

Nov. 5, 1968

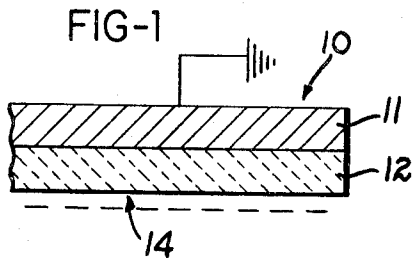
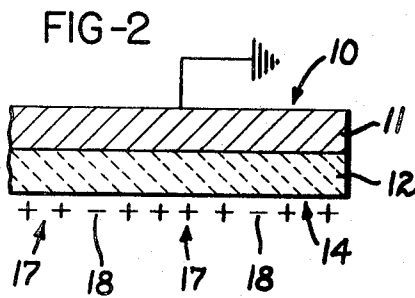
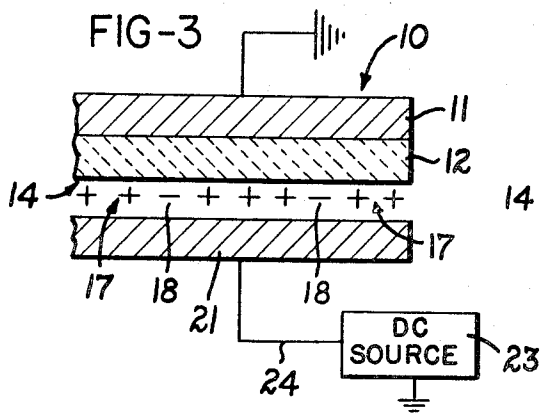
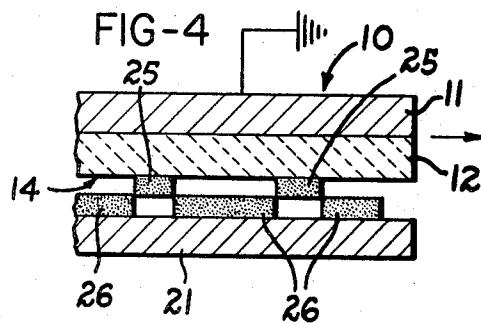
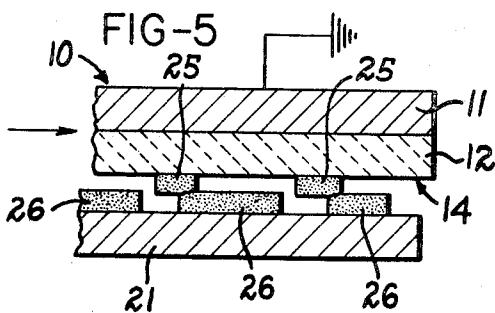
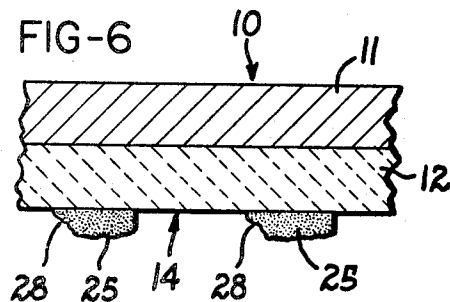
D. L. FAUSER

3,409,358

ELECTROPHOTOGRAPHIC APPARATUS AND METHOD

Original Filed March 17, 1961

2 Sheets-Sheet 1



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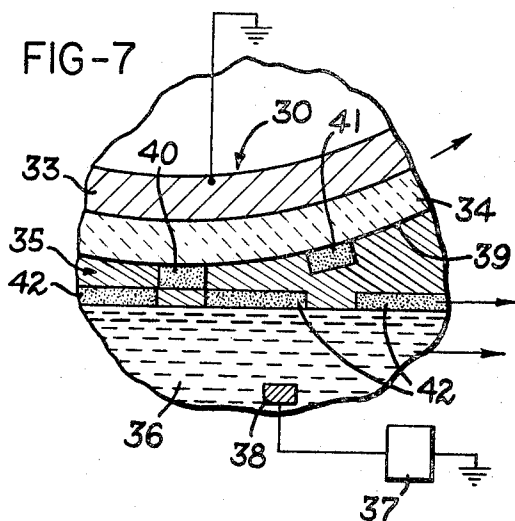
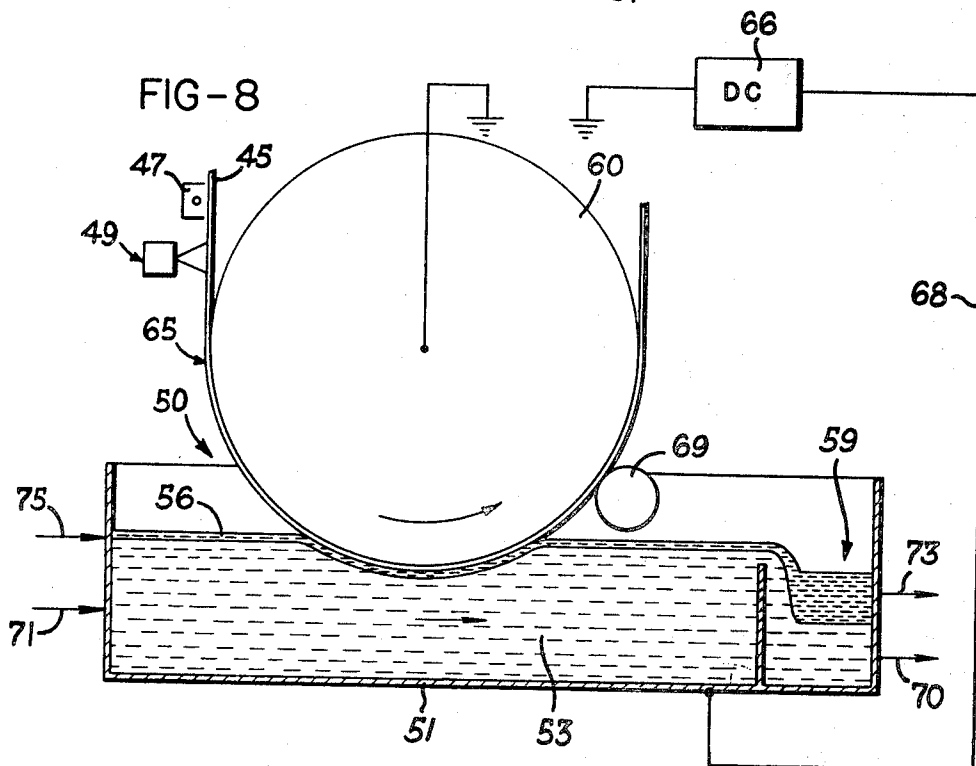
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ELECTROPHOTOGRAPHIC APPARATUS AND METHOD

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3,409,358

ELECTROPHOTOGRAPHIC APPARATUS AND METHOD

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Continuation of abandoned application Ser. No. 96,436,
Mar. 17, 1961. This application Mar. 9, 1964, Ser. No.
350,507

8 Claims. (Cl. 355—10)

This application is a continuation of application Ser.
No. 96,436, filed Mar. 17, 1961, and now abandoned.

This invention relates to a novel electrophotographic
apparatus and method and more particularly to an appa-
ratus and method for providing developed images of im-
proved clarity, contrast and definition.

In electrostatic photography, a latent image is formed
on a photoconductive member which includes an image
bearing surface supported by a suitable backing member.
In the case of rigid photoconductive members in the form
of plates or drums, a layer of selenium is deposited on a
conductive metallic plate such as aluminum, copper or
the like. The flexible image bearing members include
supporting members such as flexible plastic, paper or re-
latively thin metallic foils upon which there has been formed
a photoconductive surface including zinc oxide adhered to
the surface of the supporting member by a film forming
resin.

An electrostatic latent image, or an image in charge
configuration may be formed by uniformly charging the
surface of the photoconductor and exposing the charged
photoconductor to an original to be reproduced or a trans-
parency, as is well known in the art. Thereafter, the latent
image is developed by depositing thereon marking ele-
ments which are attracted to the surface of the photo-
conductor in accordance with the charge image areas
thereon, as is well known in the art.

Several types of developer systems may be employed
and include powder carrier development, charged droplet
development and liquid development. In the case of liquid
development, the developer includes an electrically insu-
lating liquid having dispersed therein marking elements
capable of moving through the liquid under the influence
of an electrical field to deposit on the image bearing
surface in conformity to the charge pattern thereon. The
marking elements of the developer may be such as to
render the image visible, although it is understood that
such developed image may not be visible to the eye but
nevertheless may be termed "developed" in that marking
elements are deposited on the surface in accordance with
the charge pattern thereon.

Liquid developers offer many advantages over the drop-
let or powder carrier developers in that with liquid sys-
tems, better definition and contrast may be achieved, and
it is possible to develop in shorter time than may be pos-
sible with either powder carrier, powder cloud or charge
droplet systems. In the use of liquid developers and pow-
der cloud developers the presence of "halo" or what has
been termed "edge effect" may result from the fact that
the marking elements are most strongly or intensely pre-
cipitated, deposited upon, or attracted to charged areas
to form a dark ring around a light area or a light ring
around a dark area. It is believed that the cause of such
halo or edge effect is the presence of a field existing be-
tween adjacent charged and uncharged areas. One ap-
proach to eliminating the presence of halo or edge effect
is the use of a counter-electrode which substantially elim-
inates the field which is believed to exist between adjacent
charged and uncharged areas.

In employing a counter-electrode in development of a
latent image, it is desirable to position the counter-elec-
trode in closely spaced relation to the image bearing sur-

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face, and preferably in such fashion that the counter-elec-
trode is spaced a substantially uniform small distance from
the image bearing surface. If a liquid developer is em-
ployed, it is possible to space the counter-electrode closer
to the image bearing surface than is the case with powder
carrier or other type developers, due to the fact that the
liquid is capable of uniformly and evenly occupying the
volume between the counter-electrode and the image bear-
ing surface. One convenient method of performing this
operation is to dispose a counter-electrode in the liquid
developer, and immerse or bring the image bearing sur-
face into the body of liquid such that it is spaced a uni-
form small distance from the counter-electrode. In this
manner, the effect on the field is uniform on those areas
of the image bearing surface which are in opposed spaced
relation to the counter-electrode to effect substantial elim-
ination of deposit in the non-image areas and to modify
the field advantageously in the image areas for controlling
deposition of the marking elements without materially re-
ducing the rate of deposition on the image areas.

During the development procedure, marking elements
in the liquid developer migrate to the surface of the image
bearing member in conformity to the charge pattern there-
on, and a second image may be formed on the counter-
electrode, under preferred conditions, which is the comple-
mentary image of that formed on the image bearing sur-
face. Both of these images, in physical appearance, take
the form of raised deposits of marking elements in accord-
ance with the charge configuration existing on the surface
of the image bearing member and the surface of the
counter-electrode, as will be described fully hereinbelow.

In instances wherein the image bearing member is
moved through the liquid developer, a situation arises
where turbulence or viscous drag is created and wherein
possibly the friction of the electrically insulating liquids or
elements deposited on the counter-electrode may cause dis-
tortion of the image deposited on the image bearing sur-
face. Since the marking elements on the image bearing
surface are not fixed permanently thereto, mechanical
forces caused by turbulence and/or viscous drag may
easily dislodge the marking elements and result in smear-
ing or discontinuities in the developed image. The effects
above mentioned are rather pronounced, for example in
cases where an image of high density is being moved
through the developer at the rate of 5 to 15 inches per
second, or higher.

The image formed on the counter-electrode, which
may be termed a complementary image of that formed
on the image bearing surface, is maintained on the sur-
face of the counter-electrode in a transient state. This
transient state or condition results from the electrostatic
attraction of some of the marking elements to the sur-
face of the counter-electrode. In a case where the counter-
electrode is stationary and spaced a relatively small sub-
stantially uniform distance from the surface of the image
bearing member, considerable deposition may accumulate
on the counter-electrode during continuous operation of
the electrophotographic apparatus. In such a case, the de-
posit may become heavy enough to interfere with the
image developed on the surface of the image bearing
member.

One aspect of this invention, as will be more fully dis-
cussed hereinbelow, relates to elimination of substantial
build up by providing a renewable counter-electrode sur-
face. Incident to formation of a renewable counter-elec-
trode surface is the advantage of being able to recon-
stitute or reformat the developer by redispersing the mark-
ing elements forming the counter-electrode image and re-
circulating the developer for use in a subsequent develop-
ing operation.

As will be understood, it is desirable to position the

counter-electrode a substantially uniform small distance from the surface of the image bearing member so as to provide field conditions cooperating with the field generated by the electrostatic image thereby enabling development of a print of improved contrast, clarity and definition. In employing a counter-electrode with image bearing members in the form of photoconductive paper supplied from a roll of paper, a situation may arise as the spliced portion of the web is passed between the counter-electrode and the positioning unit in which the splice will be torn due to the presence of an extra thickness of the paper, or some mechanical damage may result to the counter-electrode. The use of a deformable counter-electrode, on the other hand, obviates the above difficulties since it is capable of giving way to pressures created by a splice or other mechanical forces present, and thus substantially eliminates any mechanical problems associated with web treatment.

Accordingly, it is a principal object of this invention to provide a novel apparatus and method for producing copies by electrostatic photography wherein the reproduction is substantially free of halo or edge effects.

This primary object has been successfully accomplished in accordance with this invention by the provision of a liquid counter-electrode which is capable of being spaced a relatively small uniform distance from the surface of the image bearing member such that the effect of the counter-electrode on the field is uniform over that area of the image bearing surface which is positioned in opposed spaced relation thereto. The interaction of liquid upon deposited elements on the image bearing surface, or the interaction of marking elements on the counter-electrode with those on the image bearing surface, or viscous drag is substantially eliminated by preferably moving the counter-electrode and the developer at a rate of speed substantially equal to the linear rate of movement of the image bearing member during development.

Another object of this invention is the provision of a novel apparatus and method of developing electrostatic latent images wherein the latent image is treated with a liquid developer, and deposition of the marking elements in the developer is controlled by the presence of a counter-electrode which is spaced a uniform small distance from that surface of the image bearing member which is in contact with the liquid developer, and wherein the counter-electrode coats with the backing on the image bearing member to form an electrical field of the proper intensity.

It is another object of this invention to provide a novel counter-electrode system for use in developing electrostatic latent images by treatment with a liquid developer wherein the counter-electrode is deformable and capable of being spaced from a curved image bearing surface a relatively small uniform distance such that the effect of the counter-electrode on the field is relatively uniform with respect to the image bearing surface contacting the developer.

Still another object of this invention is the provision of a counter-electrode system including a fluid counter-electrode capable of supporting a liquid developer and wherein the counter-electrode is immiscible with the developer.

A further object of this invention is the provision of a counter-electrode system for use with a liquid developer in electrostatic photography wherein the counter-electrode is capable of being moved at approximately the same linear rate of speed as the image bearing surface so as to effect substantial elimination of the interaction or viscous drag between the image deposited on the image bearing surface and the liquid and/or marking elements in the developer.

A still further object of this invention is the provision of a counter-electrode system for use with a liquid developer in electrostatic photography wherein the counter-electrode is capable of being moved at approximately the

same linear rate as the image bearing surface, and wherein during movement of both the counter-electrode and the image bearing surface, the counter-electrode is maintained in substantially uniformly closely spaced relationship to the image bearing surface.

It is still a further object of this invention to provide a counter-electrode system for electrostatic photography wherein a counter-electrode closely spaced from an image bearing member is capable of being deformed by pronounced physical irregularities in the surface of the image bearing member caused by splices and the like in a paper web for instance, so as to prevent damage to the equipment through a mechanical binding action or tearing of the web at the splice.

It is still a further object of this invention to provide a counter-electrode system of the type above described having a renewable counter-electrode surface so as to effect substantial elimination of heavy deposits of the marking elements in the development area, and wherein redispersion of the marking elements deposited on the surface of the counter-electrode is possible.

Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

In the drawings—

FIGS. 1 and 2 represent diagrammatic views illustrating a method of forming a latent image;

FIGS. 3 and 4 are diagrammatic views explaining the operation of a counter-electrode employed with a liquid developer;

FIGS. 5 and 6 are diagrammatic views showing the effects of the viscous drag or friction created by either the liquid or marking elements deposited on the counter-electrode;

FIG. 7 illustrates the principles underlying one aspect of this invention; and

FIG. 8 represents an electrostatic photography apparatus constructed in accordance with this invention.

The principles underlying the present invention may be understood with reference to the drawings which illustrate preferred embodiments of this invention, and wherein FIG. 1 shows an image bearing member 10 including a suitable backing member 11 having a layer of photoconductive material 12 disposed on one surface thereof. In the case of what has been termed a "plate" or "drum," the suitable backing may be a self-supporting aluminum, copper or any other metallic conductor, and the photoconductive material may be selenium which has been deposited from a vapor, or any of the other well known photoconductive materials.

In the event that flexible image bearing members are employed, the backing member 11 may be of paper, thin metallic foil, or plastic while the photoconductor 12 preferably includes zinc oxide held on the surface of the backing member by a film forming binder, as disclosed in my copending application Ser. No. 640,353, filed Feb. 15, 1957, and assigned to the same assignee.

The normally insulating surface or the photoconductive surface of the image bearing member 10, which may be conveniently referred to as the image bearing surface, is such that it is normally electrically insulating and capable of holding a charge for appreciable lengths of time in the absence of light. The decay rate, or the rate of charge dissipation in the dark is preferably such that the photoconductor is capable of holding a charge for a period of time sufficient to allow subsequent operations, such as development, without substantial loss or modification of any charge condition existing on the image bearing surface. With image bearing members such as zinc oxide on paper, and the like, as above described, control of the charge decay rate in image areas is significant only to the extent that the photoconductive material exhibit a minimum decay which maintains the electrostatic image at least long enough to allow development thereof. In the case of photoconductive paper and

the like, the developed image remains permanently on the image bearing member and is not transferred as is the case with plates or drums above mentioned.

Additionally with plates or drums the light fatigue of the photoconductor may require close control since such devices may be employed in a continuous process including the cycles of forming an electrostatic latent image, developing the image and transferring the developed image to copy paper, followed by a second cycle including the same operations to form a second print of a different image. As can be understood, the light fatigue pattern formed in one cycle may interfere with the image formed in a subsequent cycle.

With either the plate, drum or photoconductive paper, the image bearing surface is charged to a uniform potential by a charging apparatus of conventional and well known design. For purposes of explanation, the image bearing member 10 shown in FIG. 1 may be charged to a uniform negative potential of about 150 volts by employing a corona unit having about 7,000 volts applied thereto. Thereafter, according to the well known methods in electrostatic photography, the uniformly charged surface 14 is exposed to an image representative of the copy to be reproduced. Those areas of the photoconductor 12 struck by light become conductive allowing portions of the uniform charge to dissipate. Such dissipation of the uniform charge may be accomplished as a result of mutual cancellation of the charge on the surface of the photoconductor and that induced at the interface of the backing member by exposure to a light pattern, or the charge in the light struck portions may migrate through the photoconductor to the backing member 11 and to ground. There now exist on the surface 14 of the photoconductor 12 an electrostatic latent image including areas 17 and areas 18 which are differentially charged to define charge image areas and non-image areas as shown in FIG. 2. In the light struck portion 17, the potential is less negative and therefore positive relative to the potential on the adjacent areas 18.

It is to be understood that the relative potential of image and non-image areas on the surface 14 depends upon whether the original was a positive or negative transparent reflect copy. Moreover, it is possible to form an electrostatic latent image by charging the surface of the photoconductor to a uniform positive potential as opposed to uniform negative potential, as is well known in the art. With a plate or drum, the charge image may be a reversal of the final image since it is usually necessary to transfer either the charge image or the developed image to a copy paper. In the case of photoconductive paper and the like, the charge image on surface 14 is what may be termed a right reading image since the electrostatic latent image which is developed on the photoconductive paper remains on the surface and is not thereafter transferred.

By way of illustration and in no way to be construed as a limitation, the image areas 18 are at about 150 to 160 volts negative with respect to ground, while the non-image areas 17 are usually at about 0 to a negative 40 volts with respect to ground. As is well known, the polarity of the charge may be reversed so that the image areas 18 are about 150 to 160 volts positive and the non-image areas are about 0 to 40 volts positive with respect to ground. Additionally, the image areas may be at a lower potential than the non-image areas depending upon whether a positive or negative transparency is employed to form the electrostatic latent image, as is well known in the art.

While the explanation of forming an electrostatic latent image has been in terms of uniformly charging and thereafter exposing, it is to be understood that these steps may be carried on simultaneously to form an electrostatic latent image by procedures and apparatus individually well known in the art. Additionally, the term image bearing member is intended to include an insulator to

which a charge image has been transferred or applied, as is well known in the art.

The electrostatic latent image, formed by any of the methods above described, may be developed by use of a liquid developer including marking elements disposed in a suitable insulating liquid such as is described in my co-pending application Ser. No. 762,756 filed Sept. 23, 1958 and assigned to the same assignee. In the development procedure, a counter-electrode 21 is arranged so as to be spaced from the image bearing surface a relatively small distance as shown in FIGS. 3 and 4. In the case of negative image areas 18, a positive developer is employed, that is, one having marking elements dispersed therein which are capable of being electrostatically attracted to the image areas on the image bearing surface 14. The presence of a counter-electrode 21 having applied thereto a potential intermediate that of the image and non-image areas, for example a negative 80 volts supplied from an appropriate D.C. source 23 and connection 24, substantially eliminates non-image area deposition during development.

As seen in FIG. 4, the marking elements are attracted to the image bearing surface and form raised deposits 25 thereon in conformity to the charge pattern. Along with the deposit on the image bearing surface, raised deposits 26 are formed on the surface of the counter-electrode 21, having a configuration corresponding to the non-image areas on the image bearing surface 10. The presence of this corresponding image on the surface of the counter-electrode and the operation of the counter-electrode in controlling deposition of the marking elements may be understood if it is considered that the image areas on the surface 14 are at a negative potential with respect to the potential on the areas of the counter-electrode opposite the image areas. Thus, a field is established between the image areas and the closely spaced counter-electrode for controlling the movement of the marking elements. This field, as established by the image, controls the uniform deposition of the marking elements in such fashion that the developed image exhibits substantially no halo or edge effect.

Adjacent the image areas on the image bearing member are non-image areas at a ground potential or a relatively low negative potential. On the surface of the counter-electrode 21, there is impressed a negative potential less than that of the image areas on the image bearing surface 14, but greater than the potential of the non-image areas on the surface 14. The result is that the marking elements are deposited on the image areas of the image bearing surface as well as on the surface of the counter-electrode to provide an image complementing the image developed on surface 14.

The presence of image and non-image areas on the surface of the image bearing member creates a field. Imposed on these fields is an impressed field brought about by the application of a potential between the counter-electrode and the backing member 11 if the latter is conductive, or a suitable conductive member positioned against the backing member 11 if the latter is non-conductive. Thus means including the counter-electrode are provided for establishing a potential across the image bearing surface which creates the impressed field. This impressed field is opposite in direction and intermediate in strength to the field created by the image and non-image areas on the surface of the image bearing member. Since electrical fields are vectorially additive, the resultant field in the non-image areas will move the marking elements toward the counter-electrode, and in the image areas, the marking elements will be moved to the image bearing surface. Such a field may be created, as shown, by applying a voltage to the counter-electrode and grounding the opposed conductive electrode which may include either a conductive backing member or any other suitable electrode. In the alternative, the counter-electrode may be grounded and a voltage applied to the opposed electrode

in order to create the field conditions as above described. Depending on the nature of the image and non-image areas, the potentials may be reversed to provide desired field actions as above described.

Since it is desirable to place the counter-electrode 21 in closely spaced relation to the image bearing surface 14 in order to increase the field strength thereby allowing the use of lower applied potentials, and for establishing more uniform field conditions, resulting from the electrostatic image, thereby reducing to a minimum edge effect, a situation arises as shown in FIGS. 4 and 5 wherein the surface of the deposited images are very close. This in itself presents no difficulty as long as the image bearing member 10 is not moved laterally with respect to the counter-electrode 21. Such relative lateral movement of the image bearing member is undesirable from the standpoint of the manipulations involved in processing, especially in instances where a continuous system is employed. The presence of a raised image on the surface of the image bearing member and a raised deposit on the counter-electrode may result in smudging and smearing of the developed image as the image bearing member is moved relative to the closely spaced counter-electrode.

An interfering amount of deposit of marking elements may be formed on the counter-electrode during successive development of a multiplicity of images. The resulting raised deposit increases to a point such that the deposit substantially fills the small space between the image bearing surface and the counter-electrode. When such a condition is achieved, interaction, that is mechanical or electrical interaction, between the marking elements in the deposit and those on the image bearing surface reaches a point wherein the contrast, definition and clarity of the developed image is virtually destroyed.

Another source of smudging or smearing is the turbulence or viscous drag created in the electrically insulating liquid as the image bearing member is moved relative to the counter-electrode. Whether or not distortion or smearing of the deposited marking elements is a result of physical contact between the image on the surface of the image bearing member and the complementary image on the surface of the counter-electrode, as shown in FIG. 5, the significant fact is that smudging does occur either as result of physical contact between marking elements of the two images or turbulence, or viscous drag created as the image bearing member is moved relative to the counter-electrode.

The result of either the turbulence, drag or the physical contact between the surfaces of the images can be seen with reference to FIG. 6, wherein the main portion 25 of the deposited image exhibits a tail like deposit 28, which in some instances may be noticeable to such a degree that the clarity and definition of the final print are seriously impaired. In the case of extremely fine lines, turbulence of the liquid, drag or physical contact between the surfaces of the images may result in a situation where fine lines appear discontinuous due to the fact that the marking elements are dislodged from the surface 14 and become redispersed in the insulating liquid.

The above disadvantages have been substantially eliminated in accordance with the present invention by the use of a counter-electrode system shown schematically in FIG. 7 wherein an image bearing member 30 including a conductive backing member 33, which is grounded, having a photoconductive layer 34 on one surface thereof is arranged so as to be brought into contact with a liquid developer 35. The liquid developer 35 consisting of an electrically insulating liquid having marking elements dispersed therein, as disclosed in my copending application mentioned above, is supported by a conductive liquid 36, having a specific gravity which is greater than that of the developer. The conductive liquid may be water or mercury, water solutions of salts, or any other conductive liquid having a specific gravity greater than the developer and immiscible therewith and preferably a conductive liquid

which exhibits little adverse effect upon the electrically insulating liquid or the marking elements therein. A suitable voltage is applied to the conductive liquid by a source 37 connected to a bus bar 38 immersed in the liquid 36.

As the image bearing member 30 having an electrostatic latent image formed thereon is rotated into the developer dispersion 35, the marking elements are deposited on the image portions of the image bearing surface 39 as indicated at 40 and 41, as above described. The counter-electrode in accordance with the present invention is conductive liquid 36 which is closely spaced from the image bearing surface 39 so as to effect substantial elimination of halo and edge effects, as above described. Disposed between the image bearing surface 39 and the conductive liquid is a fine film of developer, as will be more fully described below, and as the image bearing surface comes into contact with the developer and moves through the development area opposite the counter-electrode, a raised image consisting of marking elements is deposited on the surface 39 while a complementary image is formed on the surface of the counter-electrode as indicated at 42, as described in connection with FIGS. 3 and 4.

It should be noted that the deformable counter electrode 36 is capable of substantially conforming to the shape or the contour of the image bearing member, and may be spaced from it a relatively small uniform distance so as to provide a substantially uniform effect on the field created by the electrostatic latent image in those areas of contact between the liquid developer and the image bearing surface.

In accordance with the present invention, smudging, smearing or viscous drag of the developed image is substantially eliminated by moving at least the upper portion of the liquid counter-electrode 36 and the developer at a linear velocity approximately equal to the linear velocity of the image bearing surface. In this manner, any physical contact between the surface of the marking elements present on the image bearing surface and the elements present on the surface of the liquid counter-electrode is substantially eliminated since both images are being moved at substantially the same rate, and the developed image on the surface of the image bearing member is withdrawn from the developer without contacting any of the elements making up the complementary image present on the surface of the counter-electrode. Additionally, there is no build up of raised interfering deposits previously mentioned.

As illustrative of an apparatus constructed in accordance with the present invention employing a liquid counter-electrode, reference is made to FIG. 8 wherein a photoconductive paper 45, of the type above described, is employed as an image bearing member in electrostatic photography. A supply of paper in the form of rolls (not shown) of appropriate width is positioned so as to be fed past a charging station 47, an exposing station 49, and to a developing station 50, and thence to a cutting or trimming device, not shown. The apparatus for holding the paper roll and for advancing it at a preselected speed may be of any of the constructions well known in the art.

The developing station 50 includes a metallic receptacle 51 containing a conductive deformable counter-electrode 53 which may be of any of the liquids above described. Disposed on the surface of the counter-electrode 53 is a relatively thin film of liquid developer 56, the components of which are immiscible with and unaffected by the conductive liquid of the counter-electrode. Located in one portion of the metallic receptacle 51 is a trough 59 for receiving the liquid developer and counter-electrode liquid which is advanced past the roller member 60, as will be described below.

The conductive roller 60, which is grounded is positioned with respect to the receptacle 51 such that it will deform the film of liquid developer and possibly the counter-electrode. Tension in web is controlled to main-

tain the paper in close intimate contact with the surface of the roller 60 by web tension control units well known in the art.

In operation, the photoconductive paper having its active or image bearing surface 65 positioned so as to face the charging and exposing station is advanced past both these stations, and an electrostatic latent image is formed thereon, as described. The paper with the image on surface 65 is advanced to the developing station 50 while maintained in intimate contact with the drum 60. As the surface bearing the electrostatic latent image is brought into contact with the developer dispersion 56, the image is developed as above described in connection with FIG. 7. It should be noted that as the leading edge of the electrostatic latent image begins to dip or become immersed in the liquid developer 56, the deformable counter-electrode is spaced a substantially uniform minute distance from the paper such that as the image bearing member is carried through the developer, the deformable counter-electrode 53 is continually and substantially uniformly spaced from the image bearing surface. This permits a uniform reduction of edge effects associated with the electrostatic image and provides a substantially uniform electrical field associated with the impressed potential as described above.

A suitable potential is applied to the deformable electrode 53 from a DC source 66 having one terminal grounded and the other connected to the metallic receptacle 51 by a conductor 68. Under the influence of the resultant field existing between the counter-electrode 53 and the image bearing member, an image is deposited on the image bearing surface, and a complementary image is formed on the surface of the counter-electrode, as above described. The developed image on the image bearing member 45 is then advanced out of the developer, excess developer is removed by contact with the roller 69, and member 45 is advanced to a cutting station, not shown.

One aspect of the present invention relates to the movement of the liquid developer and the counter-electrode surface at substantially the same linear velocity as the image bearing member. This is accomplished in accordance with a preferred embodiment of the present invention by controlling the flow of the conductive liquid 53 into the container 51 at a rate such that the liquid and the paper are moving at the same linear rate. Such movement of the conductive liquid may be conveniently carried out by removing the conductive liquid from the trough 59 by a suitable connection 70 through a recirculating pump (not shown) and to the liquid input line 71 connected to the tank 51. In similar fashion, the liquid developer 56 is withdrawn from the trough 59 by a suitable conduit 73 and recirculated through a recirculation unit (not shown) to the developer input side 75 of the receptacle. By controlling the rate of flow of the conductive liquid and the liquid developer, both of these liquids may be moved through the receptacle 51 so as to have a velocity in the region adjacent the image bearing member 45 approximately equal to the velocity of the image bearing member. In this fashion, the objectionable turbulence of the liquid, viscous drag and other interaction between the surfaces of the deposited images may be avoided as described above in connection with FIG. 7.

Assuming, merely for the purpose of illustration, and in no way to be construed as a limitation on the present invention, that the image areas on the image bearing surface are at a potential of 150 volts negative, and the non-image areas at a potential between ground and 40 volts negative, then a negative 80 volts are applied to the conductive liquid by the DC source 66.

It is preferred that the film of developer 56 uniformly disposed on the surface of the deformable electrode 53 be of the order of .020 of an inch thick, and a continuous film so as to contact all portions of the image bearing surface as it is rotated downward into the tank.

The counterclockwise movement of the roller 60 carries the image bearing member 45 into contact with the developer 56, and a relatively thin film of developer is uniformly and evenly distributed over the surface of the image bearing member. This relatively thin film of developer remains upon the surface of the image bearing member due to the surface tension of the insulating liquid, and as the image bearing member is moved laterally with respect to the receptacle 51, the surface bearing the electrostatic latent image is spaced from the deformable counter-electrode by a substantially uniform small distance corresponding in dimension to the thickness of the layer of developer adhering to the surface of the image bearing member. This relatively thin film of developer includes insulating liquid having marking elements dispersed therein as above described, and the marking elements are deposited on the image bearing surface and the surface of the counter-electrode as above described.

As the image bearing surface emerges, liquid developer from which some of the marking elements have been removed is progressively advanced towards trough 59. The developer on the downstream side or the trough side of the roller 60 contains a lower percentage of marking elements than does the developer on the upstream side of the receptacle. The undeposited marking elements and the liquid float on the surface of the liquid electrode 53 into the trough 59, wherein the heavier conductive liquid 53 settles to the bottom while the developer dispersion 56 remains on the surface as shown in FIG. 8.

Due to the fact that the developer is immiscible with the conductive liquid forming the counter-electrode, these two liquid components may be easily separated and ported to the recirculating system described above.

In the place of roller 60, a stationary conductive guide member may be employed having a planar highly polished surface portion positioned so as to be spaced a substantially uniform small distance from the surface of the liquid developer, approximately equal to the thickness of member 65. In this manner, the photoconductive paper traveling through the developing station will not substantially deform the counter-electrode as may be the case with the roller member shown in FIG. 8. It is to be understood, that a voltage may be applied to the roller 60 or guide member and the conductive counter-electrode may be grounded, as above described, to provide field conditions which coact to produce the advantageous results previously noted.

Another aspect of the present invention relates to the ease with which reformation or reconstitution of the liquid developer may be carried out. The developer which has been employed in a developing sequence remains on the surface of the counter-electrode, and as it spills into the trough, the marking elements from the complementary counter-electrode image are redispersed through the used developer and partially reconstitute it to a strength somewhat less than its original strength. It is a rather simple matter to check the percentage of marking elements and add additional marking elements should the contrast of the developed images be too low. This may be conveniently accomplished by incorporating a unit with the developer recirculation system which introduces, and intimately mixes with the liquid developer, a relatively high concentration of marking elements, for example, a concentration of approximately 5 to 10% marking elements dispersed in an appropriate insulating liquid as mentioned in my copending application.

This reconstitution is performed only on used developers and not on the entire body of developer employed in the developing system. By recirculating only that portion of the developer which is depleted of marking elements, rather than a mixture of used and unused, closer control of developer concentration is possible than has heretofore been achieved.

Another advantageous feature of this invention relates to the ability of the liquid counter-electrode to deform in

instances where there are pronounced irregularities in the surface of the image bearing member tending to cause mechanical binding. In instances where a photo-conductive paper is employed and a counter-electrode is closely spaced from the paper, any pronounced physical irregularities in the surface caused, for example, by a splice or the like, will operate to deform the developer and the counter-electrode to prevent mechanical binding which may result if the system were not able to give way to mechanical pressure created by pronounced physical irregularities in the surface. As was mentioned previously, the use of a guide member having a substantial length positioned in opposed spaced relationship to the counter-electrode would not normally create any deformation of the liquid counter-electrode; however, the presence of a splice and the like in the paper presents no serious mechanical problem due to the fact that the developer and the counter-electrode are capable of being deformed an amount corresponding to the size of the physical deformation present on the surface being treated.

The apparatus above described and the method of electrostatic photography described constitute a marked improvement over those heretofore known due to the fact that the resulting print exhibits little, if any, halo or edge effect. Additionally, by means of the apparatus and the method above described, it is possible to produce finished prints of improved quality at a relatively high rate of speed.

As will be understood by those familiar with electrostatic photography, the time required to form a print by electrostatic photography is, to a great extent, dependent upon the development time, as is true with most photographic systems. With the continuous system above described, development time is significantly reduced while retaining print quality at a maximum thereby allowing formation of prints by electrostatic photography in a relatively short time.

The novel counter-electrode system and method herein described may be employed in a system of electro-photography wherein the image carrying member is either a plate or drum as above described, a flexible photo-conductive member as above mentioned, or an insulating member to which the charge image has been transferred. By use of a deformable counter-electrode which may be spaced a relatively small distance from the image bearing surface, a field condition is established which allows close control of the deposition of the marking elements. Additionally, movement of the counter-electrode surface and the image bearing surface at approximately the same linear rate eliminates any smudging, smearing or viscous drag of the image on the image bearing surface and thereby allows positioning of the counter-electrode a relatively uniform small distance from the image bearing surface. Moreover, the proper potential may be applied to the conductive liquid by a bus bar or the like immersed in the liquid, in which case the receptacle may be of insulating material such as plastic and the like.

While the methods and forms of apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise methods and forms of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. A counter-electrode system for use in electrostatic photography wherein an image bearing member includes a support element and an electrically insulating photo-conductive layer, the photoconductive layer forming an image surface having differentially charged image areas and non-image areas and wherein said image surface is brought into contact with a liquid developer, comprising a conductive liquid material forming a counter-electrode, means for positioning said image bearing member so as to place said image bearing surface, while said surface is

in contact with said liquid developer, in close proximity to said conductive liquid to cause said counter-electrode to be spaced from said image bearing surface a relatively small distance, and means including electrical connections to said conductive liquid material to apply a potential across said image bearing surface to effect formation of an impressed electrical field opposite in direction and intermediate in strength to the fields created by said image and non-image areas on the surface of the image bearing member.

2. A counter-electrode system for use in electrostatic photography wherein a member having an image bearing surface having differentially charged image areas and non-image areas on the surface thereof is brought into contact with a liquid developer, comprising a conductive liquid material forming a counter-electrode, roller means for positioning said image bearing surface, while said surface is in contact with said liquid developer, in close proximity to said conductive liquid but spaced therefrom by a layer of said liquid developer, and means cooperating with said counter-electrode and said roller means to establish an impressed electrical field which is opposite in direction and intermediate in strength to the fields created by the image and non-image areas of the image bearing surface, one of said counter-electrode and said roller means being at a ground potential and the other being at a potential other than ground.

3. An apparatus for developing an electrostatic latent image on a member having an image bearing surface comprising means containing a counter-electrode of conductive liquid having disposed thereon a liquid developer, said liquid developer including an electrically insulating liquid having dispersed therein marking elements capable of moving through said insulating liquid under the influence of an electrostatic charge to deposit on said image bearing surface in conformity to the charge pattern thereon, said conductive liquid being immiscible with said liquid developer, transport means for bringing said image bearing surface in contact with said liquid developer for causing selective deposition of said marking elements, means including said counter-electrode for creating a substantially uniform electrical field condition separate from the field condition created by said latent image for controlling the deposition of said marking elements on said surface in conformity to the latent image thereon.

4. An apparatus for developing an electrostatic latent image on a member having an image bearing surface comprising means containing a counter-electrode of conductive liquid having disposed thereon a liquid developer, said liquid developer including an electrically insulating liquid having dispersed therein marking elements capable of moving through said insulating liquid under the influence of an electrostatic charge to deposit on said image bearing surface in conformity to the charge pattern thereon, said conductive liquid being immiscible with said liquid developer, roller means for bringing said image bearing surface in contact with said liquid developer for causing selective deposition of said marking elements, means including said counter-electrode for establishing a potential difference between said roller means said said counter-electrode for controlling the deposition of said marking elements on said image bearing surface, and one of said counter-electrode and said roller means being at ground potential and the other being at a potential other than ground.

5. An apparatus for developing a latent image on an image bearing member wherein said member includes a supporting element and an electrically insulating photo-conductive layer thereon forming an image bearing surface having differentially charged image areas and non-image areas, comprising means containing a counter-electrode of conductive liquid having disposed thereon a liquid developer, said liquid developer including an electrically insulating liquid having dispersed therein marking elements capable of moving through said insulating

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liquid under the influence of an electrostatic charge to deposit on said image bearing surface in conformity to the charge pattern thereon, said conductive liquid being immiscible with said liquid developer, means for bringing at least said image bearing surface in contact with said liquid developer for causing selective deposition of said marking elements, and means including said counter-electrode for establishing a potential difference across said image bearing surface to effect formation of an impressed electrical field opposite in direction and intermediate in strength to the fields created by the image and non-image areas on the surface of the image bearing member for controlling the deposition of said marking elements on said image areas under the influence of the created field conditions.

6. An apparatus for use in electrostatic photography comprising means for forming on an image bearing member an electrostatic latent image having differentially charged image areas and non-image areas, said member including an image bearing surface and a backing member therefor, means for advancing said member through a developing station wherein said image bearing surface is treated with a liquid developer, said liquid developer including an electrically insulating liquid having dispersed therein marking elements capable of moving through said insulating liquid under the influence of an electrostatic charge to deposit on said image bearing surface in conformity to the charge pattern thereon, means forming a counter-electrode of conductive liquid positioned in closely spaced relation to said image bearing surface, means for bringing said image bearing surface in contact with said liquid developer for simultaneously causing deposit of said marking elements and for causing substantial conformity of said liquid electrode in spaced relation to the contours of said image bearing surface, and means including said counter-electrode for establishing a potential difference across said image bearing surface for controlling the deposition of said marking elements on said image bearing surface.

7. A process for developing a latent image on a moving image bearing surface having differentially charged image areas and non-image areas defining an electrostatic field, comprising bringing said surface into contact with a liquid developer including electrically insulating liquid having dispersed therein marking elements capable of moving through said insulating liquid under the influence of an

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electrostatic charge to deposit on said image areas, positioning a deformable liquid counter-electrode in close proximity to said image bearing surface and spaced therefrom by a relatively thin film of developer, applying a potential across said image bearing surface to create a field coating with said electrostatic field for controlling the deposition of said marking elements on said surface in conformity to the latent image thereon, and moving the portion of said counter-electrode in the region of said image bearing surface in the direction of movement of said image bearing surface for reducing interaction and viscous drag between said deposited elements and the other components of said developer.

8. A process for electrostatic photography comprising the steps of forming a latent image including differentially charged image areas and non-image areas on an image bearing surface defining an electrostatic field, bringing said surface into contact with a liquid developer including an electrically insulating liquid having dispersed therein marking elements capable of moving through said insulating liquid under the influence of an electrostatic field to deposit on said image areas, positioning a deformable liquid counter-electrode in close proximity to said image bearing surface and spaced therefrom by a relatively thin film of liquid developer, applying a potential across said image bearing surface intermediate the potentials of said image and non-image areas creating a field coating with said electrostatic field for controlling the deposition of said marking elements on said surface in conformity with the latent image thereon, and moving said liquid developer and said counter-electrode at a velocity approximately equal to the linear rate of movement of said image bearing surface for substantially eliminating viscous drag and interaction of the marking elements and the insulating liquid of said developer upon said deposited elements.

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