Oct. 10, 1967 R. G. OSTENSEN 3,345,925

ELECTROSTATIC PRINTING AND DEVELOPING APPARATUS

Original Filed Jan. 3, 1963 3 Sheets-Sheet 1

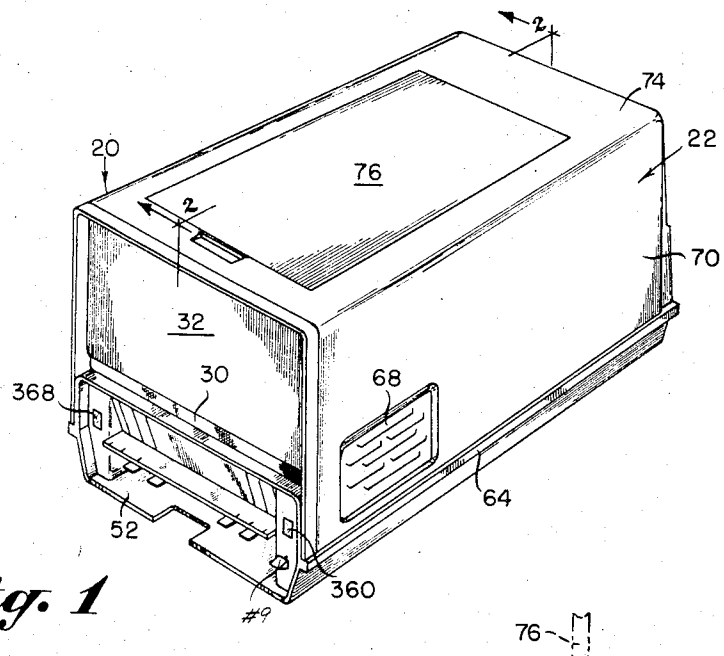


Fig. 1

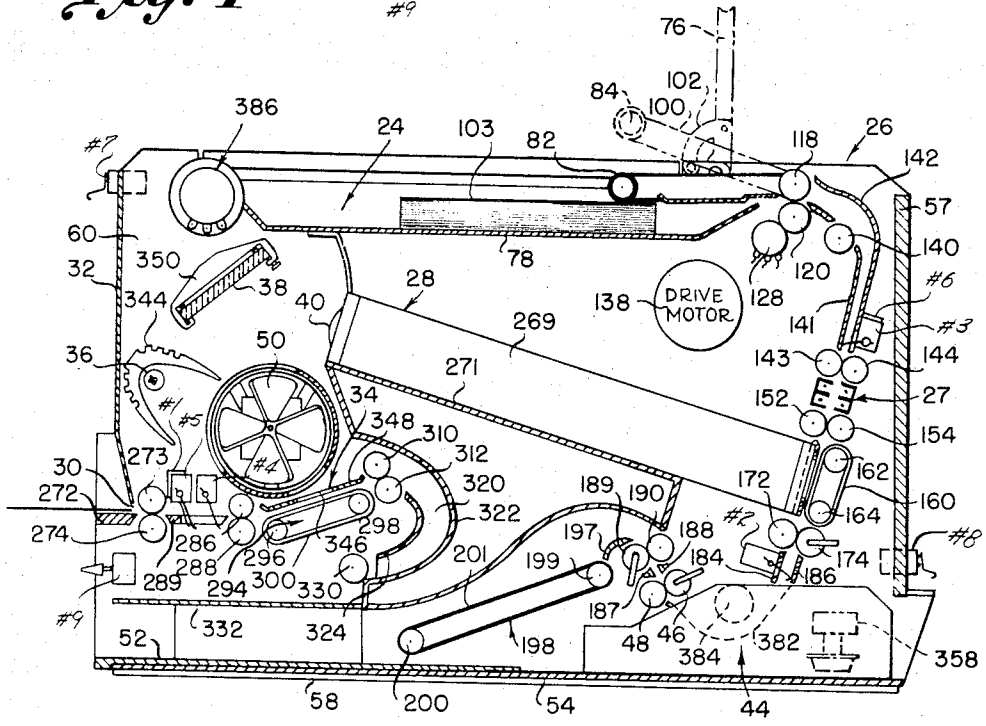


Fig. 2

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ELECTROSTATIC PRINTING AND DEVELOPING APPARATUS

Original Filed Jan. 3, 1963 3 Sheets-Sheet 2

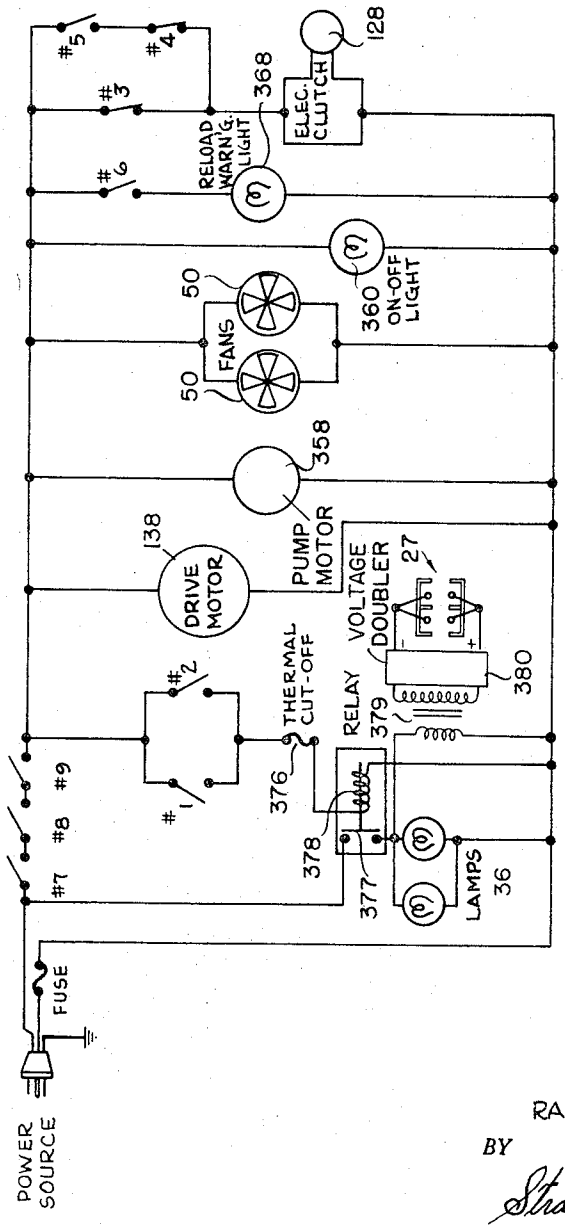


Fig. 3

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ELECTROSTATIC PRINTING AND DEVELOPING APPARATUS

Original Filed Jan. 3, 1963 3 Sheets-Sheet 3

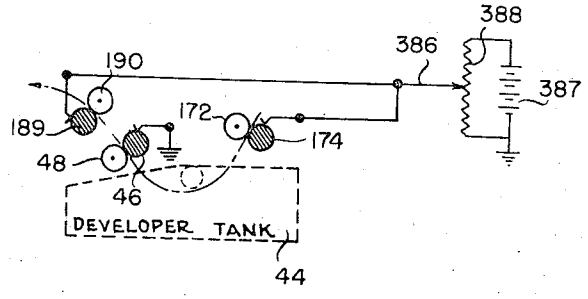


Fig. 4

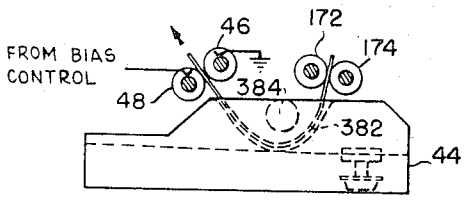


Fig. 5

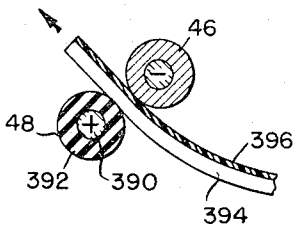


Fig. 6

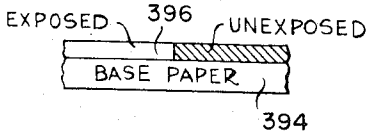


Fig. 7

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United States Patent Office 3,345,925
Patented Oct. 10, 1967

3,345,925
ELECTROSTATIC PRINTING AND DEVELOPING APPARATUS

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Original application Jan. 3, 1963, Ser. No. 249,248. Divided and this application Aug. 17, 1964, Ser. No. 390,151

10 Claims. (Cl. 95—1.7)

ABSTRACT OF THE DISCLOSURE

An apparatus for developing a latent image formed on a surface on an electrically chargeable sheet of copy paper by a partially dissipated, electrostatic charge and having a developer tank containing developer particles applied to the surface of the copy paper to develop the latent image thereon. Electrically conductive means connected to a source of voltage imparts a potential to the copy paper during the development phase to cause relatively uncharged background areas on the copy paper to repel the developer particles.

This invention delates to photocopying apparatus and, more particularly, to photocopying apparatus of the electrostatic type. This application is a division of application Ser. No. 249,248 filed Jan. 3, 1963, now abandoned.

In the electrostatic copying cycle to which the present invention relates, a uniform electrostatic charge is applied to a sheet of copy paper having a photoconductive surface layer. The image on the document desired to be copied is then projected onto the copy paper, selectively discharging the electrostatic charge and reproducing the image on latent form on the copy paper. Areas corresponding to areas of the original having intermediate shade will retain varying proportions of the original charge. The charge will be substantially unaffected on areas corresponding to dark areas on the document being copied, but will be almost entirely dissipated on areas corresponding to vary light or image free areas of the document. The latent electrostatic image is then developed by applying to the copy paper particles having a charge opposite in polarity to the charge on the copy paper. The charged particles are attracted to different areas of the copy paper in densities proportional to the charges remaining on those areas, producing a graphic image which is a substantial duplicate of the image on the original document.

One of the most persistent problems in this process is ensuring that the developer particles are applied to the exposed copy in exact proportion to the charge remaining on the exposed copy paper. The particles have been applied by forming them into a dry powder and causing the powder to be brought in contact with the copy paper as by blowing or rolling it onto the paper or by incorporating the particles into a liquid and applying the liquid to the exposed copy paper. Prior art efforts at using the liquid type developer or toner are exemplified by United States Patent No. 2,991,754, issued July 11, 1961, and Australian Patent No. 227,951, published Oct. 2, 1958.

The principal object of the present invention is to provide an improved printer of the type utilizing a liquid toner for developing the latent electrostatic image into a visible image by use of an improved biasing arrangement at the developing station. The copy paper itself contains a layer of photoconductive material and thus eliminates the need for a plate or drum of chargeable material from which the visible image is transferred as in the well-known "Xerox" process.

Another major object is to provide an improved electrostatic printer wherein a D.C. biasing voltage of opposite potential from the electrostatic charge induced in the photoconductive layer of the copy paper is evenly applied to the entire surface of the copy paper to neutralize the electrostatic charge of the nonimage or background areas of said surface and thereby reducing deposition of developer particles on these areas.

Another object is to apply a biasing voltage to the charged copy paper along its entire length as it travels through the liquid toner in a developing tank for causing the relatively uncharged background areas on said chargeable member to repel the liquid toner particles.

Another major object is to provide a compact electrostatic printer small enough to be used on a desk or table top and embodying novel paper drive systems for both the original and the copy sheet, together with a unique developing tank arrangement which provides a commercially practicable printer.

These and other objects will become more fully apparent from the claims, and from the description as it proceeds in connection with the drawings wherein:

FIGURE 1 is a perspective view as seen from the front, right corner of the electrostatic printer of the present invention shown with its cover in place;

FIGURE 2 is a sectional view of the printer of FIGURE 1 and is taken substantially along line 2—2 of that figure;

FIGURE 3 is a schematic wiring diagram of the printer;

FIGURE 4 is a schematic of a biasing arrangement for the printer of FIGURE 1;

FIGURE 5 is a schematic view of an alternate biasing arrangement which may be employed to control the electrostatic charge on the copy paper;

FIGURE 6 is a fragmentary and enlarged sectional view of a sheet of copy paper progressing through the biasing rollers in the embodiment of FIGURE 5; and

FIGURE 7 is a diagrammatic illustration of a sheet of exposed copy paper showing exposed and unexposed adjoining portions.

General description

Referring now to FIGURES 1 and 2 the electrostatic printing machine **20** of the present invention includes a housing **22** within which are arranged a paper supply compartment **24** into which photoconductive copy paper stack **103** may be loaded and a paper feed **26** for propelling sheets of the copy paper from compartment **24** through a corona charging unit **27** where a uniform charge of approximately —400 v. is imparted to the surface of the copy paper to imaging area adjacent the lower end of an image projector **28**. The original to be copied is inserted through a horizontal slot **30** in the front wall **32** of cover **22** and is transported in timed relation to the movement of the copy paper to an imaging area below the forward end of image projector **28** where light is focused by projection lamp **36**. The image is reflected from the surface of the original and a mirror **38** into the objective lens **40** of image projector **28** which projects the image onto the surface of the sheet of copy paper below corona unit **27**. As the image strikes the copy paper, the charge on the latter is reduced by an amount determined by the intensity of the reflected light, with black portions of the original reflecting such a small light intensity as to affect the charge very little and white portions of the original reflecting sufficient light intensity as to almost completely release the latent electrostatic charge in the paper.

The exposed copy sheet now contains a latent image charge pattern which is preferably passed through a de-

veloping tank 44, described in detail in my copending application 143,086, filed Oct. 5, 1961, now Patent No. 4,202,526, where a liquid developer carrying positively charged particles is applied to the latent image bearing surface of the copy paper. The positively charged particles are attracted to the negatively charged areas to a degree determined by the charge at each position on the surface of the copy paper thereby producing a graphic image. The paper feed then moves the developed copy paper between squeegee rollers 46 and 48, which remove the excess developer from the copy paper and may provide a direct voltage of relatively low magnitude to control the density of the image and/or the cleanliness of the background of the developed copy paper.

The radiant heat of the projection lamps, together with air warmed by the projection lamps and blown across the copy paper by fans 50, removes substantially all of the remaining moisture from the surface of the copy paper. Thereafter, feed system 26 deposits the copy onto surface 52 at the bottom front of the printer from which it may be removed by the operator.

Detailed description

As is best shown in FIGURES 1 and 2, housing 22 includes a base 54 supported in longitudinally extending feed 58 (only one of which is shown), a pair of spaced apart vertical side walls 60 extending upwardly from the base, vertical front wall 32, which extends between the side walls, and rear wall 57. The details of housing 22 are of no significance to the present invention and may be varied as desired. Side walls 60, for example, are illustrated in FIGURE 2 as substantially continuous, sheet-like members. If desired, they may be formed of appropriate straps or brackets since they function primarily to support various components of the printer such as the rollers for the copy paper and original document feed systems.

Supported on horizontal ledges 64 (FIGURE 1) formed adjacent the bottom of and extending around three sides of base 54 is a box-like open-ended cover 22 which may be secured in place by appropriate detachable fasteners (not shown). Louvers 68 formed in the exterior verticle side wall 70 of cover 22 permit cooling air to be circulated through printer 20 to remove the heat generated by its operation.

Image transfer

Pick-up rollers 152 and 154 at the exit side of corona unit 27, deliver the charged copy paper onto the belt of endless conveyor 160 where image projector 28 projects the image of the document to be copied onto the copy paper. Image projector 28, which may be of substantially conventional construction, includes a light tight housing 269 with the objective lens 40 supported in its upper forward end. A projection lens 270 is supported in the lower rearward end of housing 269 closely adjacent the upper run of endless conveyor 160. Image projector 28 is supported by a sheet metal support member 271 (see FIGURE 2) fixed at its opposite ends to base side walls 60.

The original document which it is desired to copy. it will be remembered, is inserted into printer 20 through a horizontal slot 30 in the front wall of its housing 22 where it is picked up by the original document feed 34. Referring now to FIGURE 2, feed 34 includes a horizontal sheet metal guide 272 fixed to base side walls 60 which guides the original into a pair of pick-up rollers 273 and 274 rotatably mounted in suitable bearings (not shown) fixed to base side walls 60. Roller 273 is continuously rotated by roller chain 132 which engages a spur gear 276 fixed to a shaft 278 rotably supported on base side wall 60. Fixed to shaft 278 with spur gear 276 is a second spur gear 280 which meshes with a spur gear 282 fixed to the shaft 284 on which roller 273 is mounted. Roller 274 is driven by roller 273.

The next components of document feed 34 are pick-up rollers 286 and 288 which are separated from pick-up rollers 273 and 274 by a horizontally extending sheet metal guide 289 supported by base side walls 60. Pick-up rollers 286 and 288 are rotatably mounted in suitable bearings (not shown) fixed to base side walls 60. Roller 288 is contiouously rotated by roller chain 132 which engages a spur gear 290 fixed to the end of the shaft 292 on which roller 288 is mounted. As in the other pick-up rollers described above, roller 288 frictionally drives roller 286.

Pick-up rollers 286 and 288 deliver the document to be copied onto an endless conveyor 294 which includes a pair of rollers 296 and 298 rotatably journalled in parallel, spaced relationship by appropriate bearings (not shown) fixed to base side walls 60. Surrounding conveyor rollers 296 and 298 is an endless belt 300 which supports the document to be copied while it is in the imaging area below the forward upper end of image projector 28. Endless conveyor belt 300 is driven by a spur gear 302 fixed to the end of the shaft 304 on which pick-up roller 286 is mounted. Spur gear 302 meshes with a spur gear 306 fixed to the shaft 308 on which endless conveyor roller 296 (see FIGURE 2) is mounted. The movement of the document to be copied while on conveyor belt 300 is synchronized with movement of the copy sheet on conveyor belt 160 by roller chain 132 and the movement of the copy sheet is coordinated by use of feeler switches and electromagnetic clutches through a circuit shown in FIGURE 3.

As the leading edge of the document to be copied travels off the rear end of endless conveyor 294, it passes between a pair of pick-up rollers 310 and 312 rotatably mounted in appropriate bearings (not shown) fixed to base side walls 60. Pick-up roller 310 is continuously rotated by roller chain 132 which engages a spur gear 314 rotatably supported by housing side walls 60. Spur gear 314 meshes with spur gear 316 fixed to the end of the shaft 318 on which roller 310 is mounted. Roller 310, in turn, friction drives roller 312.

Next in feed system 34 is a chute 320 formed from an arcuate wall portion 322 at the forward end of the support 271 on which image projector 28 is mounted and an arcuate sheet metal guide 324 supported from base side walls 60 in spaced, parallel relationship to support wall portion 322. Chute 320 diverts the document from its rearwardly moving travel back toward the front of printer 20. As the document emerges from chute 320, it passes beneath axially aligned and transversely spaced feed rollers 326, 328, and 330 which deposit the document on a tray 332 formed as an integral portion of the image projector supporting member 271. Feed rollers 326, 328, and 330 are fixed on a continuously rotating shaft 334 which is rotatably supported in appropriate bearings (not shown) fixed to housing side walls 60. Shaft 334 is rotated by roller chain 132 which engages a spur gear 336 fixed to a stub shaft 338 rotatably supported on housing side wall 60. Fixed on shaft 338 with spur gear 336 is a second spur gear 340 which meshes with a spur gear 342 fixed on the end of roller supporting shaft 334.

As was pointed out above, it is the function of feed system 34 to transport the document to be copied to an imaging area below the upper forward end of image projector 28. In this area, the document to be copied is illuminated by projection lamp 36 which, as is shown in FIGURE 2, is mounted in a conventional parabolic reflector 344 supported from housing side walls 60. The light from projection lamp 36 reaches the document supported on endless belt 300 through a slit 346 in a sheet metal member 348 supported from base side walls 60 closely adjacent and parallel to the upper run of endless conveyor 294.

It will be remembered that the image on the document is reflected from its surface to a mirror 38. Mirror 38 is supported at an upwardly and rearwardly inclined angle adjacent the forward upper end of printer housing 22 in

a supporting bracket **350** fixed, at its ends, to base side walls **60**. The details of mirror **38** and its supporting brackets **350** are not critical in the practice of the present invention and may be of any commercially available construction.

Mode of operation

Referring now specifically to FIGURE 3, the operation of printer **20** is as follows: main on-off switch #**9**, which is mounted on the front of printer base **54** (see also FIGURES 1 and 2), is closed. Connected in series with switch #**9** are a pair of interlock switches #**7** and #**8** mounted on printer base **54** (see FIGURE 2). Switches #**7** and #**8** open when cover **22** is removed, preventing operation of the printer unless the cover is in place. With cover **22** in place safety switches #**7** and #**8** are always closed and the closing of main switch #**9** completes circuits through drive motor **138**, a pump motor **358** in developing tank **44**, exhaust fans **50**, and on-off lamps **360** mounted on the front of printer base **54** (see FIGURE 1), and electromagnetic clutch **128** through normally closed switch #**3**. Switch #**3** is open when a sheet of copy paper is in position to start through corona charging unit **27**.

The function of pump **358** is not germane to an understanding to the present invention, other than that it circulates a liquid developer or toner solution which carries pigment particles that adhere to the charged portion on the copy paper as it passes through the solution. This pump, the developer tank shown in FIGURE 4, and their operation are described in detail in my copending application Ser. No. 143,086 to which reference may be had if desired.

Energization of fans **50**, as was indicated above, effects a flow of air in printer **20** to remove the heat of operation from the printer and to assist in drying the developed copy paper after it leaves developer tank **44** and passes through squeegee rollers **46** and **48**.

Energization of drive motor **138** effects operation of the paper feeds **26** and **34** described above. With drive motor **138** running and electromagnetic clutch **128** energized, feed rollers **82** are rotated in counterclockwise direction as viewed in FIGURE 2, through the drive train described above, feeding a sheet of copy paper from stack **103** through the slot formed at the rear end of paper supply compartment **24** between guides **104** and **106** to the pick-up rollers **118** and **120**.

The sheet of copy paper passes through feed rollers **118** and **120**, over idler roller **140**, and between guides **141** and **142** until its leading edge engages the actuator of a normally closed switch #**3** and a normally open switch #**6**, opening switch #**3** and closing switch #**6**. Both of these switches are mounted on guide **142**.

The opening of normally closed switch #**3** interrupts the circuit to electrogmagnetic clutch **128** which is then deenergized, stopping feed rollers **82** on top of the stack of copy paper and feed rollers **118** and **120**. The stopping of feed rollers **118** and **120** stops the sheet of copy paper passing through the printer with its leading edge just short of pick-up rollers **143** and **144** insuring that, when a document to be copied is inserted into the machine, the document and copy paper will move in timed relation through their respective imaging areas so that the entire image will be transmitted to the copy paper. The stopping of feed rollers **82** insures that a second copy of copy paper is not fed indiscriminately from supply compartment **24**.

The closing of normally open switch #**6** completes a circuit through a reload-warning lamp **368** mounted on the front side of printer base **54** (see FIGURE 1), lighting lamp **368** and indicating to the operator that the printer is conditioned to receive a document to be copied.

If the copy paper is exhausted when printer **20** is on, switch #**6** will not close and feed-reload lamp **368** will not light. Thus if lamp **368** does not light within a few seconds after main switch #**9** is closed, or after a document is inserted through slot **30**, the operator will know that the supply of copy paper is exhausted. If this occurs main switch #**9** may be opened, turning off the printer, and the supply of copy paper replenished. Main switch #**9** is then closed, reinitiating the printing cycle.

As the document to be copied is inserted through the slot **30** in printer base front wall **32**, it is picked up and fed into the printer by continuously rotating rollers **273** and **274**. Shortly after it passes through rollers **273** and **274**, the leading edge of the original contacts the actuators of two normally open switches #**1** and #**5** mounted on guide **289** with their actuators in the path of the inwardly moving original.

The closing of normally open switch #**1** completes a circuit through a thermal fuse **376** to the coil of a relay **378** energizing the relay which closes normally open contacts **377**. The closing of contacts **377** completes a circuit through and lights projection lamps **36** (which may be fixed in end-to-end relationship in reflector **344**).

The closing of normally open relay contact **377** simultaneously completes a circuit through the primary of transformer **379**. The secondary of transformer **379** is connected in the high voltage circuit of corona **27** which is nowhere grounded and therefore floats with respect to the reference voltage in the printer housing. For reasons which are not fully understood, it has been found that this arrangement background prevents discoloration on the copy sheet which sometimes occurs when a ground connection is used.

The D.C. potential between the negative and positive output terminals of voltage doubler **380** is on the order of 11,500 volts.

The closing of normally open switch #**5** completes a circuit through a normally closed switch #**4** and again momentarily energizes electromagnetic clutch **128** and causes rotation of feed rollers **118** and **120** which move the sheet of copy paper downwardly between guides **141** and **142** until its leading edge is engaged by continuously rotating pick-up rollers **143** and **144**.

An instant after the leading edge of the sheet of copy paper is picked up by rollers **143** and **144**, its trailing edge clears feed rollers **118** and **120**. Simultaneously, the leading edge of the original opens normally closed switch #**4** (which is mounted on guide **289** with its actuator positioned to be engaged by the rearwardly moving original), deenergizing electromagnetic clutch **128** and stopping feed rollers **80** and **82** and feed rollers **118** and **120**.

As pick-up rollers **143** and **144** move the sheet of copy paper downwardly, its trailing edge passes switches #**3** and #**6** permitting switch #**6** to open and switch #**3** to close. The opening of switch #**6** extinguishes the feed reload warning lamp **368**, warning the operator not to attempt to insert another original into the printer. If an original were fed into the printer at this point in the printing cycle, the original would precede the copy paper through the imaging areas, producing an incomplete copy.

The closing of switch #**3** again energizes electromagnetic clutch **128**, revolving feed rollers **82** in a clockwise direction and causing the top sheet of copy paper in stack **103** to be fed out of paper supply compartment **24** between feed rollers **118** and **120**. Shortly after the leading edge of this sheet of copy paper passes through the feed rollers it engages the actuators of switches #**3** and #**6**, opening switch #**3** and closing switch #**6**. Opening of switch #**3** stops feed rollers **118** and **120** positioning the incoming sheet of copy paper with its leading edge slightly above feed rollers **143** and **144** so that, when another document to be copied is inserted into printer **20**, the incoming copy paper will be picked up and moved through the printer in timed relation to the document in the manner described above.

The simultaneous closing of switch #**6** relights feed-reload lamp **388** indicating to the operator that the printer is conditioned to receive another document to be copied.

It will be apparent, from the above discussions, that several sheets of copy paper may be moving simultaneously through printer **20**, each of the sheets being at a different stage in the printing cycle. Consequently, successive prints can be produced at a relatively rapid rate, on the order of one copy every six seconds.

After moving through rollers **143** and **144**, the sheet of copy paper which triggered the reloading cycle just described passes through corona unit **27**. As the paper moves through corona unit **27**, uniform negative charge is provided on the upper surface of the paper, and a similar positive charge on the lower surface, the total charge being about 400 volts in the illustrated embodiment.

As is shown in FIGURES 6 and 7, the copy paper is a two layer system composed of a base **394** which preferably has a resistance between approximately 50 and 500 megohms to the square and a photoconductive layer or coating **396** which may comprise a photoconductive material such as zinc oxide in a resin binder. Therefore, when the copy paper leaves corona unit **27**, the surface of the photoconductive layer **396** will be uniformly charged.

As the copy sheet emerges from corona unit **27**, its leading edge is picked up by rollers **152** and **154**. Simultaneously, the leading edge of the original is picked up by rollers **286** and **288**. Thereafter, the original and the copy paper move at the same speed to their respective imaging areas, the original passing from feed rollers **286** and **288** onto endless conveyor **294** which carries it to the imaging area below the upper forward end of image projector **28**. The copy paper moves from rollers **152** and **154** onto endless conveyor **160** which carries it to the imaging area adjacent the lower rear end of image projector **28**.

As the original document passes through its imaging area, it is struck by the light emitted from projection lamps **36** and focused on the imaging area by parabolic reflector **344**. The image on the document reflected from the upper surface of the original to mirror **38** which reflects it into the image projector **28** through objective **40**. The image passes through image projector **28**, emerges through projection lens **270** and strikes the negatively charged surface of the copy paper. The uniform negative charge on the copy paper is reduced in proportion to the intensity of the light striking the copy paper. Since little light will be reflected from the black areas of the original, the charge on areas of the copy paper against which the light reflected from such areas strikes will be reduced very slightly. On the other hand, the charge on areas of the copy struck by the light reflected from white areas of the original, such as the white background of a letter, e.g., will be almost entirely dissipated since the most intense light will be reflected from those areas.

As the original and the copy paper continue through their respective imaging areas, the image on the original is reproduced in latent form on the copy paper through dissipation of the charge on its surface as described above.

As the leading edge of the original emerges from its imaging area, it passes off the end of endless conveyor **294** and is picked up by rollers **310** and **312**. Pick-up rollers **310** and **312** propel the original between guides **322** and **324** to feed rollers **326**, **328** and **330** which deposit it in tray **332** from which it may be removed and reinserted into the printer if multiple copies are desired. The originals are deposited face down in tray **332**. Therefore, if consecutively numbered originals are fed through printer **20**, they will be deposited in tray **332** in the same order.

Simultaneously, the leading edge of the exposed sheet of copy paper leaves the imaging area and is picked up by rollers **172** and **174** which move it toward developing tank **44**.

As the leading edge of the copy paper emerges from rollers **172** and **174**, it engages the actuator of and closes a normally open switch #2 mounted on guide **184** immediately below roller **174** as best seen in FIGURE 2. Closing of switch #2 completes a holding circuit through relay coil **378** as shown in FIGURE 3. Thus, when the trailing edge of the original clears wsitch #1, permitting that switch to open, the porjection lamps **36** will not be prematurely extinguished. When the trailing edge of the copy paper clears switch #2 (by which time the trailing edge of the original will have cleared its imaging area) switch #2 will open, deenergizing relay **378**. Upon relay coil **378** being deenergized, its contacts **377** open turning off projection lamps **36** and opening the circuit applying operating voltage to corona unit **27**.

Development of latent image

The developing tank **44** is located as closely as practicable to the image forming area for the copy sheet at conveyor belt **160**. The copy paper is directed onto curved wire guide members **382** shown in dotted lines in FIGURE 2 at the top central portion of tank **44**. The liquid toner with electrostatically attractable particles is forced through an apertured header **384** by the pump driven by pump motor **358** and applied to the upper surface only of the copy paper. Suitable electrostatic toners are well known in the art and include the examples described in the United States Patent 3,001,888 to Metcalfe, et al. and in the Journal of Scientific Instruments, volume 32, February 1955, pages 74 and 75. In such toner solution the polarity of the charge on the pigment particles can be controlled to be either negative or positive.

In the embodiment described, it will be assumed the pigment particles have a positive charge and therefore will be attracted to image area locations on the surface of the copy sheet that contain a negative charge. The upper surface of the copy paper that passes beneath header **384** in developer tank **44** has a negative charge distribution in accordance with the electrostatic latent image to be developed. The liquid applied to the upper surface runs off the sides of the paper without wetting the underneath side of the copy sheet as more fully described in my co-pending application Ser. No. 143,086.

Any liquid adhering to the surface of the copy sheet is removed by squeegee rollers **46** and **48**, and runs back into the reservoir of toner in tank **44**. The copy paper then passes between rollers **189**, **190** and into the stream of heated air circulated by fans **50** across lamps **36** to remove such moisture as remains on the copy sheet to thereby provide a nearly dry copy at surface **52**.

Clearance of background via bias

Where a good quality of copy paper is available that has good light decay characteristics and high contrast, it is possible to adjust the speed of drive motor **138** and the intensity of lamps **36** to expose the non-image areas sufficiently to neutralize the electrostatic charge and not reduce the charge in the image below acecptable limits for good printing. However, if either the paper or any other part of the system are less than optimum, it has been found that cleanliness of the non-image area can be significantly improved by use of a small D.C. voltage conductively applied to the paper either before or during the development step.

Referring now to FIGURE 4, suitable biasing circuit is illustrated which includes feed roller pairs **172**, **174**; **46**, **48**; and **189**, **190**. Rollers **174** and **189** are of a conducting material such as metal and connected to the positive terminal of a source of D.C. voltage **387**. Rollers **172** and **190** have an exterior surface of an insulating material such as rubber and hence have no effect on the charge on the copy paper. Roller **48** also has an exterior surface of an insulating material. Roller **46** is conductive and connected to the negative side of voltage source **387**.

The distance along the path taken by the copy sheet between rollers **172**, **174** and rollers **189**, **190** is substantially equal to the length of the copy sheet. As the base paper (see FIGURE 7) has a definite conductivity of from about 10^6 to 10^8 ohms, a positive field will be applied to the surface of the photoconductive layer contain-

ing the latent image next to the paper base and a relatively negative potential (ground) applied to the exposed surface of the photoconductive layer which it will be recalled was given a negative charge at the corona unit. This has the effect of uniformly reducing the charge throughout the copy sheet. By making the bias voltage sufficiently high, a complete repulsion of the positive pigment particles in the toner solution on the white background areas can be obtained without noticeably reducing the density of the accumulation of the charge particles on the colored marking areas.

After exposure to the image field on belt **160**, it has been found that the paper retains a negative charge on its surface of 200 volts in an image or marking area and about 50 volts in a non-image area. The 50 volt charge develops out as a light gray with the D.C. voltage source disconnected, but shows no development when a bias voltage of between 15 and 140 volts is applied.

The reasons for two combinations of three sets of rollers is to maintain the bias circuit through the paper for its entire length as it travels through the tank. Thus, when the paper first reaches squeegee rollers **46** and **48**, the bias circuit is completed from ground through roller **46**, the paper, and roller **174** to the positive potential on arm **386** of potentiometer **388**. By the time the trailing edge of the copy sheet passes roller **174**, the leading edge is on roller **189** thereby substituting roller **189** for roller **174** as the means applying the positive potential on the rear surface of the copy sheet.

This system inherently requires a controlled amount of conductivity of the base paper. As stated above, the resistivity the paper base apart from the photoconductivity layer should be between 10 and 500 megohms per square. The photoconductive layer should be selected to provide the greatest possible ratio between image areas and background or non-image areas.

It has been unexpectedly observed that most of the image is developed at squeegee rollers **46** and **48**. Therefore, it has been found possible to apply the bias voltage in a more simple arrangement that obviates the need for three sets of rollers.

Referring now to FIGURE 6, which is an enlarged fragmentary view of the embodiment shown in FIGURE 5, only rollers **46** and **48** are shown. These are the squeegee rollers through which the copy paper passes as it leaves the developer tank **44**. Rollers **189** and **190** of the embodiment of FIGURE 2 may be omitted. As shown in FIGURE 5, rollers **172** and **174** at the input side of developing tank **44** are retained but only to serve their usual function in the paper feed system.

In this embodiment, one of the rollers preferably roller **46**, is metal as before. The mating roller must be conductive but cannot be made to have a zero resistance since this would short out the bias voltage when no copy sheet is present or when a sheet of copy paper is narrower than the length of the rollers. Accordingly roller **48** is shown to have a metal core **390** covered with a conductive rubber coating. Conductive rubber as such is well known and has been used for example as a glossy material in high frequency transmission lines. The conductive rubber cylinder **392** may have an electrical resistance on the order of 50,000 to 500,000 ohms when measured from metal core **390** to the outer peripheral surface that is in contact with the copy paper and other conductive roller.

With reference to FIGURE 7, the copy paper is shown with the paper base **394** having the conductivity discussed above, and the layer **396** of photoconductive material which has charged image forming areas that have been unexposed to light and background areas that have been exposed to light.

This biasing system makes use of the fact that the apparent conductivity of the photoconductive zinc oxide coating layer **396** varies by the amount of light it has absorbed. It has been found that this conductivity varies within a ratio of 5:1 going from unexposed areas to exposed areas. Now, therefore, if we consider that part of a circuit which includes the conductive rubber roller **48**, the paper base **394** of the copy sheet, the zinc oxide photoconductive layer **396** of the copy sheet, and the metal roller **46**, then the total resistance through these elements will be constant except for the photoconductive layer **396**. Conductivity varies in proportion to the amount of light it received during exposure.

As a copy sheet goes through developer tank **44** it brings with it a fairly large amount of toner liquid to the squeegee rollers **46** and **48**. While the copy is being squeezed between these rollers, a potential of between 10 and 140 volts D.C. is applied to rollers **46** and **48**. Because the resistance of photoconductive layer **396** is less in the exposed or background areas, more of the positive bias charge will appear here than in the unexposed or high resistance image area. This positive charge has the desired repelling effect on the positive toner particles, and thus coloration or development of low electrostatically charged areas may be effectively prevented.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by Letters Patent is:

1. In an apparatus for developing a latent image formed on a surface of an electrically chargeable member by a partially dissipated, electrostatic charge, a developer station and means (a) for advancing said chargeable member through said station along a predetermined path, (b) for applying developer particles to said surface as said chargeable member is advanced through said station to develop the latent image on said surface, and (c) for applying a biasing potential to said surface with the developer particles thereon to repel said developer particles from the non-image areas of said surface, said last-mentioned means comprising a source of D.C. voltage providing said biasing potential, first and second means spaced apart along said path to successively engage said chargeable member leaving said developer station and being electrically connected to separate terminals of different polarities of said voltage source, and third means spaced apart from said first and second means for engaging said chargeable member entering said developer station and being electrically connected to one of said terminals, said first, second, and third means being arranged sufficiently close together that they all engage said chargeable member before said chargeable member disengages from said third means during its advancement through said developer station, whereby the potential provided by said voltage source is imparted to said chargeable member.

2. The apparatus defined in claim **1** wherein said first and second means respectively engage opposite surfaces of said chargeable member.

3. The apparatus defined in claim **2** wherein said third means engages the same surface of said chargeable member which is engaged by said second means, and wherein said second and third means are connected to the same terminal of said voltage source.

4. The apparatus defined in claim **3** wherein said image is formed on the surface engaged by said first means.

5. The apparatus defined in claim **4** wherein each of said first, second, and third means comprises an electrically conductive roller for advancing said chargeable member along said path.

6. The apparatus defined in claim **5** wherein said means for advancing said chargeable member along said

path comprises an electrically non-conductive roller cooperatively mating with each electrically conductive roller of said first, second, and third means to respectively form first, second, and third roller pairs.

7. The apparatus defined in claim 6 wherein said developer station is formed by a tank adapted to confine a liquid toner containing a suspension of said developer particles, wherein said third roller pair having the electrically conductive roller of said third means advances said chargeable member into said tank, and wherein said first and second roller pairs respectively having the electrically conductive rollers of said first and second means withdraw the chargeable member from said tank.

8. The apparatus defined in claim 7 wherein said first roller pair squeezes said chargeable member to remove excess liquid toner therefrom.

9. The apparatus defined in claim 5 wherein the electrically conductive rollers of said first and second means are connected to the same voltage source terminal through an adjustable arm and resistor of a potentiometer.

10. In an electrostatic printer having

(a) a corona unit for producing an electrostatic charge on a surface of a chargeable member;

(b) an imaging station for selectively dissipating said electrostatic charge to form a latent image on said chargeable member;

(c) a developing tank having an inlet and an outlet for coating said chargeable member with a developer substance; and

(d) a guide member disposed between said inlet and outlet for guiding said chargeable member through said developer tank; the combination of

(e) means for applying a biasing potential to said chargeable member for repelling said developer particles from the non-image areas of said surface; said last-mentioned means comprising:

(i) a first pair of rollers on the side of the developing tank nearer said corona unit, one of said rollers being of electrically conducting metal and connected to a first terminal of a D.C. voltage source and contacting the uncharged surface of said chargeable member, the other of said first pair of rollers being of comparatively non-conducting material and contacting the charged surface of said chargeable member;

(ii) a second pair of rollers disposed adjacent the outlet of said developer tank to receive said chargeable member when it has been coated with developer particles with one of the rollers of said second pair being of electrically conducting metal and connected to a second terminal of said D.C. voltage source and contacting the charged surface of said chargeable member, the other of said second pair of rollers being of comparatively non-conducting material and contacting the other side of said chargeable member; and

(iii) a third pair of rollers being disposed adjacent to said second pair of rollers to receive said chargeable member after it leaves said second pair of rollers, one of the rollers of said third pair being of metal and connected to said first terminal of said D.C. voltage source for contacting the uncharged surface of said chargeable member, the other of said third pair of rollers being coated with comparatively non-conducting material for contacting the charged surface of said chargeable member.

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