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Hastwell et al.

[11] **3,836,245**

[45] **Sept. 17, 1974**

[54] **COPY MACHINE HAVING PHOTOCONDUCTIVE BELT**

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[52] **U.S. Cl.** **355/8,** 355/10, 355/14, 355/16

[51] **Int. Cl.** **G03g 15/22**

[58] **Field of Search** 355/3, 4, 5, 6, 7, 8, 10, 355/11, 14, 16, 76, 91; 271/51, 74; 118/637, 50, 50.1, 239, 257, 62; 117/37, 38, 25; 101/134.5

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[57] **ABSTRACT**

An electrostatic copying machine for producing multiple copies of an original wherein several latent electrostatic images are formed on contiguous segments of a photoconductive surface on a moving belt supported by an air bearing. The belt is stopped for the exposing and developing (and, in one embodiment, image transfer) steps, and the scanning unit moves in opposite directions in successive copying cycles. Machine operation is controlled alternately by microswitches actuated by projections on the belt and by scanner-actuated microswitches. Three kinds of image transfer devices using pressure alone are disclosed, including one for which the belt is stopped during the transfer step.

10 Claims, 5 Drawing Figures

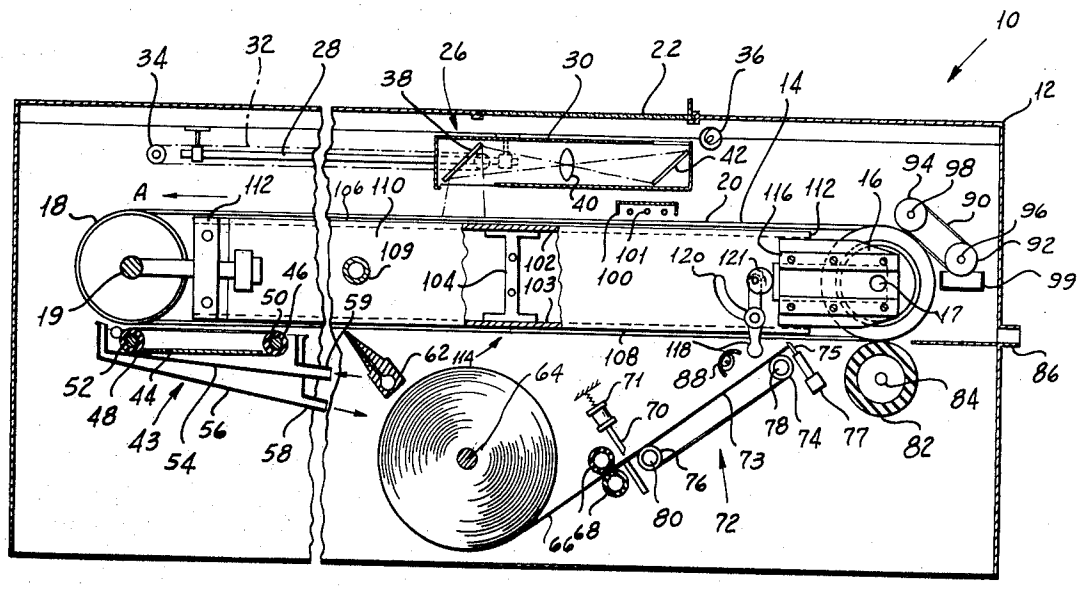
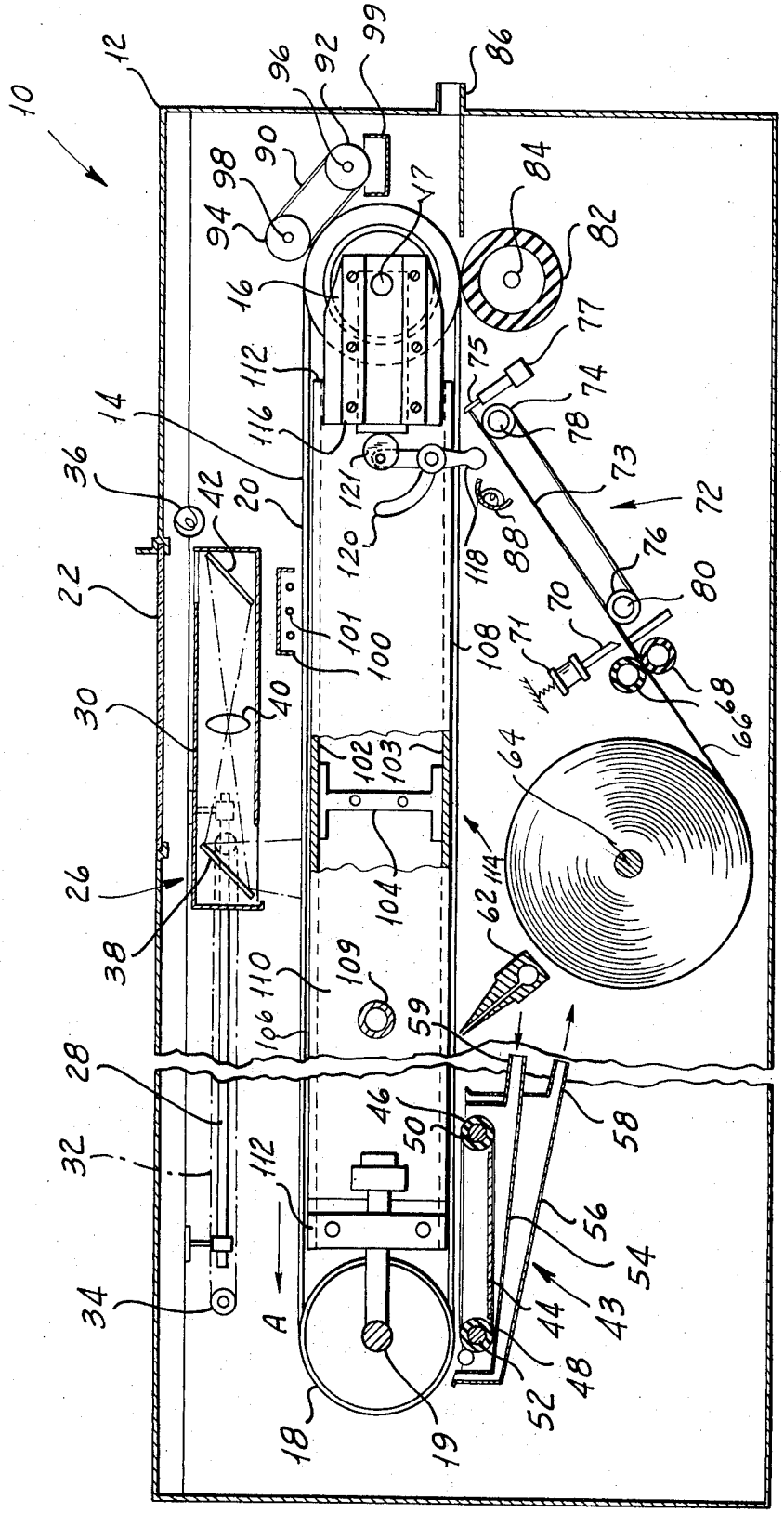


Fig 1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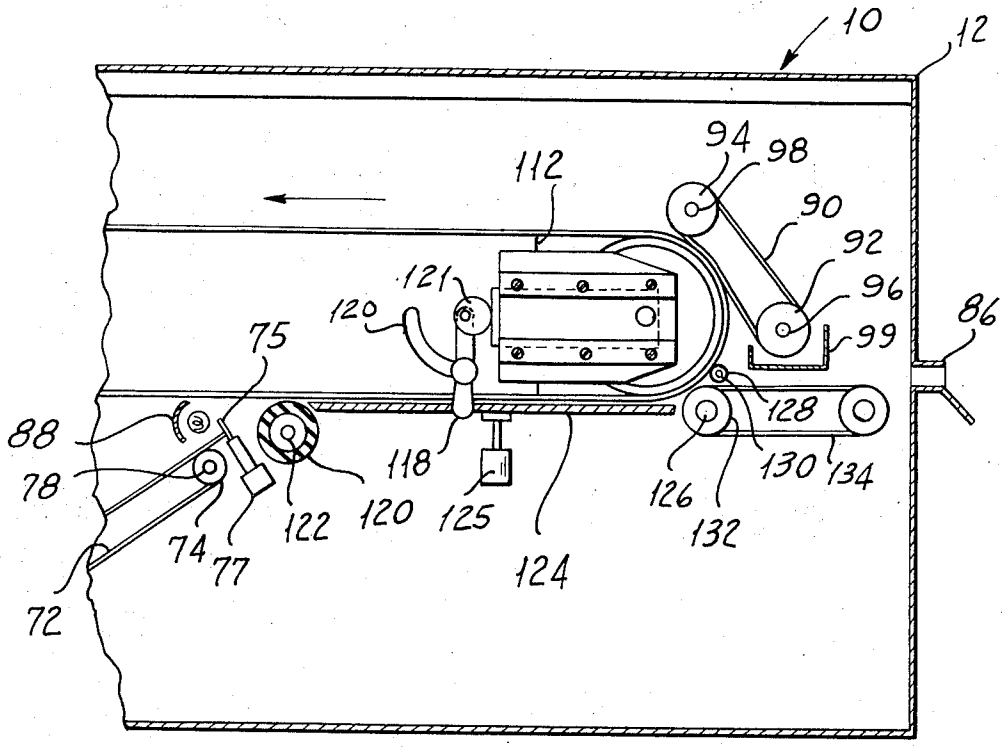
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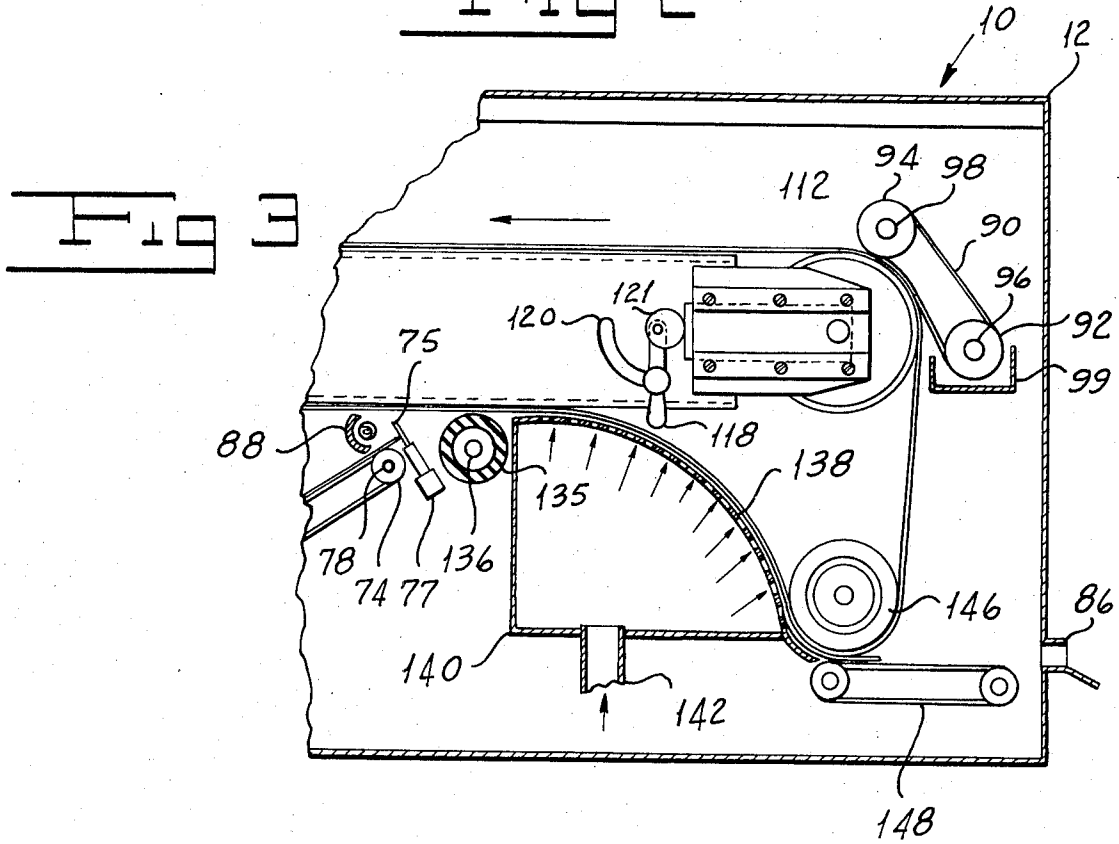
Fig 2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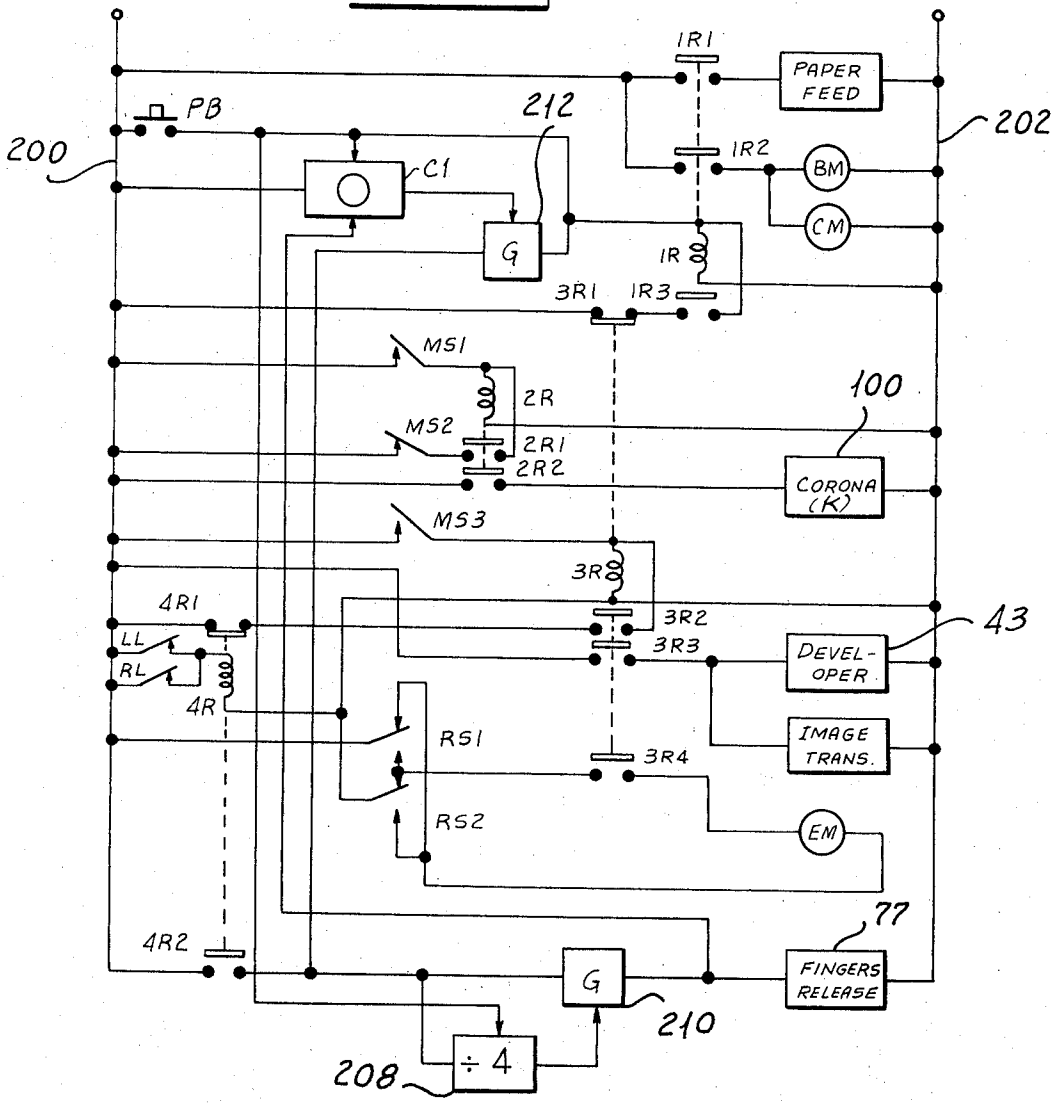
148

Fig 3

Fig 4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PAPER FEED
PB
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202
200
IR2
BM
C1
CM
G
IR
3R1
IR3
MS1
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MS2
2R1
2R2
CORONA (K)
MS3
3R
4R1
3R2
43
LL
3R3
DEVEL-OPER
RL
4R
RS1
3R4
IMAGE TRANS.
RS2
EM
77
4R2
G
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210
÷ 4
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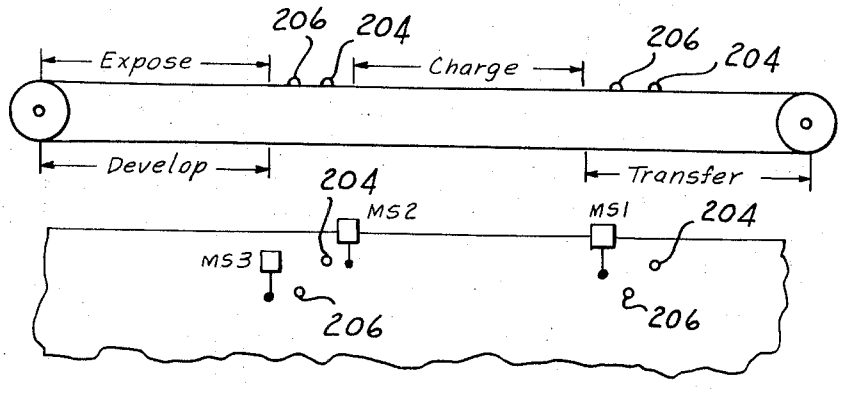
206
204
206
204
Expose
Charge
Develop
Transfer
204
MS2
MS1
204
MS3
206
206

Fig 5

COPY MACHINE HAVING PHOTOCONDUCTIVE BELT

BACKGROUND OF THE INVENTION

Electrostatic copying machines are known in the prior art in which an organic photoconductive imaging surface is charged and exposed to a light pattern derived from an original to be copied, then developed in a tacky toner and contact-transferred to copy material. An example of such a copy machine is disclosed in the copending application of Smith et al. for a "Method of Contact Transfer of Developed Electrostatic Images and Means for Practicing Same," Ser. No. 155,108 filed June 21, 1971. Such electrostatic copy machines may, for example, utilize an organic photoconductor formed over the surface of a cylindrical drum which rotates past the several units which charge, expose, develop and transfer the desired image. In its operation, the machine will produce only one photocopy per rotation of the drum, and the processing units perform their operations only once in each cycle.

Our copying system employs an endless belt whose outer surface is made of an organic photoconductor. The photoconductive belt is arranged to move over laterally disposed rollers lying in a common horizontal plane. A rectangular support structure occupies the region between the upper and lower surfaces of the belt, extending between the two rollers. The opposing horizontal walls of this support structure, adjacent the inner surfaces of the photoconductive belt are perforated and diffuse air supplied to the hollow interior of the support structure. The photoconductive belt thereby floats on a virtually frictionless air cushion. Contiguous segments of the belt are sequentially charged, exposed, developed and have their developed electrostatic images contact-transferred to copy material in a continuous manner. As one segment of the photoconductive belt is being charged another segment is being developed, and as one segment of the belt is being exposed another is transferring its developed image to the copy material. Narrow spaces between the belt's active segments are arranged to trip microswitches which energize the various processing units arranged in sequential order adjacent the periphery of the belt.

SUMMARY OF THE INVENTION

One object of our invention is to provide an electrostatic copier for use with a photoconductive imaging surface.

Another object of our invention is to provide an electrostatic copier particularly adapted for multiple reproduction of an original.

Yet another object of our invention is to provide an electrostatic copier of very simple construction, great accessibility, whose moving photoconductive surface experiences virtually no friction and whose electrical power requirements are very low.

Still another object of our invention is to provide an electrostatic copier whose sequence of photocopy operations is controlled by the motion of its photoconductive surface relative to the processing units which produce the electrostatic copy.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings which form a part of the instant specification and which are to be read in conjunction therewith and in which like reference numerals are used to indicate like parts in the various views:

FIG. 1 is a schematic sectional view of one embodiment of our electrostatic copier.

FIG. 2 is a schematic sectional view of another embodiment of our electrostatic copier.

FIG. 3 is a schematic sectional view of yet another (a third) embodiment of our electrostatic copier.

FIG. 4 is a circuit diagram showing a control circuit for our electrostatic copier.

FIG. 5 is a schematic illustration of an arrangement of punched control holes on an extended segment of out photoconductive belt.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1 we have shown one embodiment of our photocopier, indicated generally by reference numeral **10,** comprising a generally rectangular, opaque housing **12** in which we have arranged a conductive endless belt **14,** having a photoconductive outer surface **20,** to pass over conductive rollers **16** and **18** mounted for rotation on shafts **17** and **19.** The belt **14** is oriented so that its upper and lower stands are generally parallel to the upper surface of housing **12.** The belt is driven in the direction of the arrow A by a motor **M1** (not shown in FIG. 1) which imparts rotational motion to the shaft **19** by means of an arrangement of gear wheels, chains and pinions, as will be more fully explained hereinbelow. Recessed onto the upper surface of housing **12** is a glass exposure window **22** on which the original is placed, image face down, for photocopying. A rigid or flexible opaque cover sheet is hinged adjacent one edge of the exposure window **22** and is normally placed over the original to shield it from ambient light and to prevent accidental displacement of the original during the transmission of an image of the original to the photoconductive surface.

We provide an optical scanning system, indicated generally by the reference character **26,** comprising a pair of horizontally disposed parallel slide rails **28** fixed below the exposure window **22.** The rails **28** support a carriage **30** for linear travel thereon. An endless drive chain **32** carried by sprockets **34** is connected to the carriage **30** and is driven by a motor (not shown) to reciprocate the carriage **30** along the rails **28.**

The carriage **30** houses the optical system which exposes the photoconductive surface **20** to a light pattern derived from the original. As the carriage **30** advances along the rails **28,** the optical system comprising a mirror **38,** a lamp **36,** a lens **40** and a mirror **42** is activated and the system sweeps across the face of the original, transmitting to the photoconductive surface a reflected light pattern derived from the original.

We provide a developing unit, indicated generally by reference numeral **43,** positioned adjacent endless belt **14** so that an application instrumentaility such as an applicator belt **44** applies liquid to the photoconductive surface **20.** In our embodiments, the endless applicator belt **44** is arranged to pass over rollers **46** and **48** mounted for rotation on shafts **50** and **52** respectively. The shafts **50** and **52** are positioned in a developer tank **54** containing liquid developer in which applicator belt **44** is partially immersed. The applicator belt **44** applies the liquid developer over the exposed segment of the

photoconductive surface **14** to develop the latent image contained thereon. An overflow trough **56** collects excess liquid developer flowing from the belt **44.** An airknife **62** directs excess developer liquid from belt **14** to trough **56.** A pipe **58** carries liquid from tray **56** back to the developer supply system (not shown). The supply system feeds developer liquid to an inlet pipe **59** leading into tray **54.** The developer supply system may be of the type disclosed in the copending patent application of Smith et al. for "Apparatus for Developing Electrostatic Images," Ser. No. 212,155, filed Dec. 27, 1971, now U.S. Pat. No. 3,789,794. The liquid developer may be of the "tacky" toner type disclosed in the copenidng patent application of Smith et al for "Method of Contact Transfer of Developed Electrostatic Images and Means for Practicing Same," Ser. No. 155,108, filed Dec. 27, 1971.

We arrange a shaft **64** to carry a roll of paper **66** or other flexible copy material onto which the developed image on the surface **20** is to be transferred. A pair of pinch rollers **68** grasp the paper from the roll **66** and feed it past a blade **70** to a conveyor system indicated generally by reference character **72.** Upon energization of a solenoid **71,** a blade **70** cuts the copy paper to the proper length for receiving the entire developed image from belt **14.** The conveyor system **72** comprises a plurality of endless belts **73** passing over rollers **74** and **76** mounted for rotation on shafts **78** and **80** respectively. Paper delivered by the rollers **68** from the roll **66** is advanced by belts **73** into the nip between a roller **82** and the portion of belt **14** on roller **16.** Roller **82** is mounted on a shaft **84** to press the sheet of copy paper into contact with the belt **14.** The finished copy leaves the housing **12** through a discharge slot **86.** A lamp **88** preheats the copy sheet passing under it to enhance the adhesive affinity of tacky toner on the photoconductive surface for the copy sheet.

We provide any suitable means such as steel strips or the like (not shown) for holding the paper down on the belts **73.** A length of paper is releasably held in position on belts **73** by means of a plurality of fingers **75** forward of the roller **74** and adapted to be moved out of the path of the paper as a developed image on belt **14** arrives at the image transfer location. At that time any suitable means such as a solenoid **77** is energized to move the fingers **75** to permit the paper to move into the transfer station. Owing to this operation it is not necessary precisely to synchronize movement of belts **73** with movement of the belt **14.**

We arrange an endless cleaning belt **90** on rollers **92** and **94,** respectively mounted for rotation on shafts **96** and **98.** One of the shafts **96** and **98** is driven by any suitable means to move the belt **90** relative to the photoconductive surface **20** to remove residual toner still adhering thereto after the image has been contact-transferred to the copy sheet. Belt **90** may be formed of any suitable material which produces a scrubbing action on the surface of belt **14.** The lower part of the belt may be immersed in clear carrier liquid in a tank **99.**

The belt **14** is further arranged to traverse upper and lower walls **102** and **103** joined by horizontally spaced I beams **104** to form two vertically disposed, horizontal surfaces **106** and **108** lying in parallel planes. Joined respectively to the longitudinal and transverse edges of cantilevered surfaces **106** and **108,** and spanning the distance between them are side walls **110** and end walls **112,** which together with surfaces **106** and **108** form a generally rectangular housing **114.** The walls **102** and **103** having surfaces **106** and **108** are perforated. Compressed air which is supplied internally to the housing **114** by way of an inlet **109** flows outwardly through the perforations in the upper and lower walls **102** and **103** to form air cushions between the surfaces **106** and **108** and the inner surface of the upper and lower stands of the belt **14.** The air cushions reduce kinetic friction between the belt **14** and the surfaces **106** and **108,** thus reducing wear. Additionally, it prevents liquid developer from contacting the support structure **114.**

We adjust the tension in the belt **14** by the action of a tensioning mechanism **116** which extends the distance between the rollers **18** and **16** over which belt **14** passes. A crank arm **118,** constrained to move in a quadrant **120,** moves a cam **121** adjustably to position the bearing blocks of shaft **17.**

The length of belt **14** and the relative orientations of the charger station, the exposure station, the developer station and the contact-transfer station about the periphery of the belt are selected so that at any one time, as one segment of the photoconductive surface **20** is being exposed another segment is being developed, and as one segment is being charged another is contact-transferring its latent image to a copy sheet. To accomplish this result the belt **14** is intermittently driven.

In FIG. **2** we have shown another embodiment of our invention which differs from the embodiment of FIG. **1** only with respect to the manner in which the copy medium **66** is brought into contact with the developed electrostatic image on the outer surface **20** of the photoconductive belt **14.** In the embodiment shown in FIG. **2** the copy paper delivered by the conveyor system **72** is directed by a roller **120** rotatably mounted on a shaft **122** to a space between a horizontally oriented platen **124** disposed in a plane parallel and adjacent to the photoconductive belt **14.** The platen **124** is arranged to contact the developed image on the belt **14** as it passes over the surface of the platen, by actuation of a solenoid **125** which upwardly displaces the platen from its normal position. The copy sheet introduced between the photoconductive belt **14** and the platen **124** by the guide roller **120** is thereby lifted into contact with the developed electrostatic image on the belt **14.** We arrange a pair of rollers **130** and **132** respectively mounted on shafts **126** and **128** to grasp the copy sheet following its contact with the developed electrostatic image and to deliver the copy sheet to the discharge slot **86** by way of a conveyor belt **134.** It will be appreciated that in this form of our invention image transfer takes place while the belt **14** is stationary.

In FIG. **3** we have shown yet another embodiment of our invention which again differs from the embodiments of FIGS. **1** and **2** only with respect to the manner in which the copy medium **66** is brought into contact with the latent electrostatic image on the photoconductive outer surface **20** of the belt **14.** In the embodiment of FIG. **3** the copy paper delivered by the conveyor system **72** is directed by a roller **135** rotatably mounted on a shaft **136** to a space between a perforated surface **138** forming the curved wall of a one-quarter section of a hollow right circular cylinder **140** and the belt **14.** Air is delivered to the hollow interior of the cylindrical section by a compressor (not shown) by way of a pipe **142.** The air is diffusd outwardly over the curved surface **138** through the multiple perforations therein and forms an air bed which presses the copy passing be-

tween the curved wall **138** and the belt **14** into contact with the developed electrostatic image on the belt **14.** Following contact and image transfer the copy sheet is grasped between the surface of an arcuate delivery bed **144** and an adjacently mounted guide roller **146** to be delivered to a conveyor belt **148** which ultimately discharges the copy through a slot **86.**

Our photocopying logic system is particularly adapted for production of a multiplicity of copies of an original. We provide means for interrupting the continuous copy production at various stages so that any preselected number of copies, including a single copy, may be produced. We have coupled the operation of both the developer unit and the transfer unit of our photocopy machine to the operation of our exposure unit. Inasmuch as we have arranged out photoconductive belt to remain stationary during certain of the operations performed by the machine, the operation of longest duration, which is that of electrostatic imaging by exposure to a light pattern derived from the original, is arranged to control the other operations. With this arrangement, when the machine is started, the first four photoconductive belt segments which pass through the transfer unit bear no electrostatic image since they received no corona charge; the fifth segment to arrive and all those following will have been charged, exposed and developed. For this reason we must delay the delivery of copy paper to the transfer unit until the photoconductive belt surface bearing an electrostatic image arrives at the transfer unit. This delay in paper delivery is achieved by a counter whose operation will be explained hereinafter.

Referring now to FIG. **4,** we have shown a control circuit for our belt copier, the main lines **200** and **202** of which are connected across an appropriate source of potential. In the operation of our machine a counter C1 is set to produce the desired number of copies. A push button PB is momentarily depressed to initiate the sequence of copying operations. Closing of switch PB sets the main counter C1 to at least a count of 1 or to a greater count set therein by a dial or the like. The counter C1 opens a normally closed gating circuit **212.** Closing of PB further resets a divide-by-four network **208** the function of which is explained hereinbelow. It also completes a circuit through the counter to the relay winding **1R** and closes normally opened relay contacts **1R1** and **1R2.** The closing of relay contacts **1R3** complete a holding circuit through contacts **3R1** to maintain the relay winding **1R** in an energized condition. The circuits completed by the relay contacts **1R1** and **1R2** activate the belt-drive motor BM, the cleaning unit motor Cm and the paper cutting and transport unit. The belt-drive motor BM begins to move the belt surface toward the corona charging unit. The paper cutting and transporting unit draws the copy paper from the supply roll **66,** cuts the copy paper to an appropriate length for receiving the developed electrostatic image in the transfer unit, and delivers the length of copy paper thereto to await the arrival of the developed electrostatic image on the photoconductive surface of the belt **14.** As the belt **14** moves toward the corona-charging unit the projection **204** on the belt **14** closes a normally open microswitch **MS1,** which completes a circuit through the relay winding **2R** and closes normally open relay contacts **2R1** and **2R2** respectively to energize the corona-charging unit K and to complete its own holding circuit through a normally closed switch **MS2.** The belt segment moving relative to the corona charger receives a uniform electrostatic charge until projection **204** provided on the belt surface opens a normally closed microswitch **MS2.** The opening of the microswitch **MS2,** opens the holding circuit through the relay winding **2R** and deenergizes the corona-charging unit K. The subsequent closing of the microswitch **MS3** by a projection **206** on belt **14** energizes a relay winding **3R** which closes normally open relay contacts **3R2, 3R3, 3R4,** and opens normally closed contact **3R1** to disengage the belt drive motor and arrest the belt's motion. It will be appreciated that the belt remains stationary during image transfer in the form of our invention illustrated in FIG. **2** in which the platen **124** is to be raised to effect the transfer. In the other forms of our invention, the transfer is effected in the course of movement of the belt **14.**

Closing of the contacts **3R2** complete a holding circuit for winding **3R** through normally closed contacts **4R1.** Closing of contacts **3R3** completes a circuit for the developer unit **43** and for the image transfer system wherein the platen **124** is employed. Closing of the contact **3R4** completes the circuit of a drive motor EM for the exposure unit through a pair of reversing switches **RS1** and **RS2.** The position of the switches **RS1** and **RS2** is determined by the position of the carriage followig its last movement. That is, at each of its limits of travel, the carriage reverses switches **RS1** and **RS2** so that the motor EM will drive the carriage in the reverse direction on the next closing of the contacts **3R4.**

In addition to the reversing switches **RS1** and **RS2** controlled by the movement of the carriage **30,** we also provide respective left hand and right hand limit switches LL and RL which are momentarily actuated as the carriage approaches the respective limit positions. At the limit each of the switches is open. Closing of either of the switches LL or RL energizes a relay winding **4R** to open contacts **4R1** to deenergize relay **3R** at the end of the developing, image transfer and exposure operations.

As has been explained hereinabove, we do not wish to feed blank sheets of paper to the delivery slot **86** during the initial operation of the machine. For that reason, we do not energize the finger release solenoid **77** until after the first four operations of the exposure motor. Closing of contacts **4R2** in response to energization of winding **4R** applies a pulse to a divide-by-four network **208** which had been reset by operation of push button PB and to a normally closed gate **210.** After the fourth closing of contact **4R2** network **208** actuates gate **210** to pass the next pulse resulting from closure of contact **4R2** to the finger release solenoids **77** to permit a sheet of paper to move into the transfer location. This pulse indicates that a copy has been made. We apply the output of gate **210** to the counter **C1** to step it down one count. Each subsequent closure of the contact **4R2** will result in stepping counter C1 down one count until finally the desired number of copies have been made and the gate **212** is deactivated.

We also apply the signal resulting from closure of contact **4R2** to the gate **212** to reenergize relay winding **1R** to restart the belt motor BM. It will readily be appreciated that this operation continues until the main counter C1 has been stepped down to zero.

While we have described one form of control circuit which may be employed to control the operation of our

machine, it will readily be appreciated that a more sophisticated control can be devised to eliminate some of the unnecessary operations inherent in the machine. Further by way of example we have illustrated the relationship between projections **204** and **206** on belt **14** and the positions of the microswitches **M1, M2** and **M3** in FIG. **5.** of the drawings.

In operation of our endless belt electrostatic copy machine, counter C1 first is set to the desired number of copies to be made. Push button PB is actuated to initiate an operation of the machine. First, the belt **14** steps through a certain distance in which an electrical charge is applied to the photoconductive layer on the belt by the corona **100.** At the end of the application of the corona to that section of the belt, the belt stops and the exposure system is actuated to cause the carriage **30** to move, for example, from right to left as viewed in FIG. **1,** to cause an image of the original to be translated to the charged photoconductive surface to provide a latent image. Following the exposure operation, the belt **14** is again stepped to carry the latent image to the developer station. At the same time, another charged area is at the exposure station and the exposure and developer units both are actuated to cause one latent image to be produced while the preceding image is being developed. Next, the belt makes another step and the developed image is at an idle station while another image is being formed and yet another image is being developed. Next, the belt moves through another step. In the form of our invention shown in FIGS. **1** and **3,** the first developed image is at an idler station during this step and image transfer takes place as the belt is moving in the course of the next movement. In the form of our invention illustrated in FIG. **2,** image transfer takes place while the belt is stationary and the copy is delivered on the succeeding step.

It will be seen that we have accomplished the objects of our invention. We have provided an electrostatic copying machine employing an endless belt having a photoconductive imaging surface. Our machine is especially adapted to produce multiple copies of an original. The belt carrying the photoconductive surface in our machine is supported for movement with a minimum of friction. Our machine requires relatively little electrical power to operate. It is simple in construction for the result achieved thereby. The operating parts of the machine are relatively accessible for maintenance and repair.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of our claims. It is further obvious that various changes may be made in details within the scope of our claims without departing from the spirit of our invention. It is, therefore, to be understood that our invention is not to be limited to the specific details shown and described.

Having thus described our invention, what we claim is:

1. An electrostatic copying machine including in combination, an endless belt having a surface carrying a film of photoconductive material, a charging unit for applying an electrostatic charge to a surface passing thereby, an exposure unit mounted for movement between limit positions and adapted to be actuated to translate an image of an original over an area of a stationary surface positioned adjacent thereto, a developer system adapted to be actuated to apply developer to a stationary surface positioned adjacent thereto over an area corresponding in size to said area, means for effecting transfer of a developed image from said belt to a length of copy material, means mounting said charging unit and said exposure unit and said developer unit and said transfer means at spaced locations along the length of said belt, means adapted to be actuated to drive said belt to move said surface successively past said units and said transfer means, means for actuating said drive means to move said surface successively past said units and said transfer means, means responsive to movement of said belt length to a position adjacent to said exposure unit for deactivating said drive means and for moving said exposure unit between said limit positions and for actuating said exposure unit to translate said image over said area, means responsive to movement of said exposure unit for reactivating said drive means to move said length to a position adjacent to said developer unit, means responsive to movement of said belt for again deactivating said drive means with said area substantially in registry with said developer unit, and means for again reactivating said drive means to move said length toward said transfer means.

2. A copy machine as in claim **1** including means providing a cushion of fluid for supporting said belt over a major portion of the length thereof.

3. A copy machine as in claim **1** in which said belt is generally horizontally disposed to form upper and lower generally parallel stands, means mounting said charging and exposure units in spaced relationship adjacent to said upper stand and means mounting said developing and transfer units in spaced relationship adjacent to said lower stand.

4. A copy machine as in claim **1** in which said exposure unit mounting means comprises a reciprocating carriage.

5. A copy machine as in claim **1** in which said transfer means comprises means for bringing a sheet of copy material into intimate contact with an image on said belt, means for holding a sheet of copy material in escrow adjacent to aid contact means, and means for actuating said escrow means to feed a sheet of said copy material to said contacting means.

6. A copy machine as in claim **1** in which said belt driving means comprises a roller supporting said belt and in which said transfer means comprises a pressure transfer roller forming a nip with a portion of said belt on said support roller.

7. A copy machine as in claim **6** in which said means for feeding a sheet of copy material to said transfer unit comprises means for holding a sheet of copy material in escrow adjacent to said nip and means responsive to movement of a developed-image-bearing portion of said belt toward said nip for actuating said escrow means to release the sheet of copy material for movement into said nip.

8. A copy machine as in claim **1** in which said transfer means comprises a pressure platen, means mounting said platen for movement toward and away from said belt, and means for moving said platen toward said belt while said belt is stationary to carry a sheet of copy material on said platen into positive engagement with said belt, and in which said copy material feed means feeds a sheet to said platen.

9. A copy machine as in claim 1 in which said transfer means comprises pneumatic means for moving a sheet of copy material into positive engagement with said belt.

10. An electrostatic copying machine including in combination, an endless belt having a surface carrying a film of photoconductive material, a charging unit for applying an electrostatic charge to a surface passing thereby, an exposure unit adapted to be activated to translate an image of an original to a surface positioned adjacent thereto, means mounting said exposure unit for movement between a first limit position and a second limit position to cause the exposure unit when actuated to translate an image of an original over an area of said surface, a developer system for applying developer to a surface positioned adjacent thereto, means for effecting transfer of a developed image from said belt to a length of copy material, means mounting said charging unit and said exposure unit and said developer unit and said transfer means at spaced locations along the length of said belt, means adapted to be actuated to drive said belt successively past said units and said transfer means, means responsive to movement of said belt length on one operation of said machine for deactivating said drive means and for moving said exposure unit from said first limit position to said second limit position and for actuating said exposure unit to translate said image, means responsive to movement of said exposure unit into said second limit position on said one operation for reactivating said drive means, means responsive to movement of said belt length on another operation of said machine for deactivating said drive means and for moving said exposure unit from said second limit position to said first limit position and for activating said exposure unit to translate said image, and means responsive to movement of said exposure unit into said first limit position on said other operation for reactivating said drive means.

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