of the paper **10** after it has been charged at charging station **16**. The total distance between the charging station and the end of the developer station may be as little as 10 inches in a typical arrangment so that utilizing a paper flow rate of 60 inches per second in the fast speed mode, less than one sixth of a second is involved in moving the paper from the charging station to the developer. For slow operating speeds, the paper may move at rates to that as much as a minute may pass prior to development. The development apparatus **20** comprises a dispenser **22** for dispensing developer particles **24**, such as toner, into the area between a pair of biased conductive electrodes **26** and **28** which are separated by insulative material. Conductive electrode **28**, as shown in FIG. **1**, is in electrical contact with backing electrode **12**. It should be noted that backing electrode **12** may extend into the development apparatus **20** and function as a biased conductive electrode, eliminating the necessity of a separate electrode **28**. The essential requirement of the present invention is that a conductive backing be maintained in contact with the paper web from the point at which it is charged into the development area. The backing electrode **12** may be grounded, as shown in FIG. **1**, or connected to a biasing voltage source. The application of a bias between electrodes **26** and **28** is somewhat optional. The bias electrodes have been found to be most helpful for slow operating speeds. A seal **30** is provided to prevent the developer particles from escaping through the bottom of the development apparatus housing and provides a means of holding the paper web **10** in intimate contact with the conductive electrode **28**. The bias applied across the electrodes may vary normally in the range from 0 to 500 volts with a potential on the order of 200 volts being preferred. Other potentials may be employed, however, since the potential is proportional to the type of developer being utilized, the electrode spacing, and the geometry of the development apparatus **20**.

The development apparatus **20** may comprise an "I shell" bulk cascade developer in which a carrier of Pyron iron powder or glass carrier beads is employed with toner. Toners which may also be utilized in the present invention are available from Xerox Corporation of Rochester, New York under the tradenames 914 Toner, Type 10 Toner, etc. and are made of insulating materials such as rosin, modified phenol formaldehyde, polystyrene and styrene methacrylate copolymer containing coloring material such as carbon black. The toners of this type are more fully described in U.S. Pats. No. 2,788,288, 2,891,011 and U.S. Pat. No. Reissued 25,136 among others. After leaving the development apparatus **20** wherein the electrostatic image formed on paper **10** is developed, the paper enters a roll fuser **34** and is wound about a takeup roll **36** for storage. In the alternative, the paper **10** may be cut into strips of suitable length for the documents being produced. The paper may be moved through the charging station and developer at various rates ranging from 0.2 inches per second to 300 inches per second with rates on the order of 5 and 60 inches per second being preferred and 100 inches per second giving very good results. It should be noted that the paper **10** is both charged and developed while maintained in contact with a conductive electrode, whether the combination of backing electrode **12** and bias electrode **28** or backing electrode **12** alone when extended into the development apparatus **20**. The extension of a conductive electrode into the development apparatus **20** is believed to be a significant reason for the success of this system with ordinary paper. It has been found that if the paper is removed from the backing electrode before development, the charge on the top of the paper will disperse laterally as a result of the removal of the negative or opposite binding charges residing in the metal backing electrode and some of the charge will be neutralized by air breakdown at the separation. Thus, by extending a conductive electrode into the development apparatus this problem is avoided and the image may be developed so that the charges are neutralized by the toner particles and separation of the paper from the conductive electrode can be achieved without image destruction after development. It has been noted that a 600 volt input on the stylus will give, for example, a 280 volt initial residual charge which will decay to something on the order of 130 volts within 10 seconds. The decay takes place partly because of charges moving through the web and partially because of surface diffusion and lateral loss of charges on the surface of the paper. Even when the potential on the paper does not decay further the image continues to blur out rapidly. At slow operating speeds this problem has been corrected by the application of a desiccant, such as dry air or other suitable gas, by blower **18** across the surface of the charged paper to preserve image sharpness and intensity for a period as long as a minute. By use of this technique of blowing a desiccant across the paper it is possible to maintain a charge pattern of suitable quality for a far longer period than has been achievable at any time in the prior art although it is not necessary to do so unless it is desired to retain the charge prior to development for a period in excess of 10 seconds.

For while it was conventional in the prior art to predry the paper and to provide a desiccant around the paper before charging, the concept of blowing the desiccant across the paper in close proximity to the recording electrode and the actual deposition of charge is believed to be at least in part responsible for the drastic improvement in charge storage times obtainable, at slow operating speeds. By blowing the desiccant is meant the enclosing or surrounding of the paper with desiccant under a dynamic pressure differential, that is, at some overpressure so as to confine the desiccant in the region of the paper, thereby denying moist air to the paper. It is believed that the blowing of a desiccant across the charge inhibits the spread of the charge on the surface of the dried paper which was a major factor in the unsatisfactory results achieved in the prior art and has resulted in extending the time for which charge may be stored from times on the order of 10 seconds to times on the order of 1 minute. In order to provide for intimate contact between the printing electrode stylus and the recording surface, pressures in the range from about 2,000 pounds per square inch to about 3,500

pounds per square inch may be considered typical for most operations although higher and lower pressures may be utilized. It should be noted that a flexible conductive backing may be placed over the grounded backing electrode **12** for mechanical reasons i.e. for protecting the stylus from conforming to imperfections in the metal backing electrode **12**. The paper roll **8**, as set forth hereinabove, is maintained in a desiccated environment and should be located close to the charging station **16** to prevent the pickup of additional moisture by the paper **10** prior to charging. Ordinary paper in a dried condition functions as a non-conductive dielectric charge retaining media and when pre-dried for 10 minutes at approximately 250° F, the surface resistivity is increased from on the order of $10^8$ ohms per square centimeter to $10^4$ to $10^{16}$ ohms per square centimeter.

As has been noted hereinabove, the preferred embodiment utilizes metal contact styli in intimate contact with the surface of the paper. The contact stylus may be a single point electrode, an array of such electrodes and/or alphanumeric shaped character electrodes. Alternative methods such as the ion gun disclosed in U.S. application, Ser. No. 602,787, filed Dec. 19, 1966 now U.S. Pat. No. 3,495,269, assigned to the same assignee or one of the many TESI electrode means for transfer of electrostatic charge may be utilized at the charging station. It should be noted that by providing contact with a conductive electrode through the development zone a negative bonding charge, assuming an initial position charge is deposited on the surface of the paper, is provided in the electrode and neutralization of the charges by air breakdown and dispersion at separation are minimized. The application of a desiccant after the charging at slower speeds prevents the lateral dispersion of charge and results in its effective retention on the paper for a time sufficient to make the development on ordinary paper practical.

The structure of the backing electrode **12** and the development apparatus **20** can be varied in numerous ways a few of which will be illustrated by the alternative embodiments presented herein. These embodiments are merely exemplary and many other variations are possible within the scope and spirit of the present invention.

In the preferred embodiment, any suitable developer or toner may be utilized including but not necessarily limited to the toners referred to above.

The configuration of the development apparatus **20** is shown in FIG. **2**. Paper **10** passes between plate electrodes **26** and **28** (or the portion of backing electrode **12** which extends into the development apparatus **20**) which are separated by strips of insulating material **38**. The latent electrostatic image is developed as it passes through the toner particles **24**. The paper within the developing apparatus **20** is in contact with the grounded electrode **28**. The paper **10** is held in contact with the grounded electrode **28** by the action of seal **30** which may be made from any suitable resilient material, such as foam rubber. It should be noted that the backing electrode **12** in FIG. **1** may be given in a curvature which would place a tension **11** the web material **10** resulting in more intimate contact between the backing electrode **12** and the paper **10**. The grounded backing electrode **12** need not be a single plate of material as shown in FIG. **1** but be be a solid mass of material. Indeed, the only limitation on size is that it be large enough to constitute an adequate supply of electrons and that it acts as a true ground plane.

Going somewhat beyond this concept we have the embodiment of FIG. **3** in which, as described heretofore, paper web **40** is pulled off a supply roll **42** and brought into contact with a conductive belt **44** which is wrapped around a pair of rollers **46** and **48** and provided with a curved radius by means of restraint and constraining elements so as to provide a close and intimate contact with paper web **40**. The radius of the belt is indicated by **49**.

The conductive belt **44** passes along with the paper web **40** past a seal **50** made of a suitable resilient material into development apparatus **52** which has a toner dispenser **54** mounted on one side and is composed of a pair of biased plate electrodes **56**, **58**, separated by suitable insulative material. A suitable bias as described heretofore is provided by bias means applied to terminal **60**. The web of paper **40** emerges from development apparatus **52** in contact with belt **44**. It then passes into the roller fuser **62** and is then either cut into suitable sheets or rolled up on take-up roller **64**. The curved grounded backing electrode **44** in the form of a belt provides for intimate contact as well as providing a means of moving the paper web **40** through the development apparatus to provide additional agitation of the toner. Furthermore, belt **44** may be made of a flexible conductive material or may be a flexible metal belt on the outside surface of which is coated a conductive backing layer as described in conjunction with the previous embodiment.

Another form of the present invention is shown in the alternative embodiment of FIG. **4** in which a paper web **66** is removed from a container roll **68**, passed over an idler roller **70** and around a free-rotating grounded drum **72**. A flexible conductive layer **73** may overlie the grounded drum **72** for mechanical reasons as set forth hereinabove. A charging station **74** is located past the point of tangency between the web **66** and drum **72** and is followed by development apparatus **76** containing toner particles **78**. At slow speeds, a chamber containing a desiccant may surround paper web **66** in the interval between charging station **74** and development apparatus **76** to preserve the charge as set forth previously. The web **66** is thus in contact with the free-rotating drum **72** throughout its path from charging station **74** through the development apparatus **76**. Development apparatus **76** may be any suitable development system such as fur brush, magnetic brush, or cascade development. After paper web **66** passes through the development apparatus **76** it passes through a roll fuser **82** and is either appropriately cut into segments or wound about a take-up roller **84**.

Still another alternative embodiment employing the general principles described herein is shown in FIG. **5**. In this embodiment, a backing electrode separate from the paper web is not necessary. Rather, in lieu of the use of a backing electrode in intimate contact during charging and developing, the paper web **86** after being removed from a storage roll **88** is passed over a liquid applicator brush **90** which applies conductive liquid to the backside of the web **86** just before it reaches charging station **92**. The liquid applicator dips into a container of conductive liquid **94** as it rotates and thus

brings the liquid into contact with web **86**. It is important that the rate or rotation of the liquid applicator brush **90** be adjusted to apply only a sufficient amount of liquid to the web **86** so that the liquid will not penetrate to the top surface of the paper before the development is complete.

It is obvious that this adjustment depends upon the rate of speed of movement of the paper through the charging and development station. By applying the conductive liquid **96** to web **86**, before the charging at charging station **92**, the charges in the ground plane of roller **98** are able to migrate effectively to the paper web **86**. At slow paper speeds, after charging a desiccant is blown across the charged paper web from a blower **102** and is continued until the web **86** enters the development apparatus **104** through seal **107**.

The development apparatus **104** may have a bias placed across its plate electrode members **106** and **108** by applying a bias to terminal **110**. Upon completion of the developing process the paper web **86** passes through a roll fuser **112** and is then either cut into appropriate lengths or wound up on take-up reel **114**. It should be noted that depending upon the configuration of the rollers with respect to the charging station and development apparatus it may be necessary to provide a twist through web **86** to insure that the proper side of the web **86**, namely, the side opposite that which receives the charge at the charging station **92** receives the liquid **96** from applicator brush **90**. It should be noted further that in this configuration after charge is applied it is possible to leave or to separate the conductive liquid layer, or backing electrode, and the paper web if the back of the paper web remains wet with the liquid applied by applicator brush **90**. This is because the liquid **96** applied in effect transforms the paper web **86** into a temporary electrographic paper with an electrode capable of supplying electrons and bonding the charge to the paper until it is adequately developed. In the preferred embodiment any suitable material such as water which exhibits the property of being a conductive material at potentials on the order applied at the charging station may be employed. Salt solutions and similar materials may be considered to be typical materials in addition to water which would be suitable for use as the liquid **96**.

Another alternative embodiment is shown in FIG. **6**. This embodiment features on-line drying and fusing. Paper web **122** initially stored on roll **120** is passed into the on-line drying and fusing unit **124** in which a continuous overpressure of air or other suitable desiccant is maintained. Heater elements **126** are provided to assist in the drying process. As the air picks up moisture from the web **122** it is exhausted through orifice **128**. A gas flow of 2–3 cubic feet per minute through dryer **124** has been found sufficient for a paper speed of 5 inches per second. Other flow rates may be utilized for different paper speeds. Having been conditioned by the pre-drying unit, web **122** passes over roller **130** into tangential contact with conductive backing roller **134**. The stylus **132** may consist of a single electrode, a pin electrode array or an array of alphanumeric shaped character electrodes. The stylus is pulsed appropriately to deposit the desired charge pattern on web **122**. While still in contact with the conductive backing roller **134**, web **122** is passed into developer unit **138** where it comes in contact with developer **140**. The developer unit **138** may be of any suitable type and configuration in addition to that shown in FIG. **6**. Following development, the web **122** passes over guide roller **142** and into the on-line drying-fusing unit **124** again to fuse the developed image. The heat from heater elements **126** is sufficient to fuse the developed image at the paper speed for a given configuration. Variations in configuration may be utilized to increase the path length of web **122** in the fusing unit **124** if necessary for higher paper speeds. Additional fusing techniques may be employed within the on-line drying-fusing unit **124** to produce fusing as desired. Following fusing, the image on web **122** may be stored on take-up reel **144** or may be cut into sheets of appropriate lengths, as desired. The use of the same heat to dry (or pre-dry) the web and to fuse the developed image in an on-line configuration provides a design which is economical simple and reliable.

Thus, in operation, the charge applied on a paper web by contact stylus means is maintained on the web until it is completely developed by maintaining the paper web in intimate contact with a source of electrons (that is, with a conductive backing electrode). At lower paper speeds, the charge is additionally maintained for long periods by blowing a desiccant over the charge in the interval between the charging station and the development station. Development may be facilitated by the biased electrodes which result in a more effective deposition on developer powder on the charged areas. It should be noted that the developer systems described herein are not necessarily limited to development of charge patterns on ordinary paper but may be utilized to develop charge patterns on electrographic paper or on any other treated paper.

While the invention has been described with reference to its preferred embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the true spirit and scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teaching of the invention without departing from its essential teachings.

What is claimed is:

**1**. Apparatus for recording electrostatic charge images on a substrate of ordinary paper comprising:

a. means for developing an electrostatic charge image formed on a substrate of ordinary paper,

b. means for depositing an electrostatic charge image on said ordinary paper substrate, said depositing means being positioned to receive said ordinary paper substrate prior to said developing means, and

c. an electrically conductive electrode in contact with said ordinary paper substrate on the side opposite said depositing means and extending to said developing means.

**2**. The apparatus as defined in claim **1** wherein said electrically conductive electrode extends into said developing means.

**3**. The apparatus as defined in claim **1** further including means to enclose said paper between said depositing means and said developing means in a chamber containing a desiccant whereby the dissipation of said

deposited electrostatic charges prior to being developed is minimized.

4. The apparatus as defined in claim 1 further including means to apply a conductive liquid to the backside of said paper to wet said paper part way through prior to depositing said electrostatic charge on said paper, said liquid applicator means being positioned with respect to said depositing means and developing means so that said liquid has time to migrate only part way through said paper prior to image development.

5. The apparatus as defined in claim 1 wherein said electrically conductive electrode comprises a rotatable grounded metallic drum.

6. The apparatus as defined in claim 1 wherein said developing means comprises a pair of opposed parallel plate electrodes separated by insulating members, said plate electrodes and said insulating means forming a chamber-like structure containing development powder and biasing means for applying an electrical field across said paper and powder as said image carrying paper passes through said chamber-like structure.

7. The apparatus of claim 1 wherein said electrically conductive electrode comprises a flexible conductive belt.

8. The apparatus as defined in claim 1 wherein said depositing means comprises a contact stylus.

9. The apparatus as defined in claim 8, said contact stylus produces a pressure on said paper in the range from about 2,000 pounds per square inch to about 3,500 pounds per square inch.

10. The apparatus as defined in claim 1 further including a means for drying said paper positioned along the path of paper flow prior to said depositing means.

11. The apparatus of claim 10 wherein said drying means further includes means to fuse the developed image following the passage of said paper through said developing means.

12. A method of recording electrostatic charge images on a substrate of ordinary paper comprising the steps of:

a. depositing electrostatic charge images on said ordinary paper substrate, and

b. providing an electrically conductive electrode in contact with said ordinary paper substrate from the time said electrostatic charge images are deposited thereon until said images are developed.

13. The method of claim 12 further including the step of directing a flow of desiccant over said deposited electrostatic charge images from the time of deposition until said images are developed.

* * * * *