Aug. 22, 1967

C. SNELLING

3,337,339

SCREEN XEROGRAPHY

Filed Oct. 1, 1962

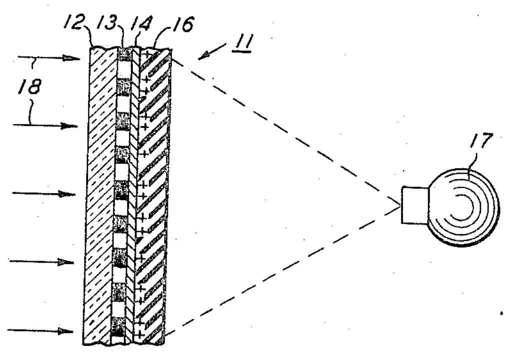

FIG. 1

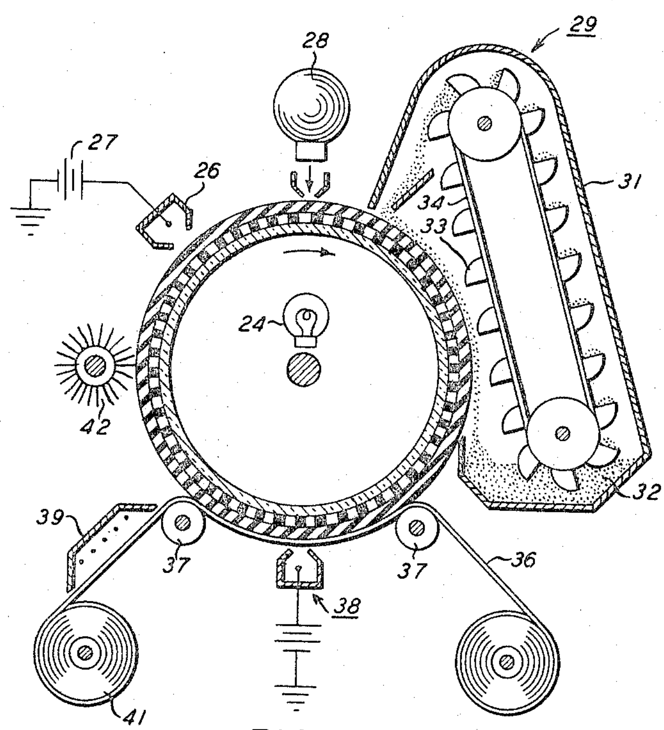

FIG. 2

INVENTOR.
CHRISTOPHER SNELLING

BY Stanley Z. Cole

ATTORNEY

United States Patent Office

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Christopher Snelling, Penfield, N.Y., assignor to Xerox Corporation, Rochester, N.Y., a corporation of New York

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This invention relates in general to xerography and in particular to an improved xerographic copying apparatus utilizing a novel xerographic plate and an improved method of xerographic copying.

In the art of xerography, as originally disclosed by Carlson in U.S. Patent 2,297,691 and as further amplified by many related patents in the field, an electrostatic latent image is formed on a photoconductive insulating layer and is developed through the deposition thereon of finely divided electroscopic material. The image may be fixed in place or transferred to a sheet of copy paper where it is permanently fixed. In most applications the photoconductive insulating layer, which may be referred to as a plate regardless of its shape, is first charged to sensitize it and is then exposed to a light image or other pattern of activating electromagnetic radiation which serves to dissipate charge in radiation-struck areas, thus forming a charge pattern conforming to the electromagnetic radiation pattern on the plate. This charge pattern is then developed or made visible by the deposition on the plate of an electroscopic or electrostatically attractable, finely divided, colored material which is referred to in the art as toner. It is the interaction between the electrostatic field set up by the retained charge pattern on the plate and the toner particles which control development of the plate. When utilizing a xerographic plate in a reproduction process one must consider not only how good the plates are in a photographic sense but also how the retained electrostatic image on the plate will affect the development process. Thus, even with a plate that accepts charge well, holds it for long periods in darkness, and selectively discharges quickly in response to a light pattern to form a good latent electrostatic image, certain difficulties may be encountered because of the effects of the field or fields set up by this pattern of charge on the development process.

The fact that charged areas set up relatively strong fringing fields at their edges or peripheries as compared to the external fields they set up near their centers is basic to an understanding of the interaction of these fields with electroscopic developing materials. Actually, these fringing fields occur not only at the periphery or edge of a charged area, but also at any place within a charged area where a high potential gradient exists. For example, a strong fringing field would exist within a large charged area wherever there are adjacent sections having relatively high and relatively low levels of charge. Because of this fringing field effect xerography has proved to be most useful in the reproduction of line copy subjects, such as printing, line drawings, and the like, which are represented on the xerographic plate by narrow areas of charge having strong fringing fields at both edges of the lines. Fairly good reproduction of continuous tone originals and originals containing large areas of uniform density has been achieved with ordinary xerographic plates. However, really good reproduction of these subjects has required special techniques to enhance the development capability

of those portions of the electrostatic images produced by these originals which do not have high potential gradients with their consequent characteristically strong fringing fields. Thus, additional apparatus and special techniques such as electrode development as described in U.S. Patent 2,777,418 to Gundlach, and screen exposure as described in U.S. Patent 2,598,732 to Walkup, have in many instances, been used to produce really exceptional continuous tone rendition and the complete copying of very large solid dark areas. This, of course, has required the use of either additional apparatus or additional process steps in the basic xerographic copying system.

Accordingly, it is an object of this invention to define a novel and improved xerographic plate capable of copying all types of original subjects with uniform excellence.

Another object of this invention is to describe a novel method of image reproduction utilizing the improved xerographic plate of this invention.

A further object of this invention is to define a novel xerographic apparatus of great flexibility which is capable of very high quality image reproduction.

The above and still further objects, features, and advantages of the present invention will become apparent upon consideration of the following detailed disclosure of specific embodiments of the invention, especially when taken in conjunction with the accompanying drawings wherein:

FIGURE 1 is a cross-sectional view of a xerographic plate according to this invention.

FIGURE 2 is a side-sectional view of a xerographic copying apparatus according to this invention.

Referring now to FIGURE 1 of the drawings, there is illustrated a xerographic plate generally designated **11**, embodying the concepts of this invention.

The present invention contemplates a vastly improved and novel xerographic plate structure which utilizes as its basic mechanism of operation an exposure to a uniform light source superimposed on an exposure to the original in the reproduction of images which produce low potential gradients on ordinary xerographic plates. The basics of this type of technique and its advantages are more fully described in U.S. Patent 2,598,732 to Walkup. It is to be noted that, in contrast to Walkup, the structure of the instant invention allows for simultaneous exposure of the plate to the original and a screen pattern without using two projectors.

It should be pointed out that none of the drawings annexed to this specification are intended to be scale drawings. Many elements in the drawings have either been exaggerated or reduced in size so as to facilitate a clear description of the invention. The plate **11** is made up of a transparent supporting substrate **12** which is sufficiently strong to provide mechanical support to the remainder of the plate so as to make it suitable for use in xerographic copying machines. This support member may be fabricated of almost any transparent material, either conductive or insulating, and may be selected from such diverse materials as glass and plastics of various types. Depending upon the particular application of the plate the support member may be relatively rigid as in the case of a plate or cylinder of glass or Lucite or may be relatively flexible as with the case of a plastic web, such as polyethylene or the like. Furthermore, in the event that the remaining plate elements are self supporting this supporting substrate may be eliminated entirely from the plate structure. Immediately above the supporting substrate **12** is an optical screen **13** made up of a number of finely divided, alternating, discrete, opaque, and transparent sections. The screen pattern of opaque and transparent areas may be a conventional dot pattern or line pattern of the type used for out-of-contact screen exposure in the fabrication of halftone plates for newspaper printing. Actually the pattern may be of almost any shape, including round dots, elliptical, lines, and the like. The spacings of the pattern may also vary so that the pattern is regular, irregular, or random. The pattern may also be varied in size from dot-to-dot or line-to-line. For reasons to be described hereinafter the adjacent transparent and opaque areas are sharply defined and of the type referred to in the graphic arts as a "hard" pattern. Since the pattern in this embodiment is utilized only for optical purposes the pattern may be either conducting or insulating. Thus, almost any commercially available hard screen pattern from many sources such as the Byrum Co. of Columbus, Ohio, and Buckbee-Nears of St. Paul, Minn., may be utilized in the fabrication of this plate. For example, the screen pattern may be made by exposure of the desired pattern to an ordinary silver halide photographic continuous film negative. If this type of a film screen is used with a supporting substrate it may be attached to the substrate with an adhesive or with connectors such as rivets or by other equivalent techniques to produce the desired opaque and transparent pattern. Immediately above the screen pattern **13** is a very thin transparent conductive layer **14** which may, for example, be fabricated of tin oxide or copper iodide. A copper iodide layer may be laid down on the screen by evaporating a very thin layer of copper on the screen and then subjecting it to an iodine atmosphere. This may be done simply by bringing the evaporated copper layer adjacent to a number of iodine crystals. Copper iodide layers of this type may be made very thin by evaporating copper onto the substrate until the film just becomes visible and it is believed that they may even reach down into the sub-micron range. The use of such a thin transparent conductive film serves to effectively eliminate any shadow or diffraction effects which might be produced by light passing through this layer from the screen **13** and substrate **12** as the light reaches an upper photoconductive insulating layer **16**, which might have been produced had a thicker layer been used.

The formation of this transparent conductive layers of tin oxide and copper iodide are more fully described in U.S. Patents 2,429,420 to McMaster, 2,769,778 to Preston, 2,772,190 to Haayman, and 2,756,165 to Lyon. As should be clear from a reading of these patents, if a tin oxide layer is used the screen upon which it is applied must be much more heat resistant.

A test plate of the above type was made starting with a 120 line per inch hard dot pattern on a photographic film known as a Byrum screen tint available from the Byrum Co. of Columbus, Ohio. This screen was protectively dip coated with a withdrawal rate of 60 inches per minute in a 2 to 1 mixture by volume of a lacquer M–5972 and a thinner EM–998 available from the Bee Chemical Co., and dried. The lacquer coated tint was then placed in a vacuum evaporator about 14 inches above an electrically heated molybdenum boat containing copper for about ½ minute until about 87 mg. of copper was driven off from the boat. The tint, which was cooled and separated from the boat by a radiation shield acquired a very thin coating of copper. The tint was then removed from the evaporator and placed in an iodine atmosphere until the copper reacted to yield a transparent copper iodide layer with a slight purple tint. This copper iodide coated layer was then overcoated with a layer of amorphous selenium in a second vacuum evaporator and the whole three layer plate was taped onto a clear Lucite drum with its Byrum tint side down after which it was successfully tested in a Xerox 914 office copier.

This hard contact pattern and its proximity to the photoconductor also allows the use of non point source illumination through the screen such as ambient room light while still providing very sharp boundaries between exposed and unexposed areas. The photoconductive insulating layer **16** may be any one of the photoconductive insulating materials utilized in ordinary xerographic plates and may include such diverse materials as vitreous selenium, any one of many organic photoconductors such as anthracene, or inorganics such as certain forms of sulphur, cadmium sulfide, zinc oxide in a film-forming binder, or any other continuous film photoconductive insulating material or particulate photoconductive insulating material or particulate photoconductive insulating material in an insulating film-forming binder. It should be noted that the thin transparent conductive layer **14** need not necessarily be "conductive" as that term is understood by persons skilled in the electrical arts. It is only necessary that this layer have sufficient electrical conductivity for the charging or sensitization of the xerographic plate and to accommodate the release of electrical charge upon exposure of the plate. Thus, the term "conductive" as applied to this member should be read in its broadest sense since its conductivity must be high only as compared with the photoconductive insulating layer of the plate. Thus, the backing member should have a resistivity lower than about 10^{10} ohm-cm. and preferably lower than about 10^5 ohm-cm. when used with a selenium photoconductor.

In an alternative embodiment the optical screen **13** and conductive layer **14** may be integrated by utilizing a screen made from a conductive material, thus simplifying the construction of the plate and completely eliminating any possibility whatsoever of diffraction or shadow effects between the screen and the photoconductive layer which might be caused by any material interposed between the screen and the photoconductor. Thus, for example, the screen pattern may be made directly of a material conductive enough to serve as a xerographic plate base by rendering selected alternating areas across its surface transparent and opaque.

In a third technique the optical screen and conductive base of the plate are combined by utilizing a conductive opaque layer with a number of fine, uniformly spaced perforations below the photoconductive layer. Thus a foraminous copper screen made by etching holes in a thin evaporated copper layer may be utilized as a plate base for this novel plate. In this case some of the photoconductor will be deposited in the foramina of the screen when it is overcoated on the screen but since the screen is very thin as compared to the thickness of the photoconductive layer it does not have a significant effect on the uniformity of the thickness of the photoconductor. If a plain copper screen is used with a selenium photoconductor, its surface should be oxidized to provide a good copper-selenium interface barrier layer, the purpose of which is more fully described in U.S. Patent 2,901,348 to Dessauer.

In operation, the plate is first charged with any one of the conventional xerographic plate charging techniques so as to sensitize it. By way of example, corona charging from a wire filament array as described in U.S. Patent 2,588,699 to Carlson or induction charging as described in U.S. Patent 2,934,649 to Walkup may be utilized. This process is carried out in darkness so that after it is completed the plate has been sensitized with a generally uniform field through the layer.

During the exposure step of the copying process the front or photoconductive surface of the plate is exposed to an image by a projector **17**. This image may be of any type, and may include such diverse subjects as continuous tone, pictures, line copy, subjects containing large solid dark areas, or the like. With an ordinary xerographic copying process utilizing the conventional xerographic plate the exposure step would normally be followed by development. However, with the novel plate of this invention a second exposure through the rear of the plate is carried out at some time between or during plate sensitization to the time of development. This exposure is to a uniform illumination as diagrammatically illustrated by arrows 18 in FIGURE 1. This exposure step may be carried out prior to, simultaneous with, or after charging, subject exposure to the front of the plate at the option of the operator, the only requirement being that this exposure be carried out prior to the development step. In fact it may also be carried out during development as long as intense enough or far enough along at the early stages of development to accomplish the purposes of this invention.

This combination of exposure steps serves to modify the electrostatic charge pattern in such a way that the fields created by charge pattern will develop well even when the original subject was continuous tone or had large solid areas of relatively uniform density. The rear exposure of the charged photoconductive insulating layer through the screen pattern serves to discharge all areas of the photoconductor directly opposite transparent areas of the screen. This exposure thus serves to divide the plate up into a great multiplicity of very small charged areas or "islands" as they will be called for purposes of description. Because of the fact that each of these charged islands is immediately adjacent to an area which has been discharged by this rear exposure a high potential gradient exists at the outer periphery of each small charged area. Because of these high potential gradients each small charged island sets up strong electrostatic fringing fields of force which have vertical components above the surface of the plate and are thus very favorable for development with the commonly used xerographic developing materials. Obviously, the number and positioning of these small charged islands will depend directly upon the fineness and transmission density of the optical screen utilized. Thus, if a coarse screen of 40–50 lines per inch is utilized the charged islands remaining after rear exposure will be relatively "large" and widely dispersed as compared with the size and separation of the charged islands resulting from the use of a 200 line-per-inch screen. At any event, the plate may be considered as uniformly charged in the macroscopic sense of the word even after the screen exposure although this "uniform" charge is made up of the sum of a great plurality of small closely spaced charged "islands."

When the subject exposure is superimposed upon the plate it serves to modulate the charge level of each one of these small charged "islands" according to the amount of light produced by the exposure from each one of its different sections. Thus, those small charged islands opposite white areas of the subject being copied are substantially completely discharged by the front exposure of the plate to the subject while charged islands on the plate opposite grays in the subject are partially discharged and charged islands opposite blacks in the subject retain their original charge level. It should be made clear at this point in the explanation of the invention that the time of the front and rear exposure with respect to each other is immaterial. If rear exposure is made prior to front subject exposure the charge islands are formed first and then modulated by the subject exposure from the front of the plate; if both front and rear exposures are made simultaneously the charged islands are formed by the rear exposure and the level of charge on the islands is modulated by the front exposure simultaneously while if the front exposure is made prior to the rear exposure the level of charge across the whole plate is first reduced according to the light received from the plate from exposure to the subject and this remaining charge is then divided up into small islands by the subsequent rear exposure through the optical screen. Regardless of which sequence is employed the resulting charge pattern on the xerographic plate is identical. In fact, rear exposure may even be made during the beginning of the development step or the end of the charging step.

After exposure the plate bearing an electrostatic image of the type described is developed. Development may be carried out utilizing any one of the conventional xerographic developing techniques such as cascade or powder cloud as described in U.S. Patent 2,725,304 to Landrigan, among others. As described above the effects of the conventional developing techniques are very favorably influenced by the electrostatic fields resulting after charging and exposure of the novel plate herein described. Since the charge patterns on the plate are broken up into small areas or islands of charge with their consequent fringing fields even low levels of charge on the plate corresponding to relatively light grays in the original develop well because even these low charge levels are used in the most effective way possible to attract the oppositely charged developing particles. Because of this breaking up of the charge pattern and its resultant improvement in the development of light grays the effective gray scale reproduction of the plate is greatly enhanced. As described more fully above, the development of uniformly charged areas even including those with high levels of charge is also enhanced since breaking up the charge pattern into islands produces many small fringing fields throughout these uniformly charged areas so that their centers may be fully developed as well as their edges.

In FIGURE 2 there is illustrated an automatic continuous type xerographic copier utilizing a cylindrical plate 19 constructed according to this invention. This plate could also be in the form of an endless belt. The plate is made up of three layers including a transparent supporting substrate 21, an optical screen 22, and a photoconductive insulating layer 23, all of the type described in connection with FIGURE 1. In this case screen 22 is fabricated of a conductive material; however, if a nonconductive screen were utilized a thin transparent conductive layer such as copper iodide or tin oxide would be included between optical screen 22 and photoconductive insulating layer 23. At any event, this transparent conductive layer would be so thin as to be difficult of illustration in this figure. The conductive drum member, whether it be the optical screen itself or a separate thin transparent layer, is grounded. A light source 24 is located within drum 19 and is provided with an external switch so that the machine operator may turn this light source on or off at will. A shield may also be provided within the drum so that internal light source 24 will only expose a portion of the internal drum periphery equal to the length of one copy. In this way the internal light may be turned on and off for successive copies. Outside the drum surface there is a charging unit 26 connected to a source of high potential 27. The charging unit 26 contains one or more wire filaments which are connected to the potential source and operate on the corona discharge techniques as described in U.S. Patents 2,588,699 to Carlson, and 2,777,957 to Walkup. Essentially, this technique consists of spacing a filament slightly from the surface of a xerographic plate having its conductive base grounded and applying a high potential to the filament so that a corona discharge occurs between the filament and the plate thus serving to deposit charged particles on the plate surface to raise its level of electrostatic charge with respect to ground potential.

The xerographic plate or drum when in operation is generally rotated at a uniform velocity in the direction indicated by the arrow in FIGURE 2 so that after portions of the drum periphery pass the charging unit 26 and have been uniformly charged they come beneath a projector 28 or other means for exposing the charged plate to the image to be copied. Subsequent to charging and exposure sections of the drum surface move past a developing unit generally designated 29. This developing unit is of the cascade type which includes an outer container or cover 31 with a trough at its bottom containing a supply of developing material 32. This developing material is picked up from the bottom of container 31 and dumped or cascaded over the drum surface by a number of buckets

33 on an endless driven conveyor belt 34. This development technique which is more fully described in U.S. Patent 2,618,552 to Wise and 2,618,551 to Walkup utilizes a two-element developing mixture including finely divided colored marking particles or toner and grossly larger carrier beads. The carrier beads serve both to deagglomerate the toner and to charge it by virtue of the relative positions of the toner and carrier material in the triboelectric series. When the carrier beads with toner particles clinging to them as cascaded over the drum surface the electrostatic fields from the charge pattern on the drum pull toner particles off the carrier beads serving to develop the image. The carrier beads along with any toner particles not used to develop the image then fall back into the bottom of container 31 and the developed image moves around until it comes into contact with a copy web 36 which is pressed up against the drum surface by two idle rollers 37 so that the web moves at the same speed as the periphery of the drum. A transfer unit 38 is placed behind the web and spaced slightly from it between rollers 37. This unit is similar in nature to the plate charging mechanism 26, 27, and also operates on the corona discharge principle. This transfer device is connected to a source of high potential of the same polarity as that employed in the charging device so that it deposits charge on the back of web 36 which is of the same polarity as the charge on the drum and is also opposite in polarity to the toner particles utilized in developing the drum. This charge on the back of the web 36 pulls the toner particles away from the drum by overcoming the force of attraction between the particles and the charge on the drub. It should be noted at this point, that many other transfer techniques might be utilized with this invention. For example, a roller connected to a high potential source opposite in polarity to the toner particles may be placed immediately behind the copy web or the copy web itself may be adhesive to the toner particles. After transfer of the toner image to web 36 the web moves beneath a fixing unit 39 which serves to fuse or permanently fix the toner image to web 36. In this case a resistant heating type fixer is illustrated, however, other techniques known in the xerographic arts may also be utilized including the subjection of the toner image to a solvent vapor or spraying the toner image with an overcoating. After fixing the web is rewound on a coil 41 for later use. After passing the transfer station the drum continues around and moves beneath a cleaning brush 42 which prepares it for a new cycle of operation.

When a relatively coarse and inexpensive screen pattern ranging from about 80 to 40 lines per inch and below is utilized with the plate of this invention a screening effect is achieved in the final copy because the charge pattern, when broken up by the optical screen in back of the plate, forms sufficiently separated portions so that after development their separation is discernible to the naked eye. Finer screens ranging up to 500 lines per inch and more tend to eliminate this screen effect. The apparatus described in connection with FIGURE 2 is particularly advantageous since the light source 24 may be shut off when the system is being utilized to reproduce line copy subjects and turned on for the reproduction of continuous tone subjects or subjects containing large solid dark areas so as to eliminate any screen effect in line copy work. When light source 24 is shut off plate 19 is effectively transformed into an ordinary xerographic plate made up of a photoconductive insulating surface layer overlying a conductive backing since the optical screen has little or no effect on the charge pattern deposited upon the plate. In this way a relatively coarse screen may be used without imparting a screening effect when the apparatus is being utilized to reproduce line copies and even the line copy from a plate incorporating a relatively fine screen is improved by shutting off the light source since the strong fringing fields at the edges of the lines

are not broken up. As described more fully above, it is unnecessary to break up the charge patterns representative of line copy on a xerographic plate in order to enhance their fringing field effects since these charge patterns are narrow enough so that their fringing fields are inherently suitable for xerographic developer. Thus, by utilizing the FIGURE 2 apparatus an operator may secure solid line copy with good definition totally devoid of any halftone appearance, or alternatively, by merely switching on light source 24 he may greatly widen the gray scale reproduction of the plate to more perfectly reproduce continuous tone originals while simultaneously enabling the full and uniform reproduction of originals having large solid dark areas.

While the specific embodiments shown and described in this specification and drawings are admirably adapted to fulfill the stated objects of this invention, it should be understood that it is not intended to confine the invention to these disclosed embodiments since it is susceptible of embodiment in many various forms all coming within the scope of the following claims.

What is claimed is:

1. A method of xerographic reproduction comprising the steps of:

(a) substantially uniformly electrostatically charging a xerographic plate comprising as an integral member an optical screen having a multiplicity of alternating discrete optically transparent and opaque areas, a photoconductive insulating layer, a first side of which is adjacent to said optical screen, and including a conductive contact with said first side of said photoconductive insulating layer, said contact being optically transparent in at least those areas corresponding to the transparent areas of said optical screen;

(b) exposing the second side of said plate to a light image;

(c) substantially uniformly exposing the first side of said photoconductive insulating layer to a light source through said optical screen at some time between the later stages of the step of sensitizing said plate to the early stages of the subsequent step of developing in a manner such that said two exposures are made to opposite sides of said photoconductive insulating layer; and,

(d) developing said photoconductive insulating layer with finely divided electroscopic marking material.

2. A method according to claim 1 wherein the two exposures are made substantially simultaneously.

3. A method of xerographic reproduction according to claim 1 wherein the screen-covered side of said photoconductive insulating layer is exposed to ambient light.

4. A xerographic reproducing apparatus comprising:

(a) a xerographic plate made up of an endless optical screen having a multiplicity of discrete alternating transparent and opaque areas, a photoconductive insulating layer, a first side of which is adjacent to said optical screen and including a conductive contact with the first side of said photoconductive insulating layer;

(b) drive means cooperating with said plate to move the plate through a predetermined path;

(c) a light source within the confines of said endless optical screen adapted to uniformly expose the first side of said xerographic plate,

(d) electrostatic charging means positioned along said path and adapted to uniformly charge the second side of said xerographic plate as portions of the plate pass by;

(e) exposure means next in the path of said plate following said charging means to expose said charged photoconductive insulating layer to an image to be reproduced from said second side of said photoconductive insulating layer to form a latent electrostatic image; and,

(f) developing means positioned next in the path of said plate adapted to contact said electrostatic latent image with electroscopic marking material to produce a visible image.

5. A xerographic apparatus according to claim **4** in which said optical screen is in the form of a rigid cylinder.

6. A xerographic apparatus according to claim **4** in which said optical screen is in the form of a flexible endless belt.

7. A xerographic apparatus according to claim **4** further including means located after said developing means to transfer said electroscopic material from said xerographic plate to a copy sheet.

8. A xerographic apparatus according to claim **4** further including means to turn said light source within the confines of said endless optical screen on and off whereby low contrast subjects may be more advantageously copied by turning said light source on and light contrast subjects may be more advantageously copied by turning said light source off.

9. A xerographic apparatus according to claim **4** wherein said conductive contact consists of an optically transparent, electrically conductive layer less than about 1 micron thick between said optical screen and said photoconductive insulating layer.

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NORMAN G. TORCHIN, *Primary Examiner.*

A. L. LIBERMAN, C. E. VAN HORN, *Assistant Examiners.*