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Baltazzi et al.

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[45] **Mar. 7, 1972**

[54] PHOTOELECTROSTATIC COPIER HAVING A SINGLE STATION FOR SIMULTANEOUSLY APPLYING TONER PARTICLES AND CLEANING THE PHOTOCONDUCTIVE MEDIUM

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Related U.S. Application Data

[62] Division of Ser. No. 675,463, Oct. 16, 1967.

[52] **U.S. Cl.** **355/15**, 117/17.5, 355/16

[51] **Int. Cl.** **G03b 15/00**

[58] **Field of Search** 117/17.5; 134/1; 355/15, 16; 15/1.5

[56] **References Cited**

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[57] **ABSTRACT**

A photoelectrostatic copying apparatus equipped with a reusable continuous belt coated with an organic photoconductive medium adapted to move in an orbital path. A series of processing stations are located adjacent the path of movement of the belt so that, in sequence, it moves past charging, exposing, developing and transfer stations producing a copy or multiple copies on plain paper. The organic photoconductive medium is reusable. It is ready immediately after a developed image is transferred to the copy sheet to receive a new image without preliminary mechanical or electrical cleaning of the photoconductive medium.

19 Claims, 5 Drawing Figures

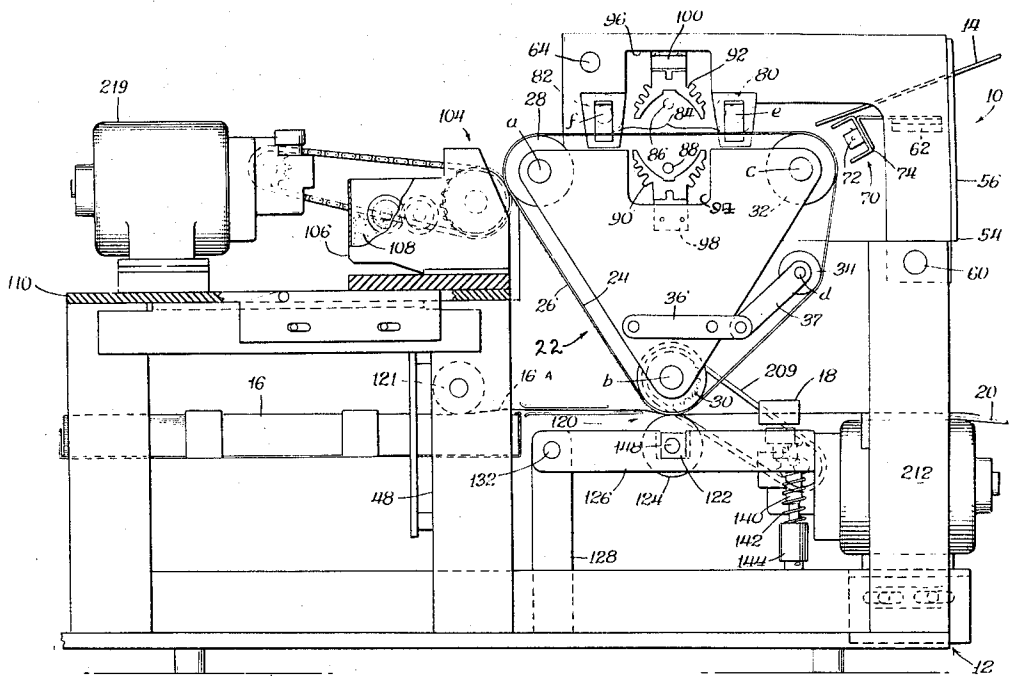
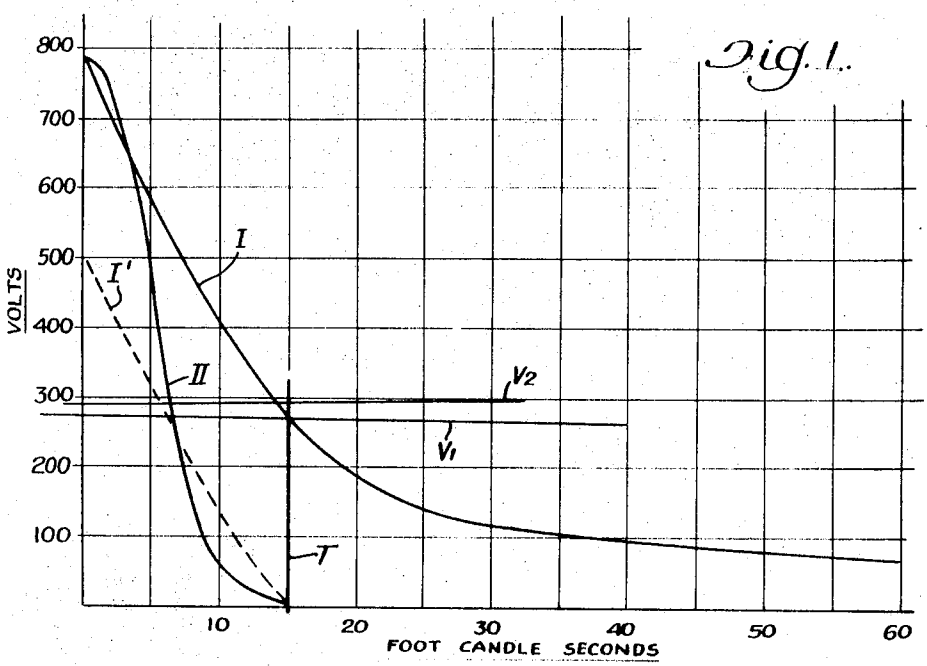


Fig. 1.



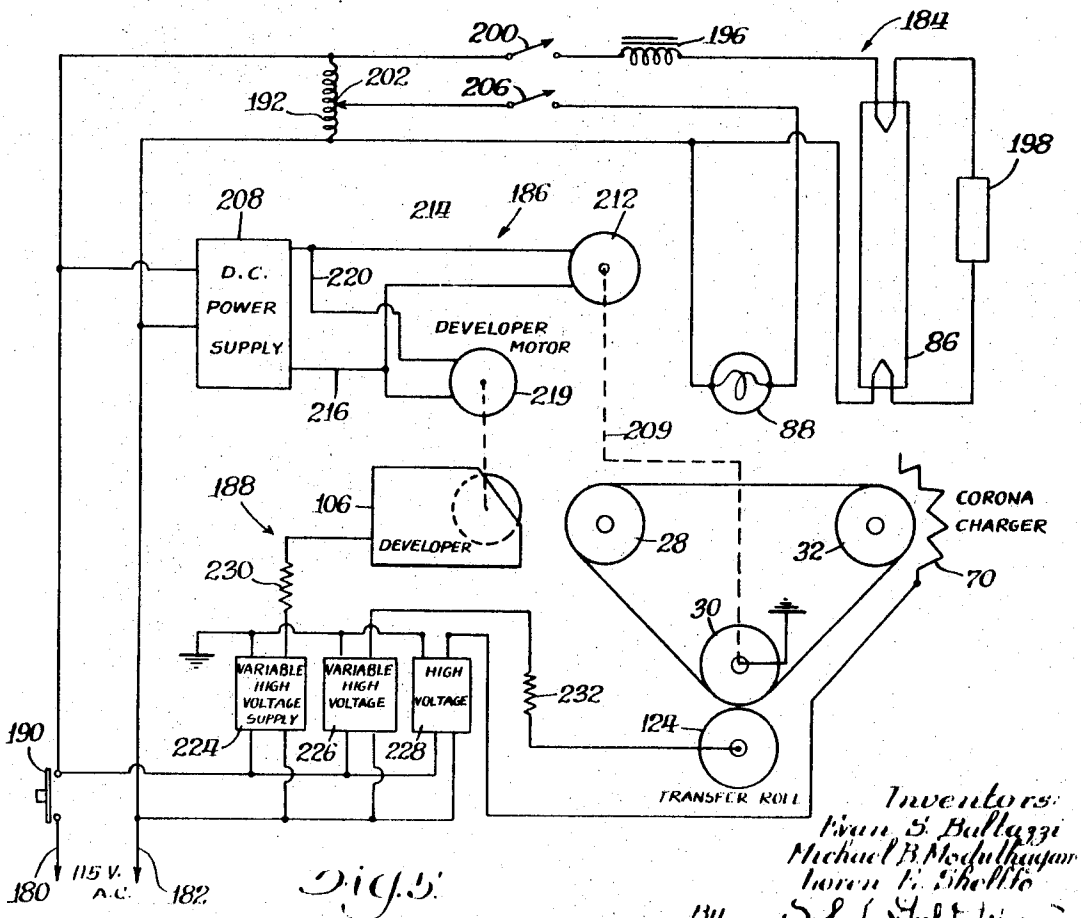


Fig. 5.

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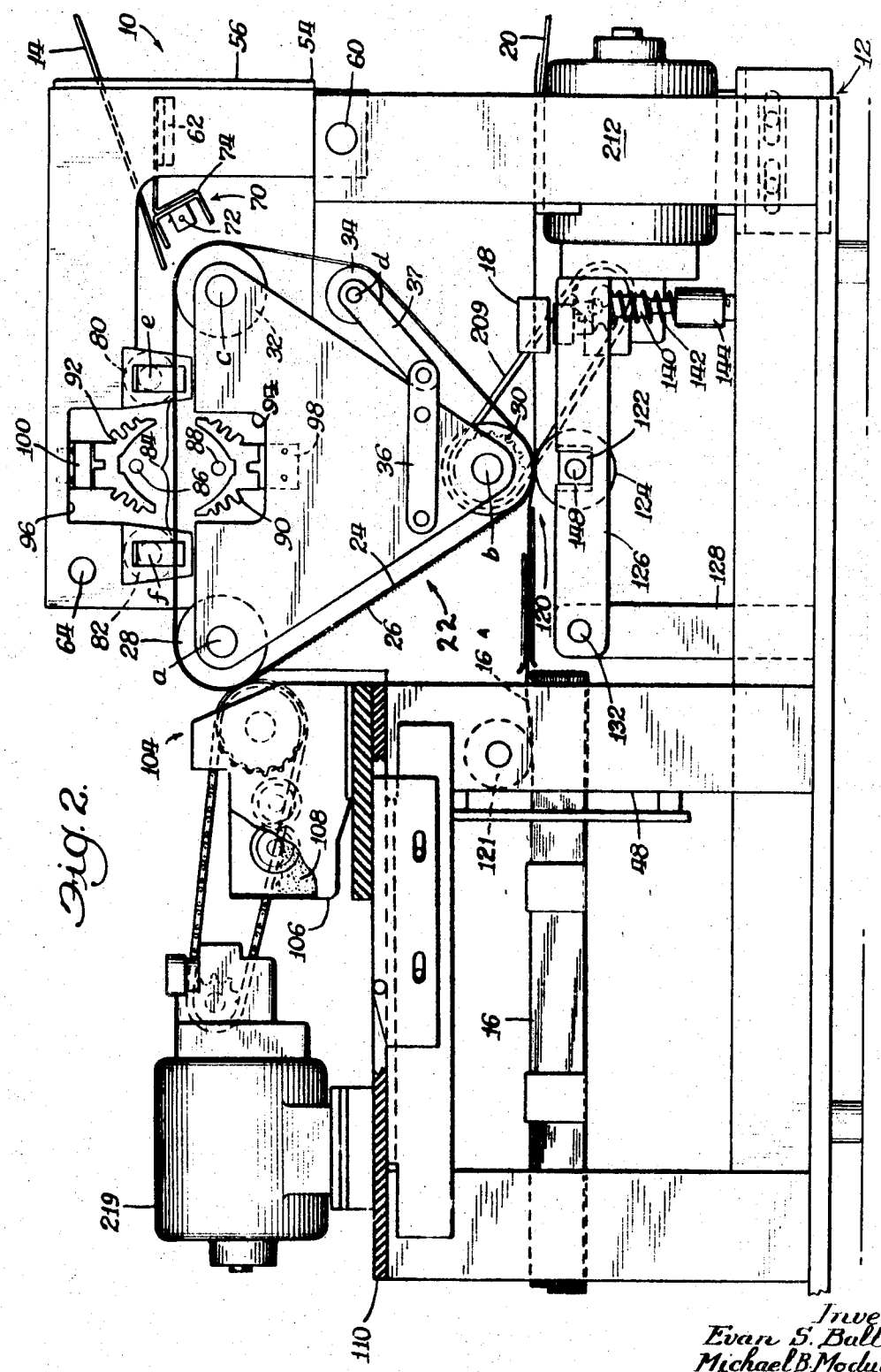


Fig. 2.

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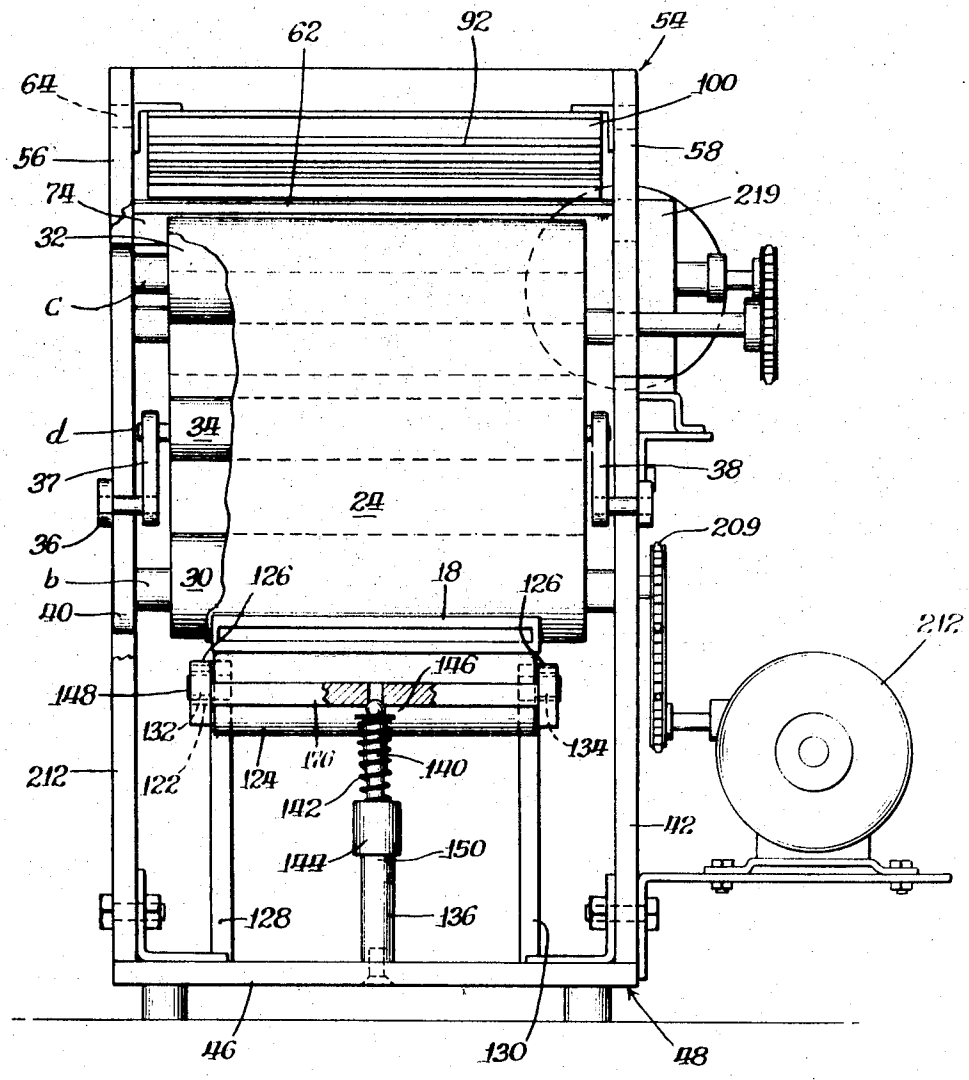


Fig. 3.

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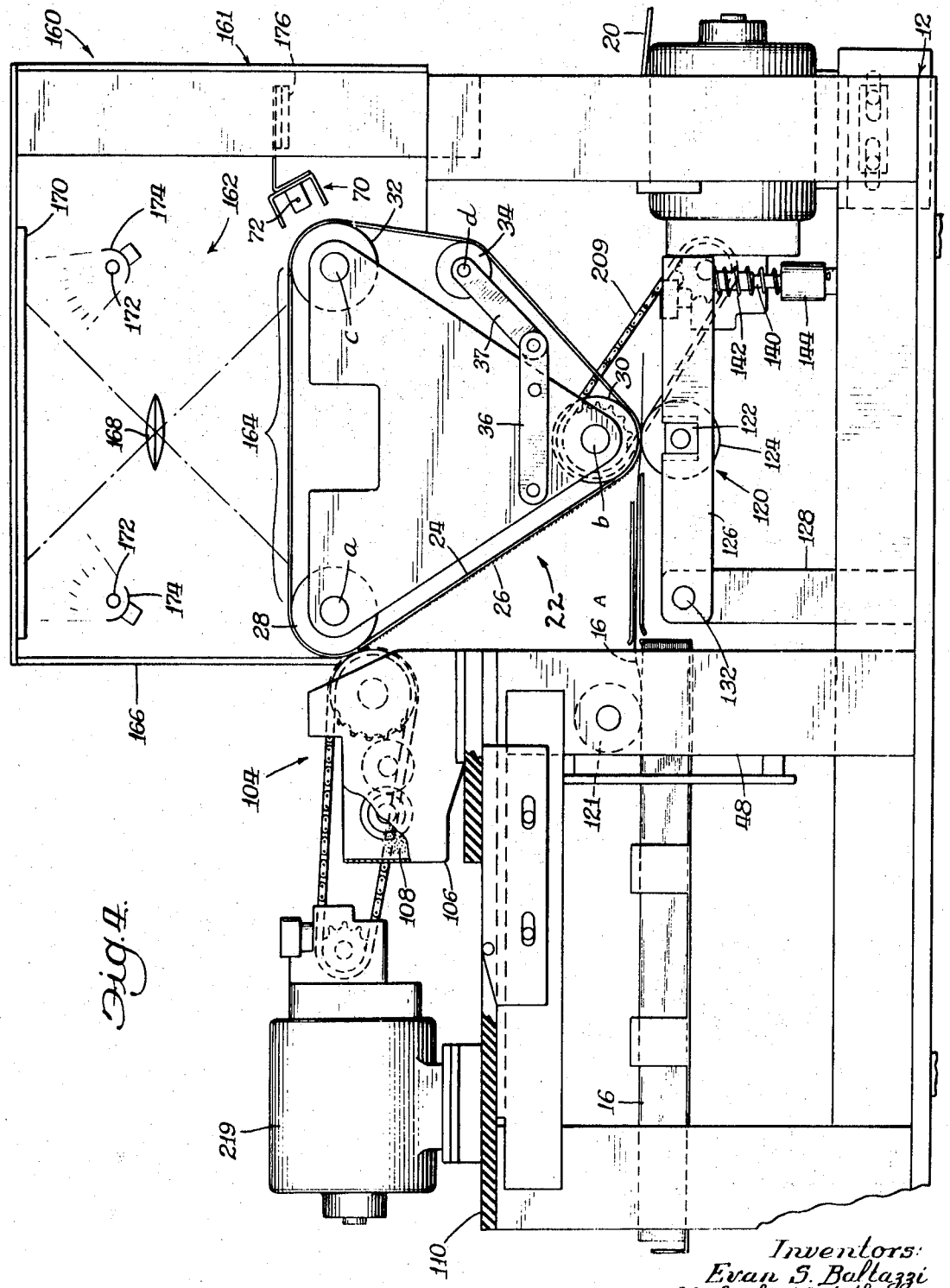


Fig. 8

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PHOTOELECTROSTATIC COPIER HAVING A SINGLE STATION FOR SIMULTANEOUSLY APPLYING TONER PARTICLES AND CLEANING THE PHOTOCONDUCTIVE MEDIUM

This application is a division of copending application Ser. No. 675,463, filed Oct. 16, 1967, Evan S. Baltazzi, Michael B. Moduthagam, Loren E. Shelffo, and assigned to the same assignee as the instant application.

BACKGROUND OF THE INVENTION

This invention relates generally to a simplified photoelectrostatic copying apparatus and more particularly to an apparatus equipped with a continuous belt coated with an organic photoconductive medium capable of transferring developed material images thereon to another surface.

Photoelectrostatic techniques for making single copies of the graphic original on a treated or coated paper are well known. These techniques are described in an article entitled "Electrofax direct Electrophotographic Printing on Paper," by C. J. Young and H. G. Greig, R.C.A. REVIEW, Volume 15, No. 4, pages 469–484, Dec. 1954. The basic "Electrofax" process involves the steps of applying a blanket electrostatic charge on the coated side of the paper while in the dark, exposing the charged surface to a pattern of light and shadow in order to form a latent electrostatic image on the photoconductive surface of said paper, the image then being developed by applying electrostatically attractable pigmented resin powder. This process has been eminently successful in producing copies directly on a flexible substrate, usually paper, which has been coated with photoconductive zinc oxide particles dispersed in a film-forming insulating resin binder. In the circumstance where multiple reproductions of a graphic original were required the complete process, including all steps, were repeated for each reproduction.

Other known techniques for electrostatic copying are based on the use of elemental selenium as the photoconductive medium on which a latent electrostatic image is produced, developed with suitable electroscopic powder, and the powder image is then transferred to an untreated surface, such as plain paper, where it is then fixed by such known techniques as heat fusion or solvent vapor fixing. Subsequent use of the selenium medium requires that the old image be removed or erased, whether it be the same image or a new image, before the next image is created on the selenium surface. Here again, multiple reproductions are achieved by repeating the full cycle for each image transferred. The known apparatus for carrying out the above described photoelectrostatic copying processes are quite complex. Depending on whether a photoconductive metallic ion containing crystalline compound, such as zinc oxide, is employed or elemental selenium, there are certain inherent disadvantages in the photocopying apparatus.

In these differing systems, those which employ zinc oxide as the photoconductive medium, suffer from the deficiency that their surfaces are not reusable. The photoconductive member will accept an image from which one or multiple copies may be prepared by various duplicating techniques such as are fully described in the copending application of Loren E. Shelffo, U.S. Ser. No. 632,819, now abandoned and assigned to the same assignee as the instant application. The same photoconductive member, once the form of the electrostatic image has been developed into a material image, cannot be reused to accept a different form of material image. In other words, the photoconductive medium has to be replaced with a fresh surface.

Reproduction apparatus based on the use of elemental selenium formed into a photoconductive drum will accept different forms of a material image on the same surface but require the intervening step of erasing or otherwise cleaning either mechanically or electrically any trace of the previous image before proceeding to the next imaging step. The step of removing the image requires the use of complex mechanisms and generally renders the equipment costly both from the manufacturing and maintenance aspects.

Apparatus employing the basic photoelectrostatic process for duplicating multiple copies of a single graphic original are known. Transfer techniques involving the use of a photoconductive drum, prepared by the vapor deposition of elemental selenium on a metal drum, require that the photoconductive surface be cleaned or the image otherwise erased after each transfer before the next image can be put on.

Duplicating techniques utilizing an inorganic photoconductive metal ion containing crystalline material as the photoconductive medium can be accomplished by establishing an image receiving medium on the photoconductive surface in the form of a latent electrostatic image and then successively developing and transferring a powder image to the copy sheet. The development and transfer of the material image from the photoconductive medium can turn out as many as 2,000 copies, but, if copies of another original are to be duplicated, a new photoconductive medium has to be used.

There is a need in the photoelectrostatic art for a simplified, low-cost service free, copier-duplicator that can make one copy from each of a number of different originals or hundreds of high-quality reproductions of the same original consistently from a photoconductive medium that is reusable.

SUMMARY OF INVENTION

In accordance with this invention apparatus is provided capable of making copies from a given original by the transfer of a material image, or copies of different originals without replacing the photoconductive medium or without cleaning or otherwise erasing the photoconductive medium between successive transfers.

The photoconductive medium is formed on the surface of a drum or into a continuous belt and stretched over a series of drive rollers so that it moves in a predetermined path that may be oval in configuration or a generally circular path. The precise form, whether it be a belt or a drum, it not critical only that it move in an orbital manner so that the various instrumentalities that give rise to the copy making function can be disposed in a planetary fashion adjacent its photoconductive surface.

The belt is comprised of a conductive base support which may be paper, which has been rendered conductive, or a plastic film such as polyethylene terephthalate, cellulose acetate, vinyl acetate, polyethylene, or other plastic materials which may be formed into a film and rendered conductive either chemically or by metallizing the surface, or the substrate may be made of any metal foil. To one surface of the conductive base support is applied a uniform coating of a photoconductive material which is of the class of organic photoconductors.

It has been found that organic photoconductive materials give surprising results because of their ability to transfer substantial quantities of the developed material image to the receiving sheet. The ability to transfer most of the powder image obviates the need for removing the powder at the end of one cycle prior to the beginning of another so that the presence of the powder does not act as a light barrier and interfere with the formation of subsequent images. The image that is transferred is of high density and generally of good quality.

Another feature of organic photoconductive systems is their ability to rapidly become dark adapted, i.e., the material does not undergo photoconductive fatigue after being charged and exposed repeatedly in rapid succession. These materials exhibit the ability to accept a saturation charge which will be equivalent to its dark adapted condition under a rapid cycling mode of operation with corresponding good dark decay and light decay characteristics. This is important in copier-duplicator apparatus where the photoconductive medium undergoes charging and exposure in rapid succession. Each new cycle requires that the photoconductive medium accept a saturation charge level in a large number of successive cycles equivalent to when the photoconductive medium is in a dark

adapted condition. Hence, the material lends itself to reusability.

A recognized deficiency of these materials is their slow photoresponse when compared to zinc oxide-resin binder systems and selenium. As will be described in greater detail hereinafter, the apparatus and method of the instant invention permits the utilization of the most desirable portion of the light decay characteristic curves of these materials by applying a potential to the developer means that are employed for applying the transferable image.

Such photoconductors may be selected from a wide range of aromatic hydrocarbons such as disclosed in U.S. Pat. No. 3,287,119 to Helmut Hoegl, et al., issued Nov. 22, 1966. Such photoconductors include aromatic hydrocarbons such as naphthalene, anthracene, benzanthrene, chrysene, p-diphenylbenzene, diphenyl anthracene, p-terphenyl, and p-quaterphenyl, and sexiphenyl; heterocyclic compounds such as oxadiazoles; triazoles; imidazolones and imidazolthiones; N-aryl pyrazolines; hydrated imidazoles; and other compounds. The organic photoconductive substances may be applied to the base support from a solvent solution or in conjunction with a film forming binder such as a natural resin such as shellac; a synthetic resin such as coumarone resin, or such binders as cellulose ethers, vinyl polymers, polyacrylates, isobutylene, polyethylene and chlorinated rubbers.

Another group of photoconductors are organic polymeric photoconductive materials. The classes of polymeric substances that have been found to be useful in the apparatus of the instant invention are vinyl polymers, and more particularly carbazole and vinyl copolymers containing vinyl carbazole units. In the circumstance where the photoconductor is an organic polymeric material, it will serve as its own film-forming agent and will not require the use of a separate binder. However, in some instances it may be desirable to add a resin to the polymeric organic photoconductive materials.

The organic photoconductive media may be sensitized to increase its photo response by including additives such as π-complex acids which are disclosed in detail in U.S. Pat. No. 3,037,861, to Helmut Hoegl, et al., issued June 5, 1962.

The belt is stretched around a series of drive rollers to form a continuous loop with the photoconductive surface facing outward from the center of the loop. The instrumentalities necessary to create a transferable material image from the belt surface are disposed along the path of movement of the belt at various stations. One of the belt drive rollers is connected to a main drive motor to move the belt along the predetermined path.

At the first station there is provided a charging means for imparting a blanket electrostatic charge to the photoconductive layer. A source of charge emission juxtaposes the belt surface spraying charges uniformly over the belt surface as it passes underneath the source. Such a charging device may be in the form of a conventional corona emission wire operating against a ground plane or a pair of opposing corona emission electrodes of opposite polarity.

The charged belt by virtue of its electrostatic charge is now sensitive to electromagnetic radiation and the drive means brings it to a second station where a pattern of light and shadow is cast upon the charged surface to create a latent electrostatic image. The exposure station may be equipped with an optical system in order to project the pattern onto the charged surface or optionally may provide for contact exposures by bringing the original subject into contiguous contact with the charged surface and then directing radiation onto the assemblage. In the circumstance that the belt is transparent, a further option is available for effecting a contact print by the reflex technique whereby the radiation is directed onto the base support side of the belt. To accomplish this, a radiation source is mounted within the loop at the second station.

At the second station the photoconductive belt is stretched between drive rollers so as to present a flat planar surface which can function as an exposure plane either for contact printing or projection imaging.

Leaving the second station, the belt moves to the third station at which a toner is applied to the latent image-bearing photoconductive surface. The developer construction provided in the instant invention is of the conventional magnetic brush-type applicator. It has been found desirable that the magnetic brush-type construction be connected to a source of direct current potential having the same polarity as the latent electrostatic image so as to provide a field between the latent image and the brushlike formation of the developer mix. The establishment of a field between the brush and the charge image requires the developer apparatus to be electrically insulated from the rest of the machine, that is, electrically floating. Any residual toner in the background areas remaining on the surface from the previous cycle is reattracted onto the brush. In this way the accumulation of toner from one run to the next is eliminated.

The toner is selectively attracted to the charge image producing a transferable material image on the organic photoconductive medium.

The material image-bearing surface of the belt is next conveyed to the fourth station where a transfer roll is in pressure contact with one of the belt drive rolls with the belt passing between the nip of the rollers. Included in the structure of the fourth station is a supply of image-receiving copy sheets which are fed in timed relation with the image-bearing portion of the belt between the transfer roll and the belt. The pressure roller set preferably should provide a resilient roller in pressure contact with a hard surface roller with either the transfer roll or the belt drive roll having the resilient surface.

The control of the amount of pressure exerted at the transfer station is significant when utilizing equipment in the duplicating mode, which involves making transfers from the same latent image, and accordingly the transfer roll is adjustable mounted permitting uniform setting of the roller position from end to end in order to produce the required pressure at the transfer station.

As the copy material exists from the transfer station it is passed through a fuser where the transferred powder image is fixed by heat, pressure or solvent vapors.

It is desirable to provide an electrical field at the point of transfer between the material image and the copy sheet. This field operating in conjunction with the controlled pressure is important to the success of the duplicating mode of operation.

As each increment of the photoconductive medium leaves the transfer station, it is automatically in condition to be reprocessed, i.e., either using the undisturbed latent electrostatic image or to again receive a blanket electrostatic charge to render the photoconductive medium sensitive to electromagnetic radiation.

It is a general object of this invention to provide a compact, economical photoelectrostatic copying apparatus that is greatly simplified in its construction and operation and capable of producing high-quality reproductions on plain paper.

It is another object of this invention to provide a photoelectrostatic machine that is compact, low cost, high speed, and produces high-quality copies on plain paper capable of making a single copy from a number of different originals or multiple copies from one original by a transfer technique.

It is yet another object of this invention to provide a photoelectrostatic machine capable of making a single copy or multiple copies either by contact printing or projection printing on plain paper.

It is yet another object of this invention to provide a photoelectrostatic machine equipped with an organic photoconductive medium that is capable of producing a single copy or multiple copies simply and economically by transfer to plain paper.

It is a specific object of this invention to provide a photoelectrostatic copying apparatus in which the photoconductive medium is an organic photoconductor formed into a continuous belt that is recycled without cleaning.

It is another specific object of the invention to provide a photoelectrostatic copying apparatus in which the application

of the developer powder is carried out in the presence of an adjustable electrical field to produce an apparent increase in the photo response of the photoconductive medium.

It is yet another specific object of this invention to provide a photoelectrostatic copying apparatus in which complete transfer of material image to a copy sheet is accomplished under controlled pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more easily understood by reference to the following detailed description and to the drawings in which:

FIG. 1 illustrates the light decay characteristics of the photoconductive materials used in this invention compared to prior art materials.

FIG. 2 is a side view of the apparatus of this invention with the side covers removed.

FIG. 3 is a front view of the apparatus with the cover removed.

FIG. 4 is a side view of another embodiment of the apparatus of this invention.

FIG. 5 is a schematic electrical wiring diagram.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Having reference now to the drawings, and particularly FIG. 1, there is illustrated the light decay curves of an organic photoconductive medium identified as I and I'; curve II represents a typical prior art zinc oxide resin binder system which has been dark adapted.

The material depicted in curve I shows a rather rapid drop in voltage upon exposure to light which tends to slow down forming a well-defined toe portion at the 200-volt level. The toe portion of the light decay curve represents a decreasing photoresponse efficiency in the electrophotographic member when attempting to achieve a lower voltage level in the nonimage areas as compared to the voltages in the image areas. It will be appreciated that when a photoconductive material, such as an organic containing medium, is said to have a slow response, it refers to the increased amount of exposure represented by the lower portion of the curve to reduce the voltage level in the light struck areas to zero so that there is achieved the maximum differential between the voltage levels in the image and nonimage areas.

It will be recognized that in order to utilize such a photoconductive medium in a high-speed copier-duplicator, unduly large exposure would be required to reduce the charge in the light struck areas to a level where they would not attract toner.

A comparison of curve I with curve II will show that much longer exposures may be required with the organic photoconductive medium to expose the nonimage area to where its voltage approaches the same zero level as zinc oxide.

It was found that by imposing a potential between the photoconductive medium and the developer the voltage level on the photoconductive medium represented by the toe portion need not be dissipated to zero by exposure to electromagnetic radiation. In the circumstance that the material was exposed for T foot candle seconds, the selected light struck areas would be at a corresponding voltage level V_1, which would attract toner. Upon the application of a potential V_2 to the developer proper at the same polarity and at a level equal to or slightly greater than the residual potential V_1, the light decay curve behaves as if it has been shifted to the position shown by the dotted line curve I'. By applying a potential V_2 to the conductive substrate while keeping the developer at ground there is provided the same control over the amount of exposure required. In the latter case the polarity is opposite in sign to the charge image and again the potential must be at least equal to charge level in the background and up to 100 volts less than the charge image.

The organic photoconductor can be charged over a range of from 100 volts to 1,200 volts, the preferred range being from 300 volts to 800 volts. The background voltage may range from 50 volts up to within 100 volts of the charge image. The potential provided between the developer and the photoconductive medium must be equal to or slightly greater than the voltage in the background area.

Referring again to FIG. 1 and curve I in particular, the effect of this control potential may be illustrated by examining the performance of a typical organic photoconductive medium such as polyvinyl carbazole. The medium is charged to a level of 775 volts. From the curve it can be seen that it would require an exposure in excess of 60 foot candle seconds to reduce the voltage in the background area to a level of 50 volts or less where it would no longer attract toner. In carrying out the objects of this invention, the exposure is reduced by varying either time or intensity to the point along the curve where the voltage is about 275 volts. This would require an exposure of about 15 foot candle seconds. In order to negate the high-voltage level in the background, a potential is provided at the developing site equal to 275 volts or greater. In the instant example the voltage was about 290–300 volts. If the potential is applied to the magnetic brush, it is the same sign as the charge image and if applied to the conductive support, it is opposite in sign. The effect of such a control potential is to permit the use of the photoconductive member in the portion of the curve with the greatest slope and, hence, give the effect of having shifted the curve to the dotted line position 1.

Another feature of this instant apparatus and method is the ability to recycle the photoconductive medium in rapid succession, producing copies from different originals by transfer without an accumulation of toner such that a separate mechanical or electrical means of cleaning the surface between cycles is not required. As pointed out hereinabove, the organic photoconductors in the proper environment have been found to substantially transfer the material image. Understandably, some of the toner will not transfer adhering in the image and background areas at the conclusion of a cycle. The amount that remains, however, does not interfere with the charging or exposing steps.

Surprisingly, there is no accumulation of toner after successive cycles, as would be expected, and it is believed that any remaining toner is recovered in the developer simultaneously with the development of a new image. The exact explanation for this recovery of toner is not fully understood, however, it is believed that the loosely adhering toner is readily attracted to the developer. As a result of this control over the toner from one cycle to the next, the belt remains substantially free of toner to the extent that high-quality images free of background are transferred at the end of each cycle and the next cycle has available a photoconductive medium free of toner that may interfere with charging and exposure of a new image.

Referring to FIGS. 2 and 3, there is illustrated a copy machine 10 constructed in accordance with the present invention. The copy machine 10 is of the photoelectrostatic type enclosed in a cabinet or housing 12, an infeed station 14 into which are fed the originals to be reproduced. At the lower portion of the housing there is provided a stack supply of cut sheets 16 from which are fed the copy sheets to which are transferred the powder images. The copy sheet passes through a fixing station 18 and emerges into a copy receiving tray 20 at the front of the housing 12.

Within the central portion of the housing is the photoconductive medium identified generally as 22. The photoconductive medium comprises a continuous belt 24 having applied to the surface thereof a photoconductive coating or layer 26. The continuous belt is stretched about a plurality of rotatable rolls 28, 30, 32, and 34 which are mounted for rotation about horizontal parallel axes *a*, *b*, *c*, and *d*, respectively. One of the rolls, such as roll 34, is swingably mounted on a bracket member 36, being designed for displacement away from the belt path to serve as a belt tensioning control. Another of these rolls, for example roll 30, is caused to be positively rotated through shaft b, by suitable driving mechanism contained within the housing 12.

The tensioning roll **34** is journaled at its opposite end in the swingable arms **37** and **38** which in turn are pivotally mounted on the end plates **40** and **42**. The remaining rolls **28**, **30**, and **32** are journaled directly in the plates **40** and **42**. The end plate **42** rises from a base portion **46** of the frame structure **48**, while the end plate **40** which receives the other shaft ends for the rolls **28**, **30**, and **32** is unsupported, giving rise to a cantilever-type mounting for the photoconductive medium **22**, so that the belt **24** may be easily mounted and removed through the release of the tensioning roll **34**. It will be appreciated that the portion of the belt passing between the rolls is in a flat planar condition and that the belt coursing over the rolls provides suitable working areas for the various instrumentalities hereinafter described.

Surmounting the photoconductive belt assembly **22** is a swingably mounted superstructure **54** formed of a pair of L-shaped members **56** and **58** hingedly secured to the frame **48** through the fasteners **60** and held in spaced apart relation by the tie bars or rods **62** and **64**. The superstructure **54** is swingably mounted to a position overlying the flat portion of the path taken by the belt **24** passing over the rolls **28** and **32**.

On the underside of the superstructure **54** is a corona discharge device **70** which includes a fine wire electrode **72** stretched inside the conductive shield **74**. The corona discharge device extends between the members **56**, **58**, being affixed to the tie bar **62**. The corona discharge device is mounted in spaced relation from one-half to three-eighths inch above the organic photoconductive layer **26** as the latter rounds the roll **32**. The photoconductive layer **26** is imparted a blanket electrostatic charge at this station.

Included on the underside of the superstructure at the portion spanning the rolls **28** and **32** are a pair of rotatable rolls **80** and **82** mounted for rotation about the shafts *e* and *f* which, in the portion shown in the drawings are parallel to the shafts *a* and *c* and reside inside the lateral dimension between the rolls **28** and **32** extending over the full width of the belt **24**. The belt, as it courses between the two sets of rolls **28**, **32** and **80**, **82** is supported from below and above, respectively, to provide a taut, flat optical exposure plane **84**. A pair of elongated radiation sources **86** and **88** are supported in suitable reflector housings **90** and **92** which straddle the belt and extend the width thereof providing the option of irradiating the photoconductive layer **26** either through the belt or directly from above. The reflector housings are mounted respectively in the cutout portions **94** and **96** provided in the superstructure and the end plates **40** and **42** through bracket members **98** and **100**. The roll arrangement also serves to bring the original which is to be reproduced into intimate and contiguous contact with the photoconductive layer **26** over the entire exposure plane **84**.

In operative association with the roll **28** is the developer assembly **104** for applying the electroscopic powder to the latent image-bearing photoconductive layer **26** as it leaves the exposure station. The developer assembly includes a trough **106** in which is contained a supply of developer powder which can be a conventional mixture **108** of iron carrier particles in an electroscopic thermoplastic powder of the type used in magnetic developers. The construction and operation of magnetic brush developers are well known and will not be discussed in detail here. It has been found necessary in the mounting of the developer assembly described hereinbefore that it be electrically floating, i.e., insulated from the rest of the apparatus. The trough is supported on a shelf or platform **110** comprised of a highly insulating plastic material, such as acrylic or polystyrene resins or the equivalent, which in turn is supported by the frame structure **48**. The metal trough is connected to the negative terminal of a DC voltage supply and the other terminal of the supply being connected to ground. It has been found desirable to apply a negative potential to the developer in the range that is equal to or slightly greater than the voltage in the background area.

It will be appreciated that the application of the developer powder has been described in terms of a magnetic brush assembly; other types of powder development may be used, such as, for example, a cascade development using conductive glass beads.

Transfer of the material image to the copy sheet is accomplished at the transfer station **120** at which a copy sheet **16A** is fed from the supply stack **16** by means of feed wheel **121** in timed relation to the arrival of the image at the transfer station. In pressure contact with the roll **30** is a transfer roll **124** which causes the powder image to transfer to the copy sheet **16A**. The transfer roll **124** operating in conjunction with the roll **30** will cause the powder to transfer to the copy sheet. The transfer roll (FIG. **3**) is journaled for rotation in an insulating bearing **122** which in turn is received in a pivotable yoke **126** which is affixed to the upright **128** and **130** through pivoting connections **132** and **134**. The yoke is supported at its front end by an adjustable plunger **140** urged against the yoke by a coiled spring **142** which surrounds the body of the plunger, one end of the plunger being received in a sleeve member **136** having an outside thread (not shown). The spring is compressed between a threaded nut **144** threaded on the sleeve and a shoulder **146** at the head portion of the plunger. The body of the sleeve which is adapted to receive one end of the plunger has markings **150** scaled in "plus" or "minus" fractions of an inch on either side of a zero position to indicate the location of the plunger therein as measured against the bottom edge of the adjusting nut **144**. When the adjusting nut is at "0" the rollers are just touching; when lined up with a minus reading the plunger is moved deeper into the sleeve and rolls **30** and **124** are apart; and a plus reading represents the amount of compression of the rubber roll **124** and, hence, a decrease in its radius at that point.

Greater or lesser pressure between the transfer roll **124** and the roll **30** is achieved by increasing or decreasing the compression of the spring. During the copy making mode the pressure may range from 2 pounds to 100 pounds per lineal contact inch. One advantage of the spring biased support is its yieldability to abnormal or unusual thicknesses of paper going through the rolls, thereby avoiding damaging either the transfer roll **124** or the roll **30**.

In the circumstance that the apparatus is to be operated in the duplicating mode, i.e., where the material image is transferred from the photoconductive surface and thereafter the latent image is successively redusted and transferred, it becomes necessary to apply a field between the surface of the powder image and the plain paper which is fed from the stack **16**. To create the proper environment for the duplicating mode, a DC voltage is applied to the transfer zone by connecting the metal shaft **148** to a DC supply applying a field having a polarity which is the same as the polarity of the electrostatic charges in the latent image portions. The transfer roll preferably is made of a conductive rubber having a resistivity in the range of from 10^{16}–10^{11} ohm-centimeters. The voltage applied to the conductive core of the roll **124** is in the range of from 1,000–3,000 volts, preferably in the range of from 1,200–2,000 volts, and the pressure in the range of from 2 pounds to 8 pounds per square inch contact area.

The stack supply of copy sheets **16** is located generally beneath the shelf **110** having a feeder wheel **121** frictionally engaging the uppermost sheet in the stack. The feeder wheels are driven from the main drive motor to feed a copy sheet for arrival at the transfer station in timed relation with the arrival of the powder image thereat.

It will be appreciated that a roll feed could be used to equal advantage in the instant apparatus in conjunction with a suitable cutting means for severing the copy sheet once the image has been transferred thereto.

Referring to FIG. **4**, there is shown another embodiment of the apparatus of this invention, identified generally as **160**, in which the exposure of the photoconductive surface is accomplished using an optical system to project a pattern of light and shadow produced by illuminating an original held on a flat transparent platen.

The apparatus **160** employing projection optics is similar in construction with respect to the processing instrumentalities to the apparatus hereinabove described with the exception of the exposure station.

Within the framework **161** is a photoconductive medium **22**, comprising a continuous belt **24** stretched about a plurality of rotatable rolls **28, 30, 32,** and **34**. The belt tensioning roll **34** is pivotally mounted on the end plates **40** and **42**.

Surmounting the photoconductive medium is an optical assembly **162** for projecting a pattern of light and shadow on that portion of the belt passing between the rolls **28** and **32** which functions as an exposure plane **164**, said assembly including a lighttight enclosure **166** having supported therein a lens element **163**. The top portion of the enclosure **166** is equipped with a window opening **170** upon which is received the original subject to be reproduced.

Adjacent the underside of the window **170** within the enclosure **166** are a pair of elongated radiation sources **172** mounted in suitable reflectors **174** to properly illuminate the original and produce a pattern of light and shadow which is then received into the lens **163** and thence projected onto the organic photoconductive layer **26** at the exposure plane **164**.

The corona discharging device **70** is mounted on extensions of the upright frame structure **48** being secured to the structural cross piece **176** in position juxtaposed the photoconductive surface of the belt as it passes over roll **32**.

The developer construction of the developer assembly **104** and the operation and construction of the transfer station **120** have been fully described hereinabove in connection with FIG. **2**.

The electrical controls of the apparatus of FIG. **2** of this invention are represented by the wiring diagram of FIG. **5** showing the feed lines **180** and **182** connected across a 115-volt AC supply which feeds three control circuits generally identified as **184, 186,** and **188** representing respectively the illumination control, developer and main drive control, and the high-voltage power circuit.

The main switch **190** is connected in line **180** which, in its closed condition, provides 115 volts AC to the variable reactance **192** connected directly across the feeder lines. The output of the variable reactance control supplies power to the fluorescent tube **86** equipped with the conventional ballast **196** and starter **198** which is energized upon closing switch **200**. The center top **202** of the variable reactance control **192** provides a voltage supply to the quartz lamp **88** which is energized upon closing switch **206**.

The drive control circuit **186** is powered by a DC power supply **208** connected across feeder lines to the power supply **208**. The main drive motor **212** is connected by conductors **214** and **216** to the supply **208** which drives the roll **30** through a suitable belt drive **209**. The developer motor **219** is connected to the supply **208** through conductors **220** and **216**.

The high-voltage power supply circuit **188** includes separate power supplies **224, 226,** and **228** which are connected across the feeder lines. The supply **224** provides a variable voltage to the developer assembly **104** through a resistance **230** (25 megohms), supply **228** provides voltage to the charging device **70**, and supply **226** provides the voltage to the transfer roll **124** through a resistance (25 megohms).

In operation the apparatus is turned on by closing contact **190** which applies 115 volts to the high-voltage power supplies **224, 226, 228** which supply the developer, transfer roll and the corona discharge. The power supplies to these instrumentalities remain energized during operation.

At the same time the drive motors **219** and **212** are energized through normally closed contacts **218** and **222** so that the belt moves past the various stations.

The operator next selects the mode of exposure which may be by contact or projection and in the former case the exposure may be through the original by the lamp **86** or through the transparent base support in which case lamp **88** must be energized. The selection is made by closing switch **200** for energizing lamp **84** or switch **206** for turning on lamp **88**.

The lamp selected remains energized in order that the portion of the photoconductive medium between exposed areas is discharged so it cannot attract toner. In the projection mode the lamp is turned on only for exposure but a separate lamp is used to clear the charge. Lamps **172** would be used for projection.

The photoconductive medium, prior to advancing to the exposure area, received a first charge level as it passed beneath the corona wire **72**.

A printed one-side original is fed in at the infeed station **14** and is carried into the nip between the roller **80** and the belt **24**. The length of the belt extending between rollers **80** and **82** forms a flat exposure and the original is exposed by lamp **86** since a one-sided original is used. The exposed original exits from roll **82**.

The surface **26** now has a latent electrostatic image including a second level of potential in the exposed areas and advances to the developer **104** where the image is developed.

As the belt leaves the developing station, a control device (not shown) for the feeder wheel is energized to feed a sheet of paper in timed relation with the image portion of the belt so that both arrive at the transfer station in alignment to properly locate the image.

The transfer occurs under a pressure setting in the range of from 2 pounds to 100 pounds per lineal contact inch, preferably in the range of from 10 pounds to 50 pounds per lineal contact inch, and thence through the fuser **18** into the copy tray **20**.

The medium is then immediately ready for another original.

While the apparatus has been described in terms of a negative corona, it is contemplated that the apparatus and method can be utilized with a positive corona and a reversal developer material while imposing a positive potential to the developer, or a negative potential to the base support.

The invention has been described with some particularity. The use of organic photoconductive systems which exhibit the feature of reusability without fatigue is unique and one skilled in the art may make variations which would come within the scope of the instant invention.

What is claimed is:

1. In an apparatus of the type described for making reproductions of graphic originals on copy sheets from a reusable photoconductive medium, the combination comprising:

continuous conductive support means carrying thereon said photoconductive medium comprising an organic photoconductive film;

drive means for cycling said support in a predetermined path past a series of processing stations during any one cycle, said stations comprising:

means for charging said photoconductive medium,

means for producing a differential charge pattern comprised of image and nonimage areas,

developing means for developing said pattern into a transferable material image by applying toner to said medium,

means for transferring a substantial portion of said material image to said copy sheet under pressure,

means for feeding a copy sheet to said transfer means in timed relation with the arrival of said material image thereat,

said developer means reattracting any untransferred toner remaining on the medium during the next cycle as the belt proceeds along said predetermined path whereby the image and nonimage areas presented to said transfer means during any one cycle contain essentially the toner applied during the current cycle.

2. In an apparatus of the type described for making reproductions of a graphic original on a copy from a reusable photoconductive medium, the combination comprising:

continuous conductive support means carrying thereon said photoconductive medium comprising an organic photoconductive film;

drive means for cycling said support in a predetermined path past a series of processing stations during any one cycle;

means for applying a uniform electrostatic charge at a first level of potential at a first station;

means for reducing said first level of potential in selected areas on said photoconductive medium to a second level of potential at a second station along said path;

developer means for developing a transferable material image by applying toner to said charge pattern at a third station;

means for transferring a substantial portion of said material image to said copy sheet at a fourth station so that the amount of untransferred toner does not interfere with the processing at the first and second stations during the next cycle,

means for feeding a copy sheet to said fourth station to receive said material image,

means for imposing a potential at said third station at a level that is between said first and second levels,

said developer means reattracting any untransferred toner at the third station on the medium during the next cycle as the support proceeds along said predetermined path whereby the medium presented to said fourth station during any one cycle contains essentially the toner applied during the current cycle.

3. The apparatus as described in claim 2 in which means are provided for imparting a potential to said conductive support at a level of potential that is between said first and second levels and having a polarity opposite to said charge image.

4. The apparatus as described in claim 2 in which said means for imparting a potential to said developer comprises a magnetic developer brush insulated from ground potential and connected to a DC supply source.

5. The apparatus as described in claim 4 in which the polarity of said applied potential is of the same sign as said first level of potential.

6. The apparatus as described in claim 2 in which said graphic original is placed in contiguous surface contact with said photoconductive layer at said second station.

7. The apparatus as described in claim 2 in which said exposing means includes an optical system for projecting a pattern of light and shadow onto said photoconductive medium.

8. The apparatus as described in claim 2 in which a transfer electrode is provided at the fourth station which is connected to a DC power supply having a polarity of the same sign as the first level of potential.

9. The apparatus as described in claim 2 in which said transfer means includes pressure control means for regulating the pressure at the transfer station to be exerted against said copy sheet.

10. The apparatus as described in claim 9 in which said pressure is within the range of from 2 to 100 pounds per lineal contact inch.

11. The apparatus as described in claim 2 in which the photoconductive film is polyvinyl carbazole.

12. In an apparatus of the type described for making reproductions of graphic originals on copy sheets from a reusable photoconductive medium, the combination comprising:

continuous transparent conductive support means carrying thereon the photoconductive medium comprising an organic photoconductive film;

drive means for cycling said belt in a predetermined path past a series of processing stations;

means for applying a uniform electrostatic charge at a first level of potential at a first station;

means for reducing said first level of potential in selected areas on said photoconductive medium to a second level of potential at a second station along said path by irradiating said original in contact with the medium with electromagnetic radiation directed through said transparent support means to produce a differential charge image on said medium;

developer means for developing a transferable material image at a third station by applying toner to said charge image;

means for transferring a substantial portion of said material image to said copy sheet at a fourth station so that the amount of untransferred toner does not interfere with the processing at said first and second stations during the next cycle;

means for feeding a copy sheet to said fourth station to receive said material image;

means for imparting a potential at said third station at a level that is between said first and second levels, said developer means recovering any untransferred toner on said medium at said third station during the next cycle as the support proceeds along said path whereby the medium presented to said fourth station during any one cycle contains essentially the toner applied during the current cycle.

13. The apparatus as described in claim 12 in which the developer means is a magnetic brush connected to a DC power supply.

14. The apparatus as described in claim 13 in which said first level of potential is in the range of from 100–1,200 volts, said second level of potential being at least 100 volts less than said first potential and the potential applied to said developer is equal to or slightly greater than said second level.

15. The apparatus as described in claim 12 in which the potential is applied to said conductive support and is opposite in sign to the first level of potential.

16. The apparatus as described in claim 12 in which a transfer electrode is provided at said fourth station which is connected to a DC voltage supply having a polarity of the same sign as said first level of potential.

17. The apparatus as described in claim 12 in which said transfer means includes pressure control means for regulating the pressure exerted on said copy sheet.

18. The apparatus as described in claim 17 in which the pressure applied ranges between 2 pounds and 100 pounds per lineal contact inch.

19. In an apparatus for making a copy of a graphic original on a copy sheet by developing latent electrostatic charge images with electrostatically attractable material,

a flexible endless belt including a conductive layer having an organic photoconductive film on one surface, said film having a light decay characteristic such that the film retains a charge of a given voltage sufficient to attract the electrostatically attractable material in illuminated areas after a given quantity of illumination has been received by the film,

drive means for repeatedly moving the flexible belt over a given path,

means positioned adjacent the path for establishing a latent electrostatic image on the belt in accordance with an original to be copied by subjecting the film to said given quantity of illumination,

developing means disposed adjacent the path for applying electrostatically attractable material to the belt so that the latent electrostatic image is developed as a material image,

means for applying a potential gradient between the conductive layer and the developer means of a magnitude at least as great as said given voltage so as to prevent the retention of material by the film in illuminated areas,

and means disposed along the path subsequent to the developing means for transferring the material image to a copy sheet.

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