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 [45] Patented **Dec. 15, 1970**
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Primary Examiner—Peter Feldman

Attorney—Curtis, Morris and Safford

[54] **ELECTROSTATIC PRINTING APPARATUS**
9 Claims, 24 Drawing Figs.

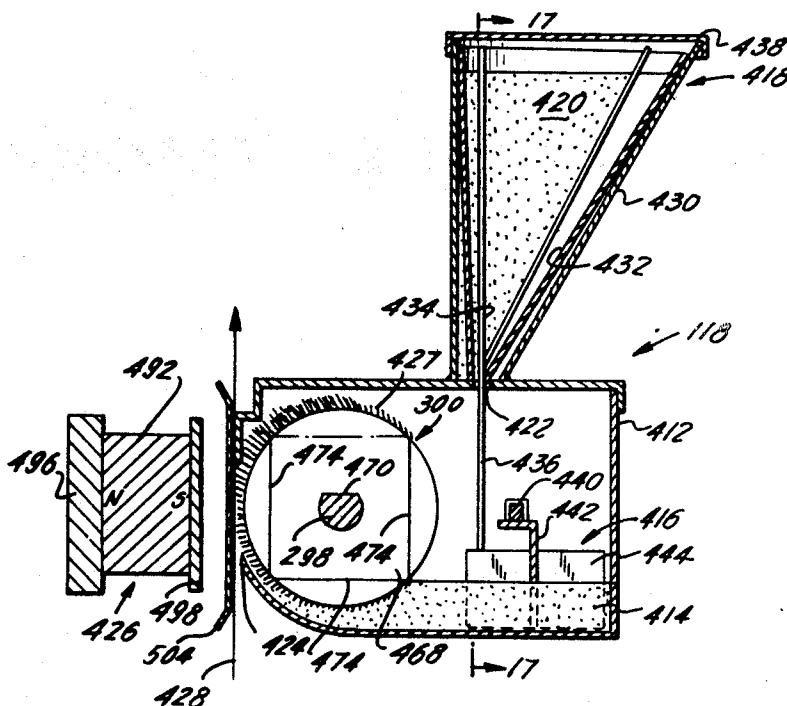
[52] U.S. Cl. **118/637;**
 117/17.5; 222/161, 222/231
 [51] Int. Cl. **B05b 5/02**
 [50] Field of Search 118/637, 7,
 9, 11; 117/17.5; 222/161, 56, 231, 232; 335/302

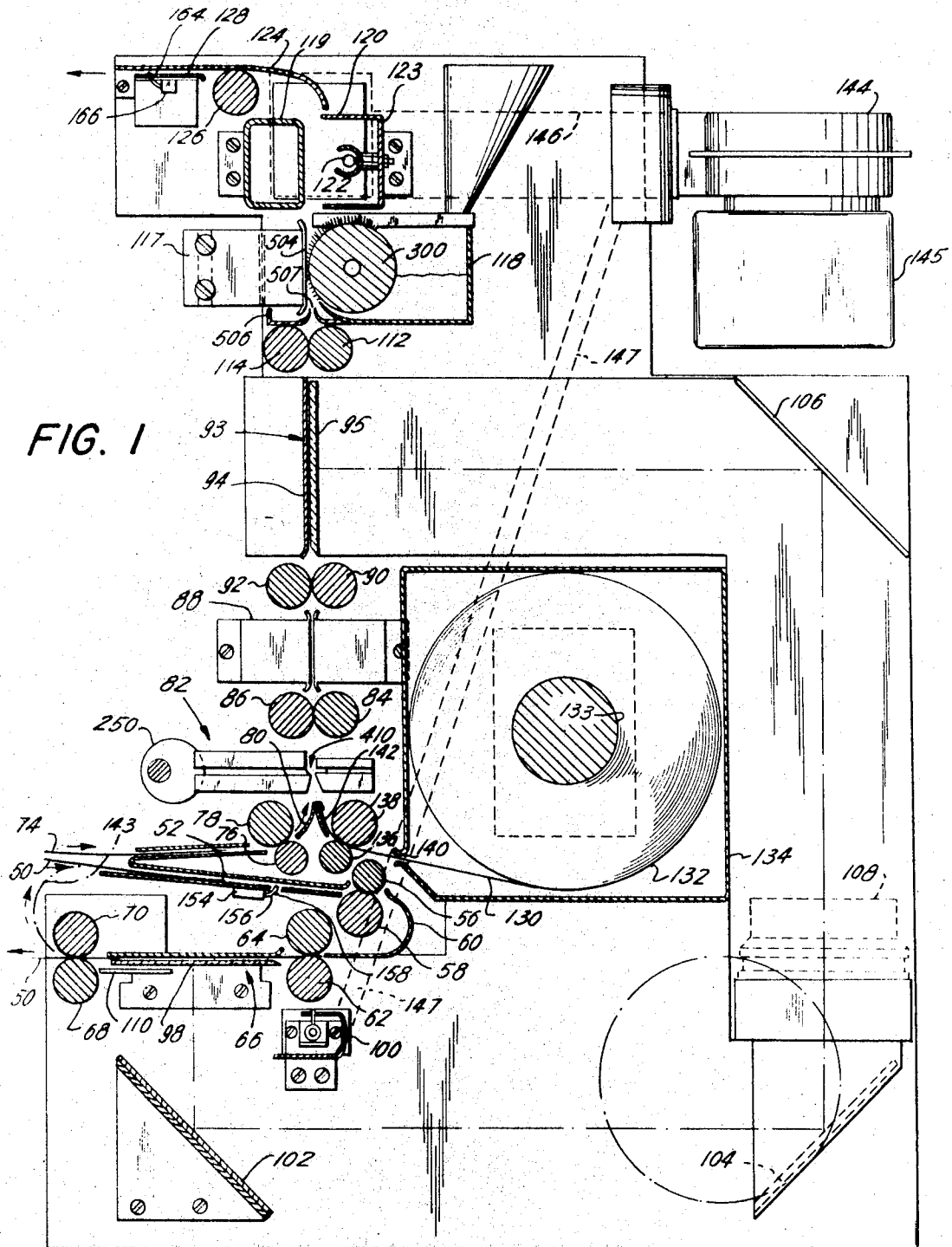
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ABSTRACT: Latent electrostatic images are developed by means of a magnetic brush having a plurality of washers, each bent along the lines of a polygon, mounted on a rotary shaft. In effect, the surface of the washers oscillate back and forth along the image-bearing surface, so that the magnetic brush moves back and forth and thoroughly develops the latent image when the washers are rotated. A toner dispenser dispenses toner powder into a mixture of toner and carrier particles, in an amount metered by the effective oscillation of the brush-forming washers. In an alternative embodiment, the brush is formed by a tube made of magnetic material and having holes arranged in a spiral pattern.





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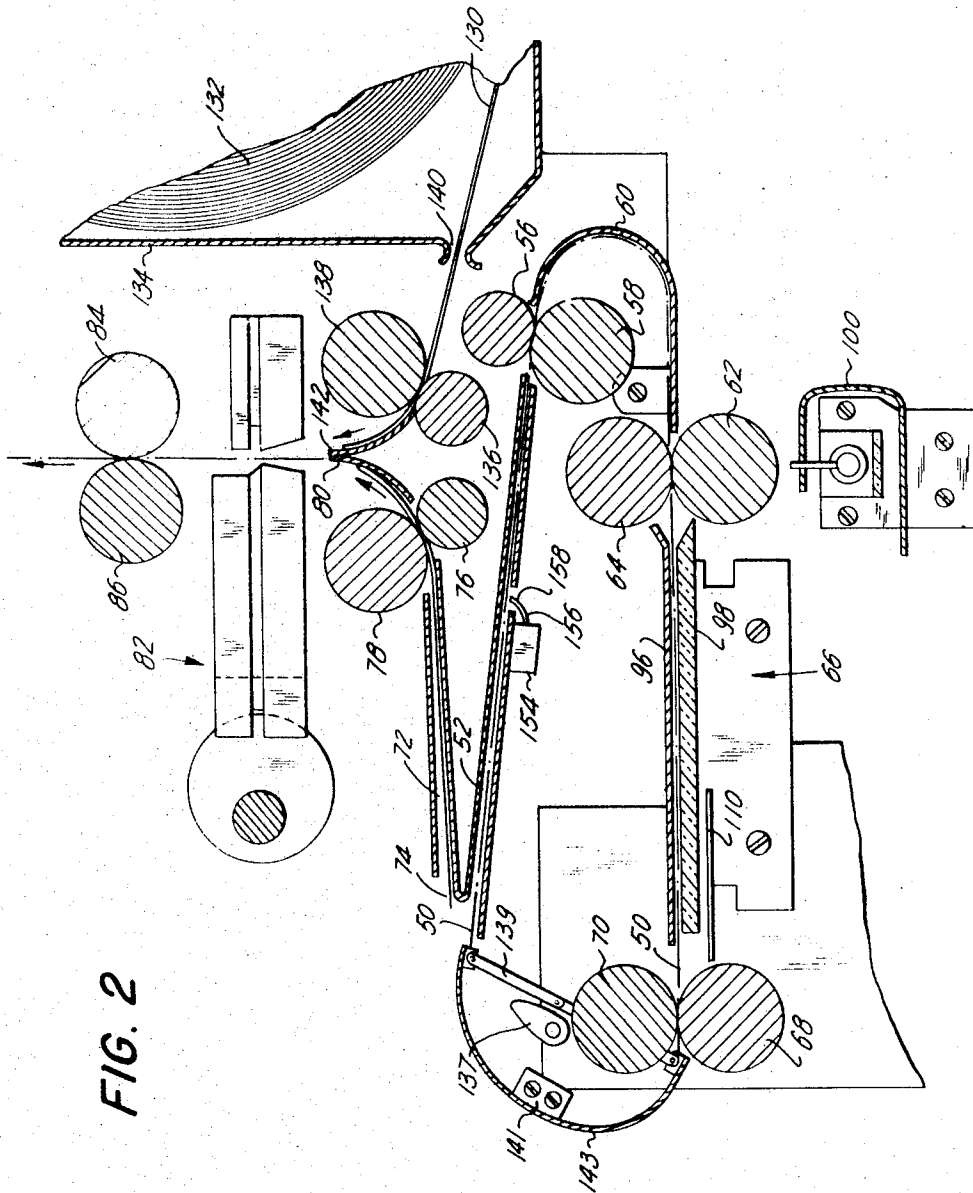


FIG. 2

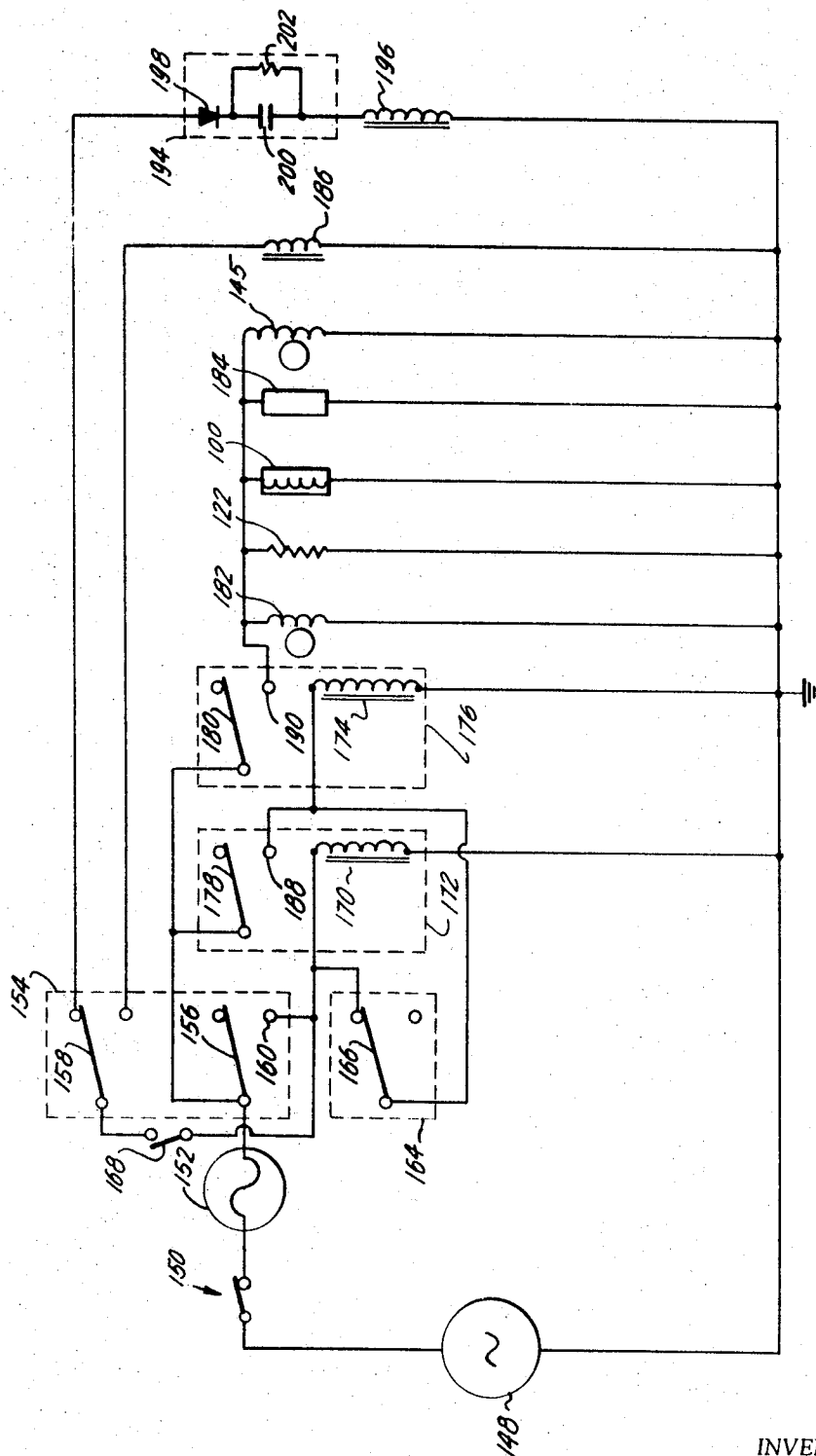
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FIG. 3



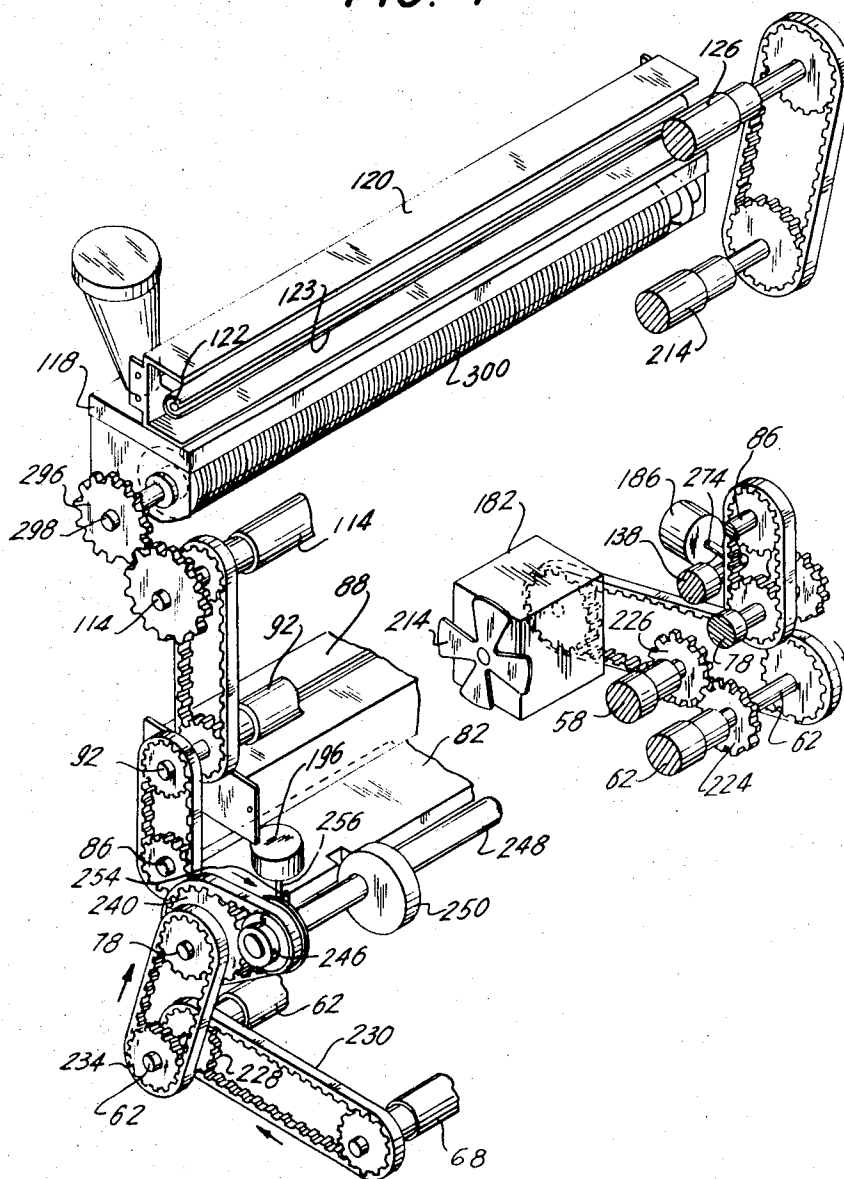
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FIG. 4



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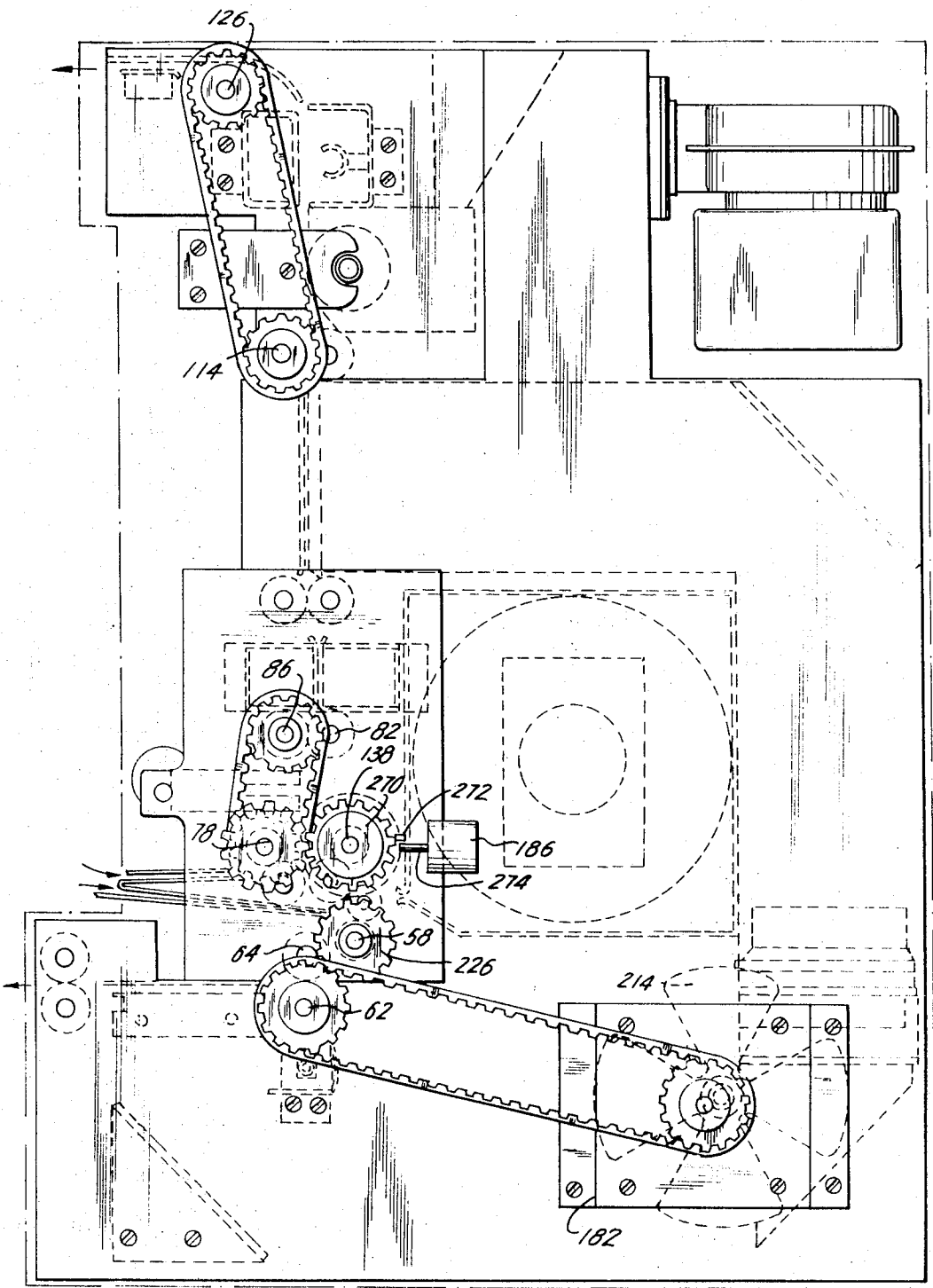


FIG. 5

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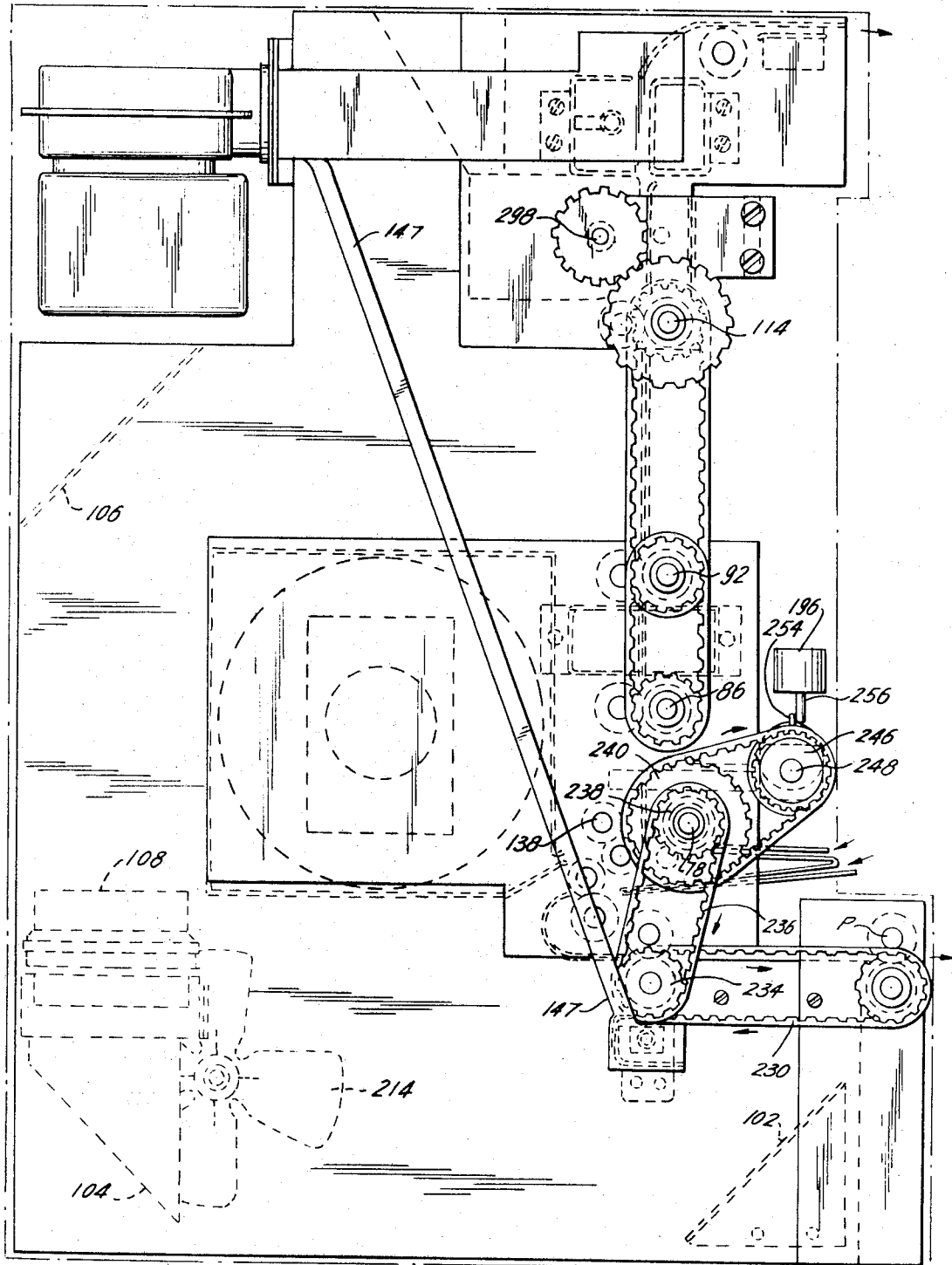
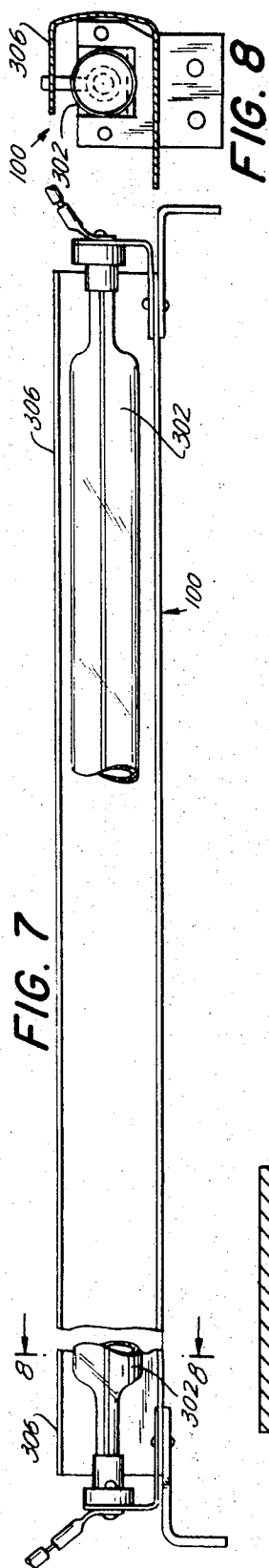
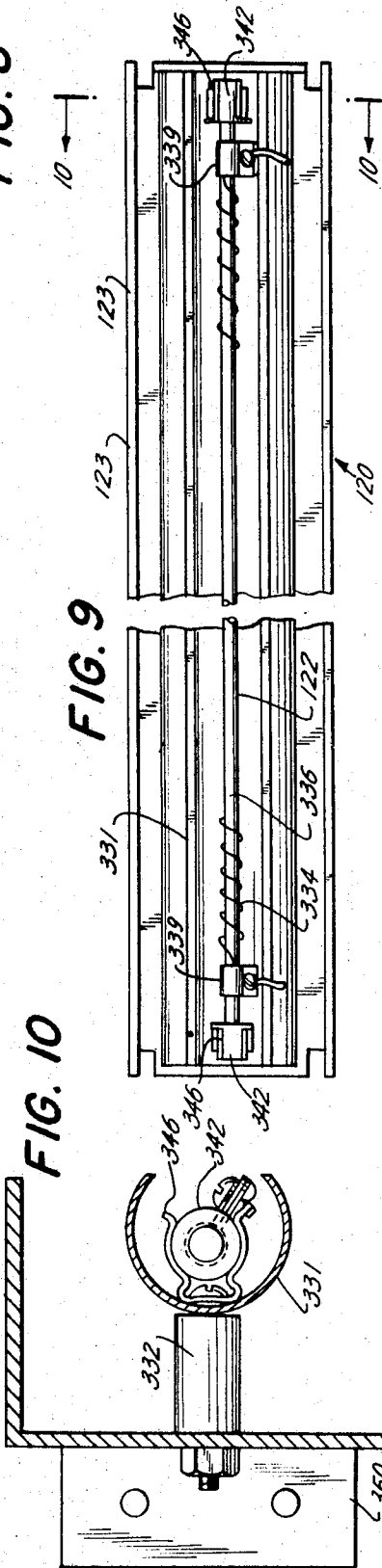
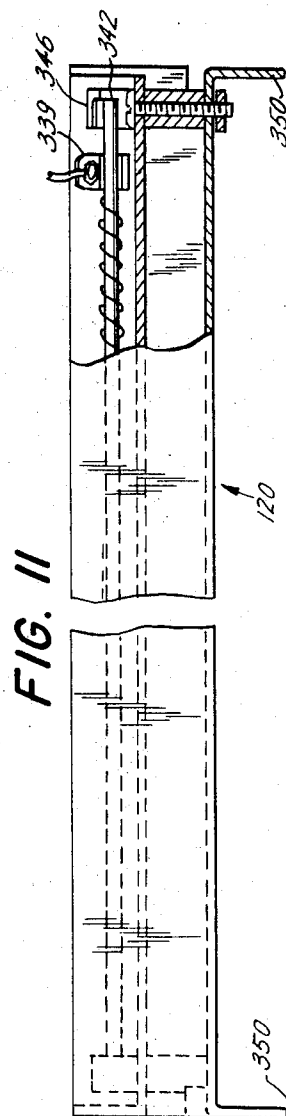


FIG. 6

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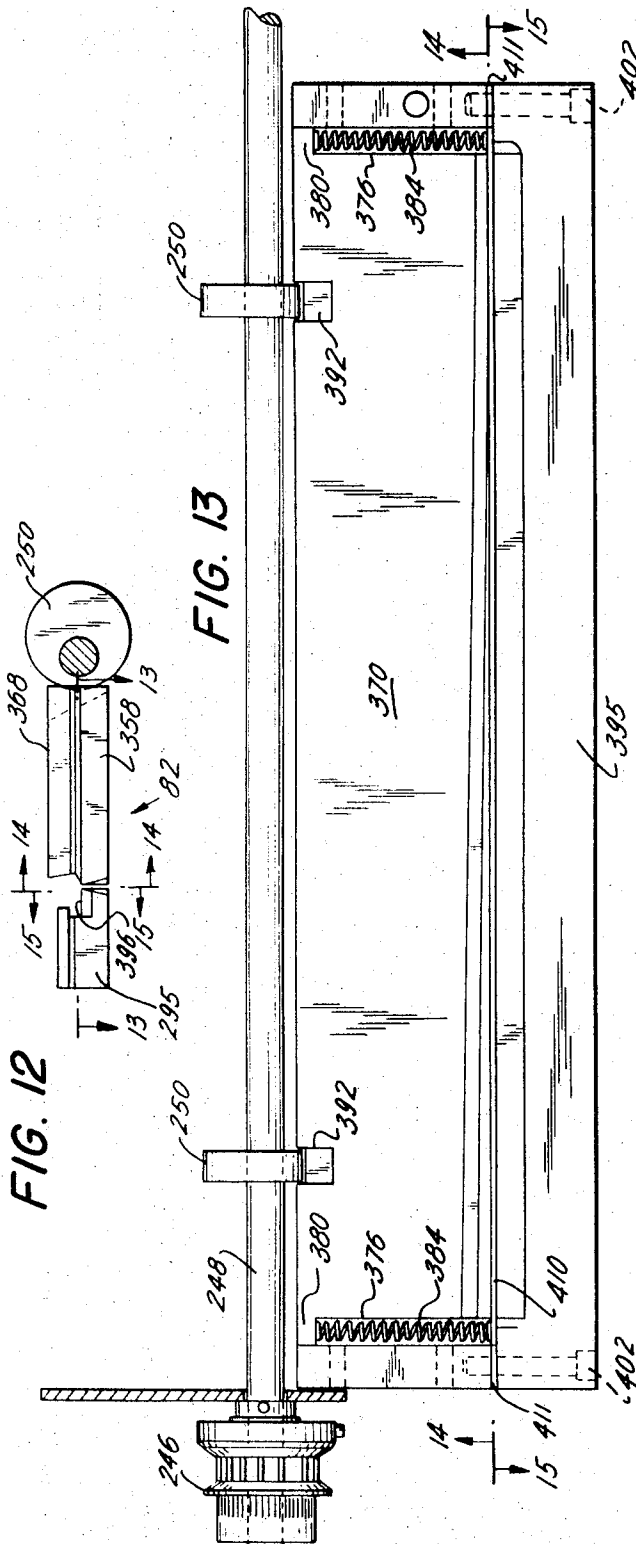
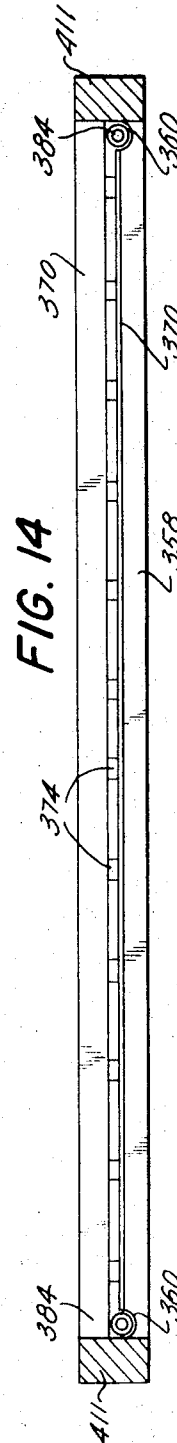
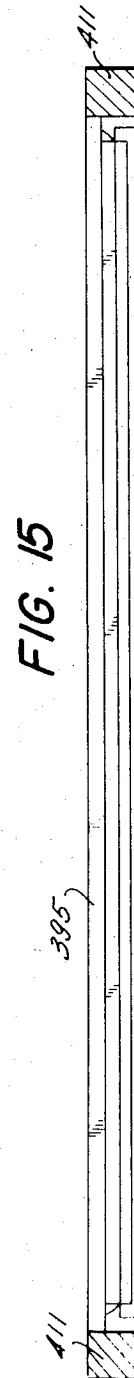


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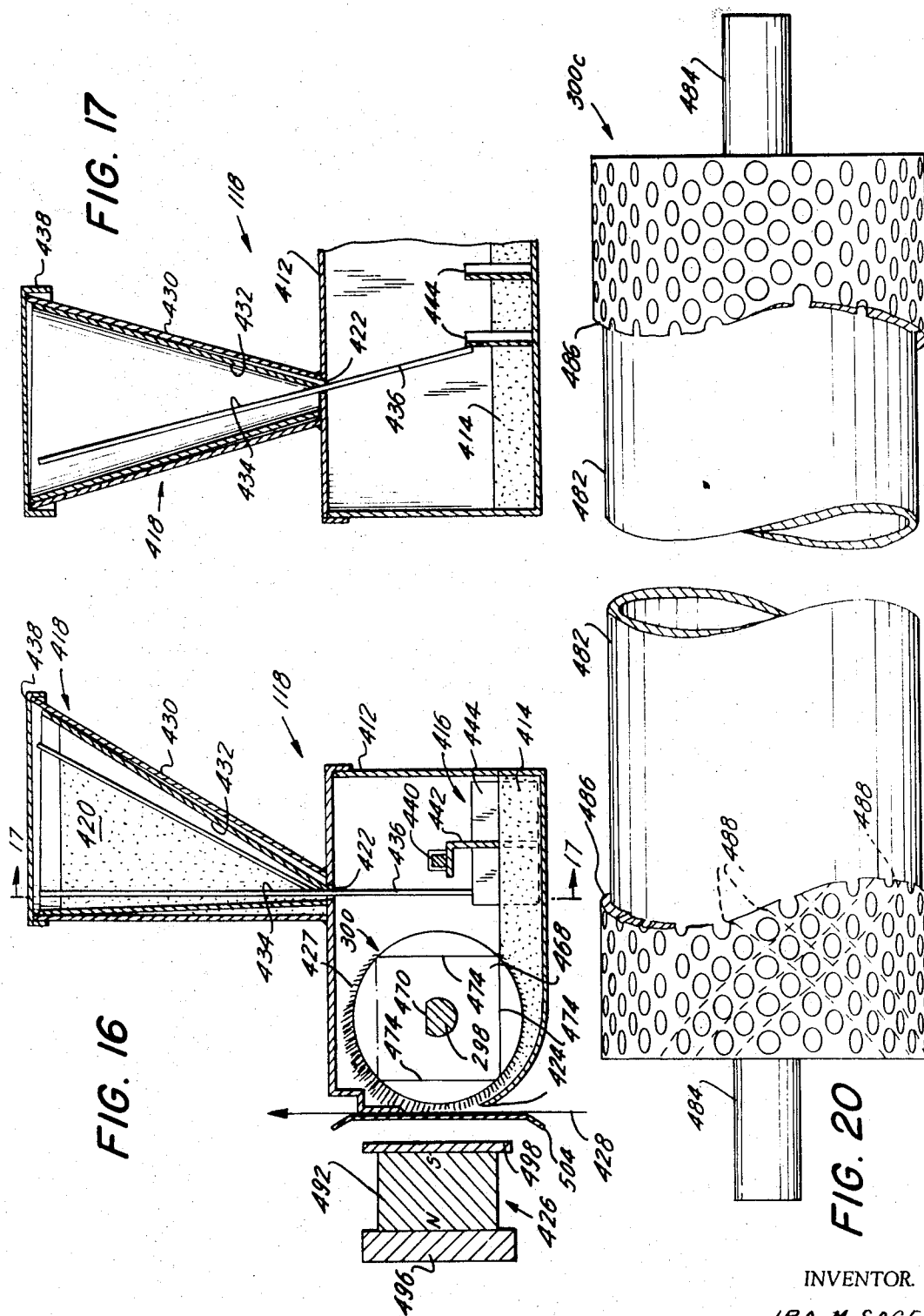
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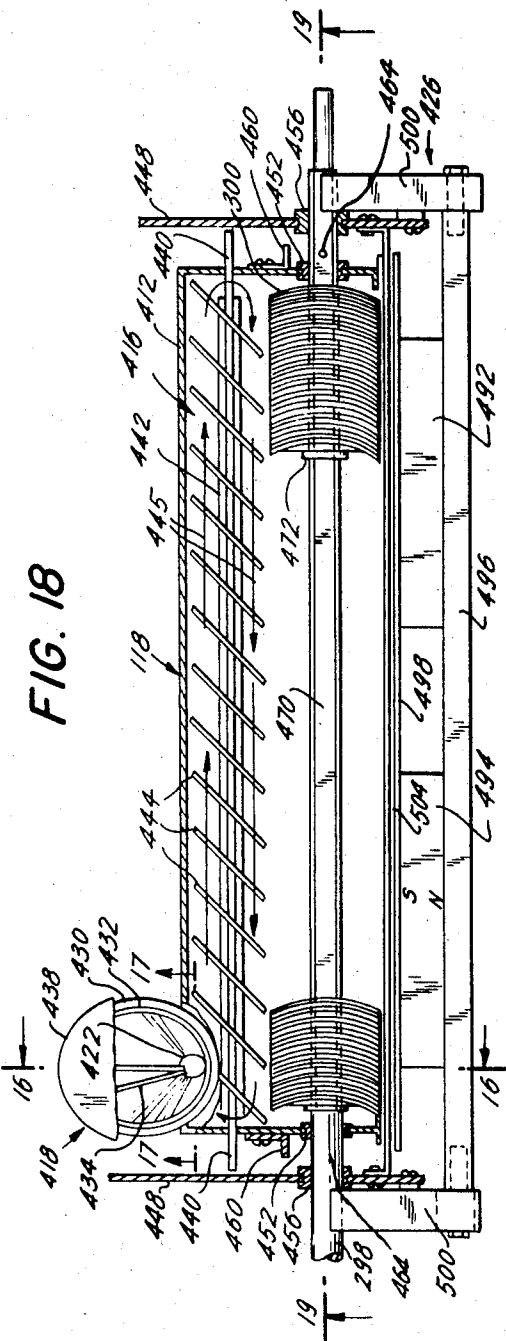
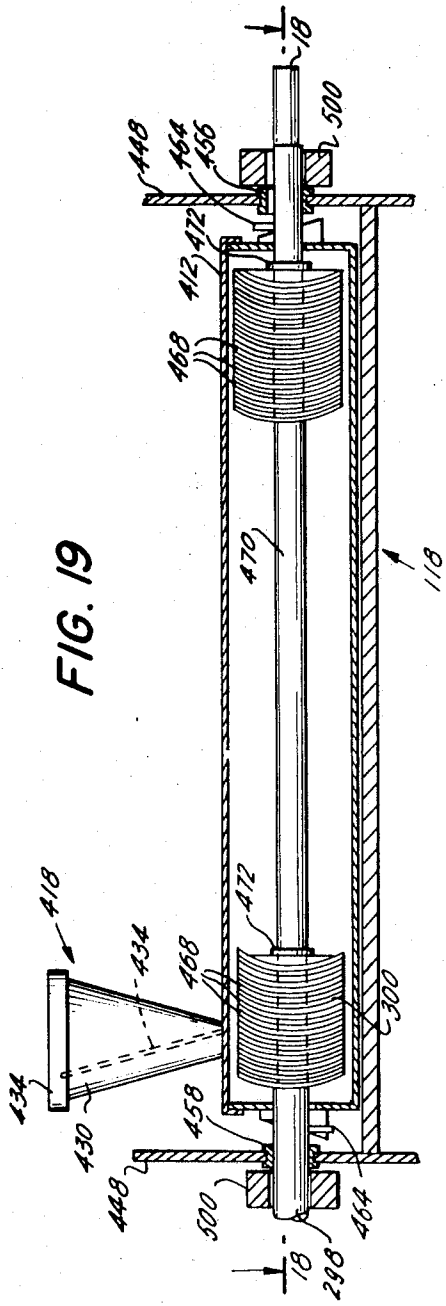


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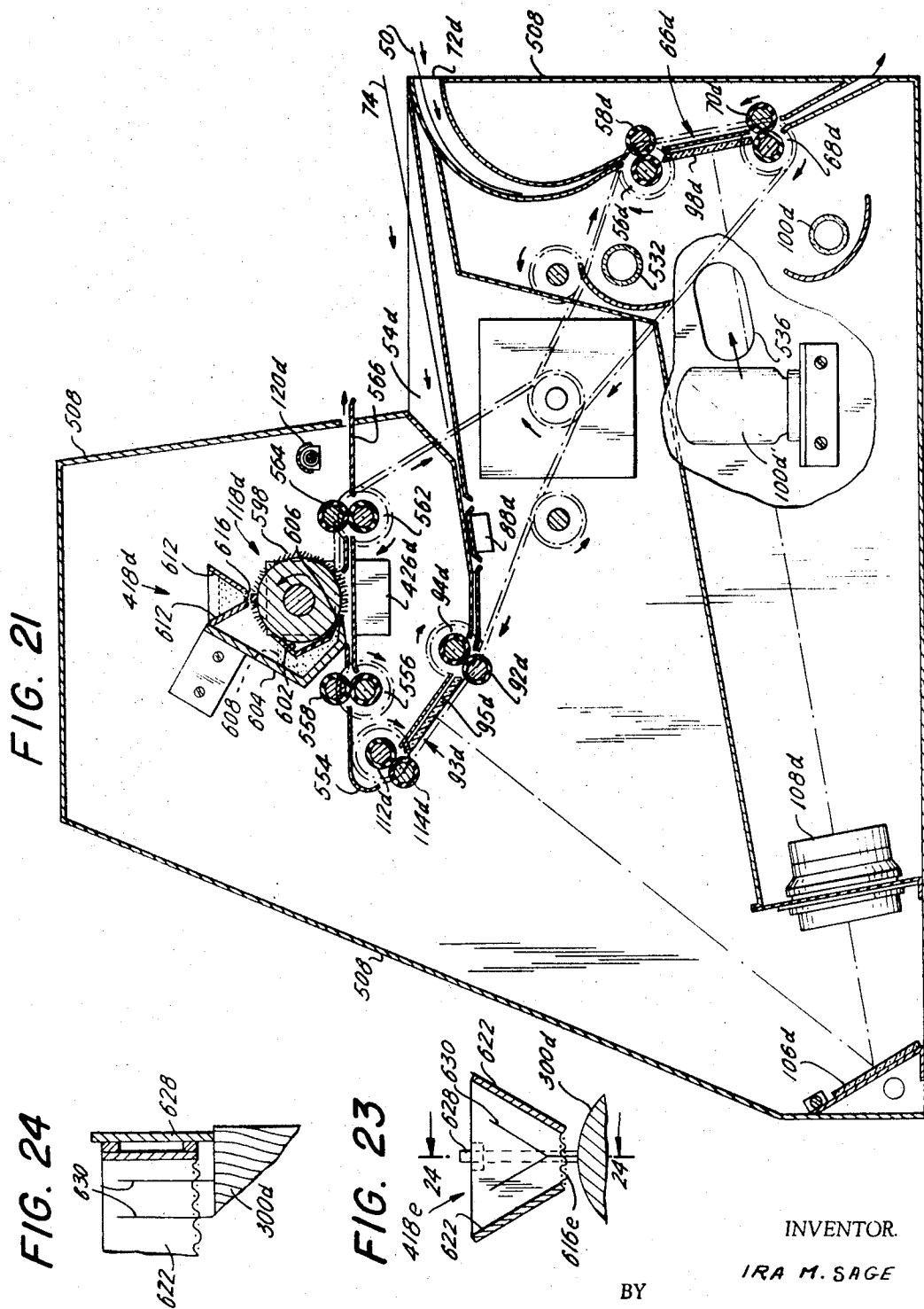
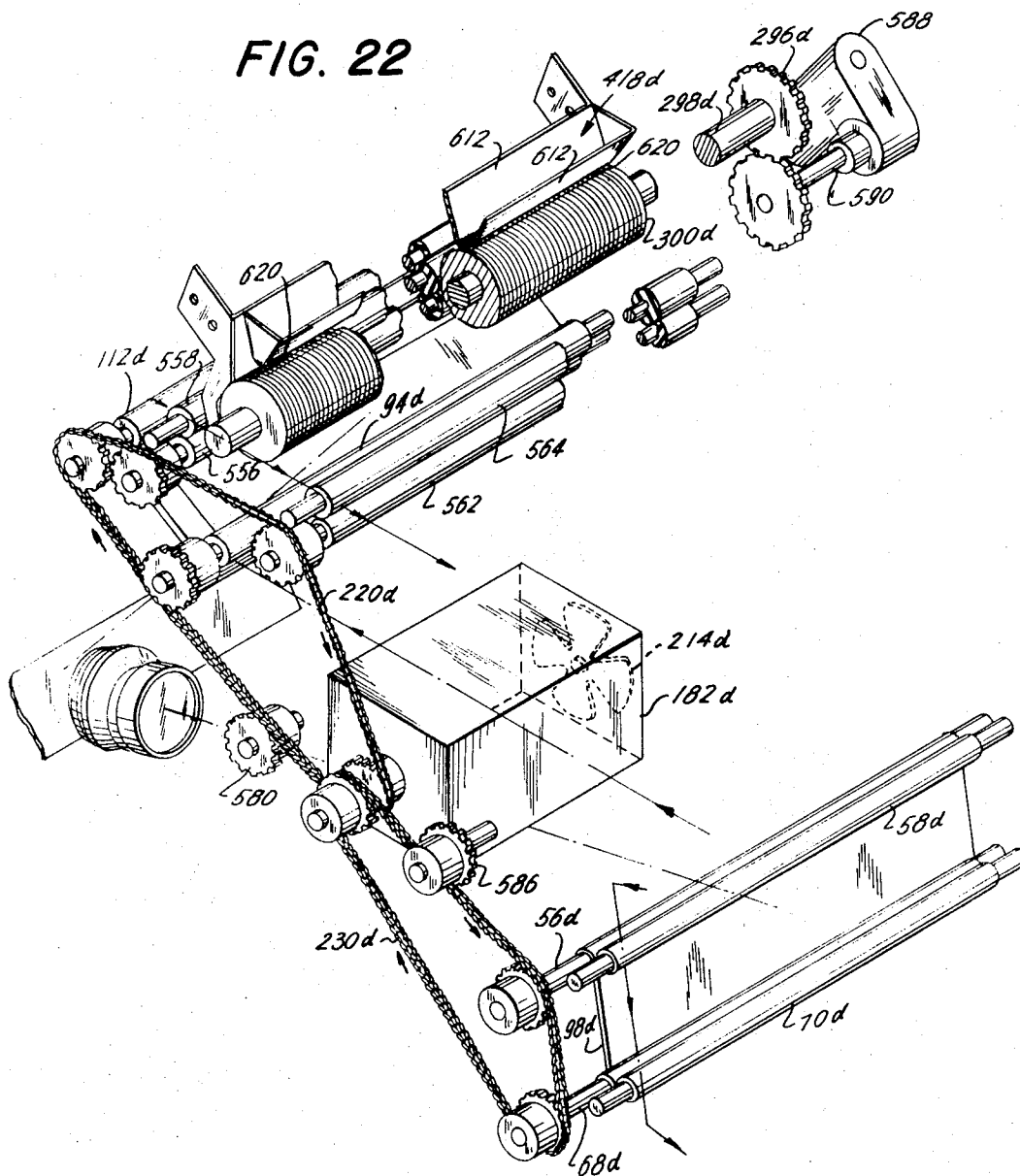


FIG. 22



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ELECTROSTATIC PRINTING APPARATUS

This is a Division of U.S. Application Ser. No. 295,652, filed Jul. 17, 1963, now U.S. Pat. No. 3,451,320.

This invention relates to electrostatic printing apparatus. More particularly, this invention relates to a compact and portable electrostatic office copier for copying documents on photosensitized sheet material.

An object of this invention is to provide electrostatic printing apparatus that produces clear and accurate printing quickly at a low cost.

Another object of this invention is to provide an electrostatic copying machine which is relatively inexpensive to manufacture, occupies relatively little space, can be moved from place to place without permanent installation, and produces copies of documents at a low cost.

A further object of this invention is to provide such a copying machine which is convenient and simple to operate, requires little maintenance, and operates with a high degree of reliability.

Other objects, aspects and advantages of the present invention will be pointed out in, or apparent from, the following description and drawings, of which:

FIG. 1 is a schematic view, partly in section, partly in elevation, and partly in phantom, of an embodiment of the copying machine of the present invention.

FIG. 2 is an enlarged detail drawing of a portion of the machine shown in FIG. 1.

FIG. 3 is a schematic drawing of an electrical circuit for the copying machine shown in FIG. 1.

FIG. 4 is a schematic drawing of the drive system of the copying machine shown in FIG. 1.

FIG. 5 is a right side view of the machine shown in FIG. 1.

FIG. 6 is a left side view of the machine shown in FIG. 1.

FIG. 7 is a front view of the lamp used with the copying machine shown in FIG. 1.

FIG. 8 is a sectional view taken along line 8-8 of FIG. 7.

FIG. 9 is a front view of the fuser unit used in the copying machine shown in FIG. 1.

FIG. 10 is a sectional view taken along line 10-10 of FIG. 9.

FIG. 11 is a partially cutaway top plan view of the fuser shown in FIG. 9.

FIG. 12 is an end view of the knife unit used in the copying machine shown in FIG. 1.

FIG. 13 is a plan view of the knife unit shown in FIG. 12.

FIG. 14 is a view taken on line 14-14 of FIG. 13.

FIG. 15 is a view taken on line 15-15 of FIG. 13.

FIG. 16 is a schematic and partly sectional view of the developer unit used in the copying machine shown in FIG. 1.

FIG. 17 is a sectional view taken on line 17-17 of FIG. 16.

FIG. 18 is a view partly in plan, partially cutaway, and partly in longitudinal horizontal section, of the developer unit shown in FIGS. 16 and 17.

FIG. 19 is a view in vertical section taken on line 19-19 of FIG. 18.

FIG. 20 is a plan view, partly broken away, of a brush core used in the developer unit shown in FIGS. 16 through 19.

FIG. 21 is a schematic drawing of another embodiment of the present invention.

FIG. 22 is a schematic isometric representation of the copying machine shown in FIG. 21, but with parts broken away for clearer showing.

FIG. 23 is a detail view in vertical section of an alternative construction of a portion of the developer unit of the copying machine shown in FIGS. 21 and 22.

FIG. 24 is a detail vertical sectional view taken along line 24-24 of FIG. 23.

Referring to FIGS. 1 and 2, a document 50 to be copied is inserted into the copying machine through the lower passage 52 of an inlet guide with the surface to be copied facing upward. At the end of the passage the forward edge of the document meets a pair of rolls 56, 58 which feed the document forward. A curved guide 60 bends it over and into another pair of rolls 62, 64. Rolls 62, 64 feed the document through an expo-

sure window 66, from which an image of the surface to be copied is transmitted to the printing portion of the machine by a combination of mirrors and lenses. The document then passes on to another pair of rolls 68, 70 which feed the document out of the machine.

In accordance with the present invention, the document 50 may be copied by the machine upon either precut photosensitized sheets, each of which is fed individually into the machine along with the document, or upon photosensitized paper fed from a roll and cut to length within the machine. The machine's operator may select between these modes simply and quickly by operating a selector switch located on the outside of the machine.

The upper passage 72 of the inlet guide is used to guide precut sheets 74 of photosensitized copy paper into the machine when the precut sheet mode of operation is selected. It is desirable that the leading edges of such precut sheets be synchronized in the copier with the corresponding edges of the documents to be copied. This is most simply achieved by aligning the edges of the document and sheet before inserting either; then, holding them together at a distance from the leading edges, one spreads them apart just enough to feed the document into the mouth of passage 52 and the copying paper sheet into the mouth of passage 72. When the document and copy sheet are inserted into the machine in this manner, the leading edge of the document 50 depresses a pair of feeler switch fingers to start the machine's operation. Almost simultaneously, the copy sheet engages in the bight of rolls 76, 78 to start its journey upwardly to the printing apparatus of the machine. The document then passes on to the bight of document-transfer rolls 56, 58 and out of the machine as described above.

Photosensitized paper suitable for making copies in the machine is shown, for example, in U.S. Pat. No. 3,052,540 to H. G. Grieg. One which I have found particularly suitable can be made, for example, by coating paper with a mixture of an insulating binder, photoconductive pigment, e.g. zinc oxide, and a dye or dye combination to give panchromatic sensitivity. This coating is essentially nonconductive when in the dark or weak light, but becomes electrically conductive when exposed to stronger light. Since the coating is panchromatically sensitive, the document 50 may be any flexible sheet material bearing lines and/or characters of any desired color or colors.

As exposure to light and shadow may deteriorate such paper, it should be protected from strong light, and especially from nonuniform light. Protection from such light while the paper is passing through the machine may be provided by a light-tight housing for the entire machine or by shielding enclosing the paper's path.

Sheet 74 is moved by the driven rolls 76, 78 onward along a curved guide 80, and through a knife unit 82, which cuts copy paper to length during the roll-feed operation of the machine but performs no function when precut sheets are used. Sheet 74 then moves on to another pair of rollers 84, 86 which feed the sheet through an electrostatic charging unit 88. This charging unit comprises a corona discharge device, such as that shown in U.S. Pat. No. 2,922,883, which establishes a uniform negative charge on the coated surface of the copy paper passing through it.

The sheet 74 is then engaged by a pair of rollers 90, 92 and fed out of charging unit 88 past an image location 93, between a backing guide plate advantageously made of metal, 94, and a glass plate 95.

Guide rolls 76, 78 and 84, 86 are interconnected or synchronized with rolls 56, 58 and 62, 64 so that at the instant the sheet 74 reaches the image location 93, the document 50 likewise reaches the exposure window 66. This exposure window includes a backing guide plate 96, advantageously of metal, and a lower guide plate 98, advantageously of glass. A lamp 100 is positioned below glass plate 98 to illuminate the lower surface of document 50 as it passes the exposure window 66.

Three mirrors 102, 104 and 106 are used to reflect the image of document 50 through a focusing lens system 108 and through the glass plate 95 onto the sensitized sheet. Each of these mirrors is set at an angle of 45° to direct the light onto glass plate 95 and is advantageously of the "first-surface" type; that is, it has a reflective surface exposed to the incident light. The lens 108 is placed in the path of the image-forming light, e.g. between mirrors 104 and 106 and is adjusted to focus the image upon the sensitized sheet 74 at the image location 93.

Sheet 74 when driven past image location 93 is synchronized with document 50 moving past the window 98 so that the image of document 50 projected upon sheet 74 remains fixed relative to sheet 74 throughout its travel past the location 93.

In this manner the charged photosensitive surface of sheet 74 is differentially discharged by a light pattern corresponding to that of the illuminated surface of document 50. In the areas where light strikes the charged surface of sheet 74 the coating becomes conductive and the charge is dissipated, while the charge remains on the dark areas, thus leaving a charge pattern corresponding to the dark markings on document 50.

An adjustable screen 110 is positioned below glass plate 98 in order to adjust the total light received from window 66 to form the focused moving image at 93. The area of the plate 98 in which this screen intercepts light is adjustable to vary the time required for exposure of the copy paper to the focused image of the document at 93 and, hence, the strength of the electrostatic image on sheet 74.

Sheet 74, now bearing the electrostatic image, moves on to rolls 112, 114 which feed the sheet into a developer unit 118 (see also FIGS. 16—19 described in greater detail below). In the unit 118 developer powder is uniformly distributed across the image-bearing surface of sheet 74 under conditions such that it is held on the sheet only where a charge exists.

This powder is composed of a fusible printing material such, for example, as a thermoplastic resin mixed with carbon black, or other dark pigment or dye, which is positively charged. This powder is brushed onto the image-bearing surface where the charged developer particles are attracted to and held by the oppositely charged areas on the sheet corresponding to dark areas on the document. Powder particles touching discharged areas are not held, but pass on or fall away. Thus, the sheet 74, when it emerges from the developer unit 118, has on its surface a visible pattern of adhering developer particles. This gives a sharp and clear reproduction of the document 50.

The darkness of this pattern depends upon the amount of powder held by the electrostatic image. The amount of powder so held in each area depends in turn upon the degree to which the area has been discharged and, consequently, upon the whiteness or darkness of the corresponding area on the document and the intensity of light from source 100 and the amount of such light which is allowed by screen 110 to reach the document. Light screen 110 therefore serves as a means for controlling the darkness of copies made in the machine.

Sheet 74, now bearing a fusible developer powder image of the document 50, emerges from the developer unit 118 and passes between the outside surface of a rectangular-shaped backing tube 119 and a fuser unit 120. Fuser unit 120 has a radiant heat source 122 and heat reflector 123 which heats the developer powder pattern and fuses it into the copy paper to produce a finished copy having a permanent, sharp and clear reproduction of the document.

The finished copy is next fed around a curved guide 124 which guides the copy over a transport roll 126, an outlet guide plate 128, and out of the machine. A tray or other appropriate means may be attached near the outlet opening to catch copies as they emerge.

As was mentioned above, the machine illustrated is equipped for using either precut sheets of copy paper inserted into passage 72 or copy paper dispensed from a roll. Such roll-fed copy paper 130 is stored in a roll 132 which is rotatably

mounted on a hub 133 and stored in a light-excluding compartment 134 in the machine. When the machine's operator selects the automatic roll-feed mode of operation for the machine, driven feed rolls 136, 138 withdraw copy paper 130 from the roll 132 through a dispensing slot 140 in compartment 134 and feed the paper upwardly around curved guide 142, past knife 82, which cuts the paper into lengths corresponding to those of documents being copied, and on to rolls 84, 86 and the printing apparatus of the machine. This printing apparatus performs the same functions on such machine-cut sheets as on precut sheets fed through passage 72.

This roll-feed mode of operation is semiautomatic in that the operator need not feed in copy paper when he inserts the document into the machine; all he needs to do is insert the document and wait a short time for his copy to emerge. The electrical circuitry used to provide this semiautomatic operation will be described in greater detail below.

For making multiple copies of a document, a curved repeater guide 143 (shown fully in FIG. 2 and in dashed lines in FIG. 1) is attached between the input end of document passage 52 and the outlet side of rollers 68, 70. Guide 143 turns the document back into the passage 52 to be recopied, as many times as desired.

Guide 143 is advantageously made of a stiff resilient sheet material and secured to the housing of the copying machine at its midportion by means of a pair of tabs 141. The resiliency of the material of guide 143 biases its ends away from one another. A toggle linkage 139 pivotally connects these ends of guide 143 together, and a cam 137 is pivotally mounted near linkage 139. Cam 137 can be turned by the machine's operator to the position shown in FIG. 4 so that it does not engage with linkage 139. In this position the links of linkage 139 are aligned with one another and the ends of guide 143 are positioned to receive the document 50 from rolls 68, 70 and guide it upward into passage 52 to be recirculated and recopied. When cam 137 is turned into engagement with toggle linkage 139, the ends of guide 143 are drawn inwardly by linkage 139 and permit the document to exit from the machine in the manner described above.

Since the sensitivity of the copy paper may be impaired by exposure to light, the paper storage compartment 134, is substantially light-tight and has nonreflective inner surfaces, e.g. an anodized black coating used to line the feed slot 140 as is common in photography. Advantageously, as many of the other interior parts of the machine as practicable are made dark to absorb any stray light.

A centrifugal blower 144 (top of FIG. 1), driven by an electric motor 145 blows air through a duct 146, past the fuser unit 120, and through the tube 119 to cool these components and avoid overheating of the copies. A smaller duct 147 (FIG. 1) feeds air from duct 146 to cool lamp 100.

In FIG. 3 is a diagram showing the interconnection of the electrical components used in the copying machine of FIG. 1. These components are energized from an AC power supply 148, e.g., a standard 120 volt, 60 cycle power supply, through an on-off switch 150 and a fuse 152. This FIG. shows the circuit as it is initially, before any document has been inserted into the machine, but with on-off switch 150 closed to "turn on" the machine.

As shown in FIGS. 1 and 2, a starting switch 154 is located below passage 52 of inlet guide 54. Switch 154 has a pair of side-by-side "feeler" type contact arms 156 and 158 extending upwardly into passage 152. These contact arms 156 and 158 are lightly biased in the upward direction to contact their upper terminals, as is shown in FIG. 3. Arms 156 and 158 are depressed substantially simultaneously by the leading edge of a document 50 which is inserted into the machine. The depression of arms 156 and 158 causes them to contact the lower terminals of switch 154 and energize the printing and feeding components and the roll-feed apparatus of the machine, as will be described below.

A shutoff feeler switch 164 is located below outlet guide 128 at the top of the machine, as is shown in FIG. 1. Switch 64 has a contact arm 166 which extends into the outlet passage near guide 128. Arm 166 is lightly biased upwardly to contact the upper terminal of switch 164 and is depressed by a finished copy emerging from the exit of the machine. Switch 164 shuts the machine off when the finished copy has exited from the machine and no document is being copied.

Referring now to FIG. 3, a manually operated switch 168 serves as a means for selecting precut sheet or roll-feed operation of the machine. Selector switch 168 connects terminal 160 of switch 154 to contact arm 158. By closing switch 168 roll-feed operation is selected and by opening it precut sheet operation is chosen.

Assuming that selector switch 168 has been opened to provide for precut sheet operation of the machine, when a document is inserted into passage 52 it depresses arms 156 and 158 of starting switch 154. However, since selector switch 168 is open, the depression of arm 158 has no effect on the operation of the machine. The depression of arm 156 causes it to contact terminal 160 and connect a coil 170 of a ratchet relay 172 to the power supply 148. When coil 170 is energized in this manner, it pulls arm 178 into contact with terminal 188 and connects the coil 174 of a power relay to the power supply 148. This causes contact arm 180 of relay 176 to be pulled into contact with terminal 190 and connects the electrical printing and feeding components of the machine. These components consist of a paper roll drive motor 182, fuser heating element 122, lamp 100, a source of high voltage 184 for electrostatic charging unit 88, and a blower motor 145.

Relay 172 is used to maintain the energization of coil 174 of relay 176 and keep the printing and feeding components of the machine energized until the machine is shut off by relay 164. Relay 172 is a standard ratchet relay whose contact arm 178 is mechanically held in one position until its coil 170 receives an electrical pulse. The contact arm 178 of this relay is switched into contact with the opposite terminal of the relay only when such an electrical pulse is received. Hence, when arm 156 of starting switch 154 is depressed, it suddenly connects coil 170 of ratchet relay 172 to the power supply, thus pulsing the coil and closing the relay. However, relay 172 does not open when arm 156 rises after the document has moved past it because arm 178 is mechanically held in place. This maintains the energization of coil 174 of relay 176 and the machine's printing and feeding components.

When a finished copy depresses arm 166 of switch 164, the energization of coil 170 of the ratchet relay is removed. However, relay 172 remains closed because its contact arm is mechanically held in place.

When the finished copy moves past arm 166, it rises and connects coil 170 to power supply 148 through the contacts of relay 172 itself. This pulses coil 170 and causes relay 172 to open and deenergizes coil 174 to shut off the printing and feeding components of the machine.

When the operator of the machine closes selector switch 168 to select the roll-feed mode of operation, the operation of the electrical circuit is essentially the same as described above except that arm 158, which is depressed almost simultaneously with arm 156, makes contact with a solenoid 186 which causes a clutch (to be described below) to engage and thereby cause rollers 136 and 138 (FIG. 1) to be driven and initiate feeding of copy paper 130 from roll 132 upwardly into the printing components of the machine. Copy paper is fed from roll 132 until the trailing edge of the document 50 passes over arms 156 and 158 and allows them to rise. Arm 158 then connects a pulse network 194 to the power source 148 through ratchet relay 172. Upon being so connected to the power source 148, pulse network 194 delivers an electrical pulse to a solenoid 196 which causes a single revolution clutch (to be described below) to engage and thereby actuate the knife unit 82 to cut the copy paper to a length approximately equal to the length of the document 50.

Pulse network 194 consists of a silicon junction diode 198 connected in series with a capacitor 200 which is connected in parallel with a discharge resistor 202. The transient direct current which surges through capacitor 200 when the pulse network is first connected to the power supply 148 is the electrical pulse output of the network.

The position of switch 154 in passage 52 is adjusted so that the distance between feeler arms 156 and 158 and the entrance of exposure apparatus 66 is substantially equal to the distance between the cutting edge of knife unit 82 and the entrance of exposure station 93. By this adjustment, the length of paper cut off by knife 82 will be equal to the length of the document 50 being copied.

The drive mechanism of the copying machine is shown in FIGS. 4, 5 and 6. Referring to these FIGS., drive motor 182 and its cooling fan 214 are mounted in the lower portion of the copying machine (see FIG. 5). The output shaft of motor 182 is connected to intermediate document transport roll 62 located at the input end of exposure window 66.

In the example illustrated, all drive connections have a one-to-one ratio unless specifically stated otherwise.

A gear wheel 224 is secured to one end of roll 62 (FIG. 4). This mates with a similar gear 226 on feed roll 58 at the end of document passage 52. At the opposite end of shaft 62 is attached toothed pulley 228 which is coupled by means of a timing belt 230 to a pulley secured to roll 68 at the output end of the window 66. Another pulley 234 attached to shaft 62 drives roll 78.

A larger pulley 240, approximately twice the diameter of the pulley on 246, is connected through a belt and a clutch 246 to a shaft 248 to which is attached a pair of eccentric cams 250. These cams actuate the knife 82.

Clutch 246 is a single-revolution clutch, and has a tab 254 which is engaged by a plunger 256 of a solenoid 196 to release the clutch in order to prevent the knife 82 from cutting until the plunger 256 of solenoid 196 is lifted to cause clutch 246 to engage. Such a clutch is sold under the trade name "Tiny" clutch by Taylor-Helander Manufacturing Company.

Roll 78 is connected by belt and pulleys to roll 86, which is located immediately above the knife 82. Roll 78 is geared to roll 138 located just below the knife 82. A second "Tiny" clutch 270 has a tab 272 (FIG. 5) which is engaged by a plunger 274 of solenoid 186 to disengage the clutch. When plunger 274 is moved back to a position in which it does not engage tab 272, clutch 270 is engaged and rolls 136 and 138 are driven to dispense a measured amount of copy paper from roll 132.

The opposite end of roll 86 is coupled to roll 92 positioned immediately above the charging unit 88 (see FIGS. 4 and 6). Roll 92 is also coupled to roll 114 positioned above the image location 93. The opposite end of roll 114 is coupled to roll 126 located adjacent output guide 128 and curved guide 124. Shaft 114 is geared to a magnetic toner brush 300 which brushes toner powder onto the electrostatic image on the copy paper. The gear 296 is advantageously somewhat larger than the gear on 114 so that the peripheral speed of brush 300 is somewhat greater than the speed of the copy paper moving past the brush.

Lamp 100 is shown in detail in FIGS. 7 and 8. An iodine-filled lamp tube 302 is mounted in a reflective housing 306, which is mounted on the inside wall of the copying machine, as shown in FIG. 1. Two or more tubes may be used, if desired.

Fuser unit 120 is shown in detail in FIGS. 9, 10 and 11. Referring to these FIGS., fuser unit 120 consists of a housing 123 having one open side, with a curved reflector 331 and heating element 122 mounted in housing 123 upon an insulating spacer 332.

Heating element 122 consists of a length of nichrome wire wrapped around a ceramic core and having its ends attached to the core by a pair of terminal clamps 339. The ceramic rod advantageously has metallic caps 342 on its ends which may be clipped into receptacles 346 to provide for easy removal and replacement. Heating element 122 is mounted in reflector

331 by means of receptacles 346. Electrical connections to heating element 122 are made at clamps 339. A pair of mounting brackets 350 are provided for mounting fuser unit 120 in the copying machine as shown in FIG. 1.

FIGS. 12 through 15 show the knife unit 82 in detail. Referring to these FIGS., a base block 358 having a pair of semicylindrical grooves 360 (see FIG. 14) is bolted to a top block 368 and held spaced therefrom by several spacer blocks 374. A knife blade 370 is positioned between base block 358 and blocks 374. Blade 370 also has a rectangular slot 376 at each end forming projections 380 at the rear portion of the blade. Coil springs 384 are fitted into grooves 360 and slots 376 so as to abut projections 380. Blade 370 has a pair of indentations 392 at its rear edge for receiving the edges of cams 250.

A shear block 395 having its front edge formed to a cutting edge is affixed to base block 358 by bolts 402 (FIG. 13). A slot 410 is formed by a pair of spacers 411 between the blade-carrying base block 358 and the shear block 395. Slot 410 (see also FIG. 1) permits the passage of copy paper through the knife 82 until the paper is cut. The front ends of springs 384 abut upon the front edge of block 356 to provide a spring return for blade 370 after it has completed a paper cutting cycle.

When it is required to cut paper passing through knife 82, solenoid 196 (see FIG. 4) is actuated by pulse network 194 (see FIG. 3) to pull its plunger 256 up and allow clutch 246 to engage shaft 248 for one revolution and thereby turn cams 250 through one revolution. Since plunger 256 is raised for only the short duration of the pulse from network 194, it will be returned to its down position by the time shaft 248 has turned through one revolution. Since these cams are eccentric circular discs, blade 370 will be moved towards and over shear block 395 to cut the paper in slot 410, and will then be returned to its initial position by springs 384.

FIGS. 16 through 19 show the developer unit 118 in greater detail. Developer 118 includes a housing 412 which contains a quantity of developer mixture 414.

Developer mixture 414 is composed of developer or "toner" powder mixed with iron powder. Developer powder 42 is dispensed from a hopper 418 through a hole 422 into housing 412 where it is mixed with iron powder to form the developer mixture 414. The developer powder may have the composition described above, that is, thermoplastic resin with carbon black or light absorbing dye, etc. The particle size of the powder is preferably between 3 and 25 microns. Also, the material of which the powder is composed should be separated from iron in the triboelectric series so that when the iron and developer powder particles are rubbed together the developer powder particles will become charged oppositely to the iron particles and will cling to them. The iron powder particles should be larger than the developer powder particles, preferably being of a size capable of passing through a 100 to 200 mesh screen.

Housing 412 has an opening 424 in its face through which a small segment of the brush formed on 300 extends to brush across a copy paper sheet 428 passing through the developer. A magnet assembly 426 is positioned opposite slot 424 and is arranged so that brush 300 acts as its armature and is magnetized by it.

As copy paper sheet 428, bearing an electrostatic image, is passed between the magnet assembly 426 and the protruding brush 300, the brush 300 is rotated and picks up iron particles which arrange themselves along its lines of forcetlike bristles. The developer powder particles cling to the iron particles in these "bristles." As these "bristles" are brushed over the electrostatic-image-bearing surface of sheet 428, the developer powder particles, which bear a charge opposite to that of the image areas of the electrostatic image, are attracted away from the iron "bristles" and cling to the image areas of sheet 428 to form a visible powder image capable of being fused to make a permanent finished copy. The iron particles are held magnetically by the brush 300 until they reach the side of the

brush farthest away from magnet assembly 426, at which point the magnetic flux is so weak that the particles fall back into the body of the mixture 414.

Housing 412 and developer powder hopper assembly 418 are oscillated longitudinally so that developer powder 420 is shaken from hopper assembly 418 into housing 412 where it is mixed and rubbed together with iron particles. A paddle assembly 416 helps to mix and circulate the mixture 414 and distributes it evenly along the length of brush 300.

Developer powder hopper assembly 418 includes a conical outer hopper housing 430 which is shaped like the frustum of a cone and is affixed to developer housing 412 with its bottom opening surrounding hole 422. A movable hopper 432 is positioned in housing 430. Movable hopper 432 is shaped like hopper housing 430 except that it is slightly shorter and its sides have a larger included angle between them. A generally Y-shaped jiggle rod 434 is positioned inside movable hopper 432 with its stem 436 extending down through hole 422 into housing 412 to a position near paddle assembly 416. A lid 438 covers the upper opening of housing 430 to prevent developer powder 420 from spilling out.

Paddle assembly 416 includes an elongated support rod 440 with a series of L-shaped arms 442 attached to the underside of rod 440 with their long portions extending downwardly. Attached to this long portion of each of arms 442 is a flat, rectangular flexible sheet metal blade 444 which forms a paddle. These paddles 444 are aligned parallel to one another and at a 45° angle (see FIG. 18) with the longitudinal axis of rod 440. The ends of rod 440 extend through square holes in housing 412 and abut against side frame members 448.

Housing 412 is slidably mounted upon the shaft of brush 300 by means of bushings 452. The brush 300 is rotatably supported by side members 448 and bushings 456.

Triangular cams 460 are affixed to the exterior of housing 412 near shaft 298 and pins 464 extend perpendicularly from shaft 298 in directions angularly displaced 180° from one another. When the shaft is rotated, pins 464 engage cams 460 alternately and impart an oscillatory motion to housing 412 in a direction parallel to the longitudinal axis of brush 300. The frequency of these oscillations is advantageously about 75 cycles per minute.

The ends of paddle support rod 440, by abutting side frames 448, hold the paddles 444 stationary while housing 412 oscillates. Since paddles 444 are flexible, their rear portions bend toward rod 440 when housing 412 moves to the right (FIG. 18) and permit a quantity of developer mixture 414 to pass between these paddles and the rear wall of housing 412. When housing 412 moves to the left, the rear portions of paddles 444 bend away from rod 440 and prevent the developer mixture from returning to its original position.

A similar mixing action in the developer mixture 414 is set up between the paddles 444 and brush 300. The developer mixture 414 is thus circulated as indicated by arrows 445 on FIG. 18 and thoroughly mixed so that developer powder is substantially uniformly distributed in the iron powder and properly charged by rubbing against the iron particles before it is captured in the brush. In addition, this distributes the mixture evenly along the length of brush 300 and avoids piling up at either end of housing 412.

Oscillating paddles 444 hit the lower end of jiggle rod 434 and cause the bottom opening of movable hopper 432 to be alternately aligned and unaligned with the inlet hole 422 in housing 412 during each cycle of oscillation. This causes a metered amount of powder to flow into the housing during each cycle and makes the rate of powder replenishment approximately proportional to the rate of its removal from the mixture. Jiggle rod 434 also stirs the powder in the hopper to prevent it from caking and to make it flow smoothly into housing 412.

As is shown in FIGS. 18 and 19, brush 300 includes a series of discs 468 mounted in closely spaced relation along shaft 298. One side 470 of shaft 298 is flattened and the central holes in the discs conform to the cross-sectional shape of the

shaft, assuring their accurate assembly and retention of the shaft. Each disc 468 is separated from the next disc by a washer 472.

Referring now to FIG. 16, each of the discs 468 is made of soft iron or similar magnetic material and each is advantageously bent along lines 474, which describe a polygon, advantageously a square whose corners are located at the edge of disc 468. The bends along some of these lines are made in one direction and bends along others of these lines are in the opposite direction, e.g. in FIG. 17 bends along alternate lines 474 are made towards the observer while bends along intermediate lines 474 are made away from the observer. The angle of these bends is fixed at a value such that the edge of each disc describes a substantially smooth wavy curve, as is best seen in FIGS. 18 and 19. Because the discs 468 have this shape, the instantaneous position of the edge of each disc progresses from side-to-side in the direction of the longitudinal axis of shaft 298 relative to any point at opening 424 when the disc is rotated. This relative motion creates a thorough brushing of the entire surface of copy sheet 428 with developer powder.

Discs 468, which are bent along lines describing a square, create two such side-to-side oscillations for each revolution of shaft 298. The number of these oscillations per revolution may be varied by increasing or decreasing the number of sides of the polygon along the sides of which the bends are made. For example, bending discs 468 along the sides of a hexagon would produce three oscillations per revolution instead of two.

FIG. 20 illustrates an alternative brush member 300c which can be used in the developer unit 118 in place of brush member 300. This brush member comprises a hollow cylinder 482 made of magnetic material such as soft iron and having a pair of spindles 484 at its ends. A perforated sleeve 486 made of magnetic material is secured to the outside of cylinder 484. As is indicated in the drawing, the holes in sleeve 484 are "staggered" with respect to one another thus leaving generally spiral-shaped ribbons of material such as those indicated by dashed lines 488. Since the distance between magnet 426 and the brush member 300c is the least at points along these ribbons, the iron powder "brush bristles" tend to concentrate along these ribbons and "sweep" the surface of the copy paper 428 from side-to-side.

A brush similar to brush 300c can be produced by substituting for sleeve 484 a screen comprising wires made of magnetic material. The wires of the screen should be aligned at an angle to the longitudinal axis of cylinder 484 so that the wires describe spiral paths like the ribbons of material in sleeve 484.

An advantage of both of these forms of brush 300c is that they are relatively simple and inexpensive to manufacture while providing efficient and complete "sweeping" of the copy sheet.

Magnet unit 426 includes a permanent magnet or magnets 492 as well as paramagnetic members which concentrate and direct the flux. In preferred example shown, two permanent magnets 492, which advantageously are ceramic magnets, are arranged with their north poles connected together by a magnetic pole piece 496 their south poles connected together by a second magnetic pole piece 498. These pole pieces are advantageously of soft iron. A pair of magnetic end pieces 500 are bolted to pole piece 496 and nonmagnetic side supports. Members 500 each have a semicircular cutout end portion bearing against shaft 298 of brush 300, so that, together with the brush 300, members 500 constitute an armature for the permanent magnet. In this arrangement, the lines of magnetic flux flow from the north poles of magnets 492 through polepiece 496 and end pieces 500, through shaft 298 and discs 468, through the air gap between polepiece 496 and end pieces 500, through shaft 298 and discs 468, through the air gap between pole piece 498 and the edge of discs 468, and on to the south poles of magnets 492. In this manner, a strong and evenly distributed magnetic flow is created across the air gap to create strong iron powder "bristles" 427 for brushing sheet 428.

Magnets 492 are composed of permanently magnetized particles imbedded in ceramic material and are manufactured under the trade name "Indox V" by Indiana Steel Products Corporation, a division of Indiana General Corporation. This material is made of barium carbonate and iron oxide, powdered, compressed under high pressure, and sintered. The resulting material is believed to be $\text{BaFe}_{12}\text{O}_{19}$. These magnets have advantage over other permanent magnets in that they provide a large amount of flux despite their elongated shape. Thus, unit 426 can be more compact and efficient than magnetic devices used previously.

A tray 506 (see FIG. 1) is positioned below developer unit 118 to catch any powder which may be spilled by brush unit 118. This is a shallow, removable tray with a slot in its bottom having upwardly converging edges 507 to permit paper to pass through the tray while preventing the powder from falling through.

A paper guide 504 (see FIGS. 1 and 16) is bolted to support members 448 and is positioned near opening 424 in housing 412 and near the protruding "bristles" of brush 300 to guide copy paper past the brush.

The entire apparatus will ordinarily be enclosed in a compact housing which is omitted from FIGS. 1-20 for the purpose of simplification.

FIGS. 21 through 24 show another embodiment of the copying machine of the present invention. The copying machine so illustrated a housing 508 having an inlet guide 54d for a sheet of copy paper 74 and an inlet guide 72d for a document 50 to be copied.

Document 50 moves down passage 72d to a pair of rolls 56d and 58d, which feed document 50 into exposure window 66d along the face of glass plate 98d. A pair of rolls 68d and 70d feed the document away from the window 66d and out of the machine through an outlet guide passage.

A central lamp 100d and a pair of lamps 100d positioned on the outside of the machine and shining through windows 536 in the housing combine to illuminate the document as it passes the window 66d. The image of the document is formed by focusing light which passes through the lens system 108d and on to a mirror 106d which reflects the image up to the image location 93d.

Photosensitized copy paper, which may be of the type described above, is inserted into inlet guide 54d and moves over a charging unit 88d which produces a uniform electrostatic charge on the sensitized surface of the sheet. As the sheet passes to and across the screen 95d at the image location 93d, it is exposed to the image of the document which induces a corresponding electrostatic image on the sheet. Rolls 114d and 112d feed the sheet around guide 554 and on to another pair of rolls 556, 558 which pass the sheet on to a developer unit 118d where the latent electrostatic image received at the window 93d is converted into a visible image by use of fusible developer powder in the manner described above. The sheet passes on through rollers 562, 564, over the support plate 566, and under fuser unit 120d to fix the image on the sheet, and then out of the machine through a slot as shown.

Referring now to FIG. 22, which illustrates the drive system of copy machine shown in FIG. 21, a drive motor 182d and its cooling fan 214d are mounted centrally in the housing of the machine. The motor shaft drives a chain 220d. This chain connects the drive sprockets on rolls 562, 556, 112d, and 94d, for feeding the sheet of copy paper through the machine. An idler sprocket 580 maintains the necessary tension on the chain.

The motor shaft also drives a second chain 230d which connects drive sprockets on rolls 68d and 58d with the motor shaft to feed the document 50 through the machine. An idler sprocket 586 maintains tension in chain 230d.

A brush drive motor unit 588 has an output shaft 590 and an output gear meshing with a drive gear 296d on the developer brush shaft 298d to drive brush 300d.

The brush 300d of the developer unit may be the same as brush 300 or brush 300c described above, or may be of any similar construction.

Referring again to FIG. 21, brush 300d is positioned near the sheet of copy paper as it passes through the developer unit 118d. Positioned on the other side of the sheet is a magnet unit 426d used to form the "bristles" for brushing the toner powder onto the sheet.

Sidewalls 602 and 604 of developer unit 118d form a housing which holds a supply of iron powder and developer powder mixture 608. The mixture is applied to the brush 300d only in the gap 606 near the bottom of the housing, primarily by magnetic attraction. This arrangement minimizes loss of developer mixture in transit from the housing to the brush.

The brush rotates in the direction indicated by the arrow in FIG. 21 and the "bristles" which form in the magnetic field on the lower side of the brush, slump back onto the brush assembly near the top position. The released developer mixture is guided by wall 602 back into the mixture body 608 where it is remixed and enriched with additional toner before being reapplied to the brush 300d. The uppermost edge of wall 602 is positioned close to brush 300 to remove as much of the loose mixture from the brush as possible.

Toner powder hopper 418d has a pair of converging sidewalls 612 and a bottom screen 616. A pair of supports 620 (see FIG. 22) are provided at the ends of this hopper to support it with respect to the brush 300d. These supports follow the side-to-side oscillating motion of the bent washers of brush 300d and thus shake toner powder onto the brush, where it is mixed with iron powder and is carried into the developer mixture body where the toner powder and iron powder are rubbed together and dispensed to the brush as described above. In this manner, toner is replaced in developer mixture 608 as it is used, and at a rate proportional to the oscillations of the brush discs.

An alternative toner powder feed device is shown in FIGS. 23 and 24. This device has a hopper 418e with converging sidewalls 622 and a bottom screen 616e. The hopper is supported by members 628 at its ends which contact the top surface of brush 300d to follow the edges of the bent discs of the brush to provide side-to-side oscillation in the same manner as described above. Several flexible, y-shaped wires 630 have their stems depending through screen 616e to contact the surface of brush 300d. Wires 630 agitate the toner powder in the hopper in accordance with the oscillation of the brush and thus facilitate dispensing the powder in a smooth and steady flow, and at a rate proportional to the oscillations of the brush.

Although preferred embodiments of the invention and certain modifications have been set forth in detail, these are not exhaustive or necessarily limitative; on the contrary, the showings herein are for the purpose of illustrating the invention and its principles so as to enable others skilled in the art to adapt the invention in such ways as best meet the requirements of particular applications, it being understood that various modifications may be made without departing from the scope of the invention as defined by the claims.

I claim:

1. In electrostatic printing apparatus utilizing a mixture of carrier particles and developer powder particles in a manner such that the number of carrier particles remains relatively constant while the number of developer powder particles is reduced; rotary means for distributing said developer powder upon a surface to be printed, drive means for rotating said rotary distributing means, a housing containing said mixture and said distributing means, said housing having an upper opening for receiving particles into said housing, means for replenishing the supply of said developer powder particles in said mixture at a rate approximately equal to the rate at which said number of developer powder particles is reduced, said replenishing means comprising a developer powder container having a lower outlet positioned to feed into said upper opening of said housing, a resilient vibratory member positioned in said developer powder container and having one end depending through said lower outlet and through said upper opening and into said housing, and means associated with said drive means for flexing and vibrating said resilient member in an

oscillatory manner, at a rate proportional to the rate of rotation by said drive means, each such flexing causing said lower outlet of said developer powder container to be alternately aligned and unaligned with said upper opening in said housing and thereby causing a metered amount of said powder to flow into said mixture.

2. Apparatus for bringing developer powder into contact with a surface bearing a latent electrostatic image to be developed by said powder, said apparatus including; a quantity of developer mixture having a relatively constant number of carrier particles mixed with and carrying a relatively depletable number of particles of said developer powder; an elongated member for brushing said powder particles onto said image-bearing surface; a housing for containing said mixture near said brushing member; means for replenishing said powder to replace the particles brushed out from said mixture, for thoroughly mixing said carrier particles with said powder particles, and for distributing said mixture evenly along said brushing member, said replenishing mixing and distributing means including an elongated support member disposed in said housing substantially parallel to said brushing member, a plurality of vanes, each of which is affixed to said support member at an acute angle with said support member and said brushing member, means for oscillating said housing with respect to said vanes in the direction of the longitudinal axis of said support member, a developer powder container having an outlet positioned above and directed into the body of said mixture, and a resilient vibratory member positioned in said container and having one end depending through said outlet.

3. In an electrostatic printing device utilizing developer powder mixed and transported in a medium of magnetic particles, apparatus utilizable in association with a source of magnetic flux for bringing said powder into intimate contact with a surface bearing an electrostatic image to be developed by said powder, said apparatus comprising; an elongated mounting spindle; and a plurality of generally washer-shaped members made of magnetic material and mounted in series at spaced intervals along said spindle, each of said members being bent along lines describing the sides of a polygon, each of said lines having its ends terminated at the outer edge of said member, successive ones of these bends being made in opposite directions so that said outer edge of each of said members oscillates, with respect to a fixed reference point, in a direction generally parallel to the longitudinal axis of said spindle when said spindle and said members are rotated together.

4. In an electrostatic printing device utilizing developer powder mixed and transported in a medium of magnetic particles, apparatus utilizable in association with a source of magnetic flux for bringing said powder into intimate contact with a surface bearing an electrostatic image to be developed by said powder, said apparatus comprising; an elongated and generally cylindrical mounting spindle having a flatted surface; a plurality of washers, each of which is made of magnetic material and has a central cutout portion whose outline generally conforms to that of said spindle, said washers being mounted in series through said cutout portions at spaced intervals upon said spindle, each of said washers being bent along lines describing the sides of a square having each of its four corners terminated at the outer edge of said washer, successive ones of these bends being made in opposite directions so that said outer edge of each of said washers oscillates, with respect to a fixed reference point, in a direction generally parallel to the longitudinal axis of said spindle when said spindle and said washers are rotated together.

5. In an electrostatic printing device having a magnetizable rotary brush member for brushing a mixture of magnetic particles and developer powder onto a surface bearing an electrostatic image to be developed by said powder; the surface of said brush member being adapted to effectively oscillate with respect to the longitudinal axis of said brush member as said member is rotated; apparatus for supplying said mixture to said brush member, said apparatus comprising; a housing for

containing said mixture near said brush member, mixing said magnet particles with said powder, and providing a metered supply of said mixture to said brush member, said housing having a relatively wide inlet opening, an upper edge positioned close to the outer edge of said brush member at a position relatively remote from the position at which said outer edge brushes said image-bearing surface, said housing edge being utilized for scraping magnetic particles from said brush member after said powder has been transferred from said particles to said surface to be developed and directing said scraped particles into said inlet opening, said housing also having a relatively narrow outlet opening located below said inlet opening and adjacent said edge of said brush member at a position just preceding said position at which said image-bearing surface is brushed, said outlet opening serving to meter the flow of said mixture to said brush member; and developer powder storage and dispensing means positioned above said housing inlet for feeding metered amounts of said powder into said housing to be mixed with said magnetic particles as they are scraped from said brush member, said powder storage and dispensing means including means responsive to said oscillations of said brush surface for agitating said powder storage and dispensing means and metering the flow of said powder to said housing.

6. In an electrostatic printing device having a magnetizable rotary brush member for brushing a mixture of magnetic particles and developer powder onto a surface bearing an electrostatic image to be developed by said powder; the surface of said brush member being adapted to effectively oscillate with respect to the longitudinal axis of said brush member as said member is rotated; developer powder storage and dispensing apparatus, said apparatus including a housing having an outlet opening directed into the body of said mixture, said outlet opening having dimensions such as to prevent passage of said powder therefrom until said housing or said powder is agitated; and means coupled to said housing and said brush member for transmitting the oscillations of said brush member to said housing and thereby providing flow of said powder from said outlet to said mixture in metered increments occurring at a rate corresponding to the rate of said oscillations.

7. In an electrostatic printing device having a magnetizable

rotary brush member for brushing a mixture of magnetic particles and developer powder onto a surface bearing an electrostatic image to be developed by said powder; the surface of said brush member being adapted to effectively oscillate with respect to the longitudinal axis of said brush member as said member is rotated, developer powder storage and dispensing apparatus, said apparatus including a housing having an outlet opening directed into the body of said mixture, said outlet opening having dimensions such as to prevent passage of said powder therefrom until said housing or said powder is agitated, and means coupled to said brush member and extending through said outlet opening and into said powder supply for agitating said powder in accordance with the oscillations of said brush member and providing flow of said powder from said outlet to said mixture in metered increments occurring at a rate corresponding to the rate of said oscillations.

8. In an electrostatic printing device utilizing developer powder mixed and transported in a medium of magnetic particles, apparatus utilizable in association with a source of magnetic flux for bringing said powder into intimate contact with a surface bearing an electrostatic image to be developed by said powder, said apparatus comprising: a cylindrically-shaped member made of magnetic material; a sleeve made of magnetic material and secured to the surface of said member, said sleeve having a plurality of holes in it; and means associated with said member for supporting said member for rotation about its central axis.

9. In an electrostatic printing device utilizing developer powder mixed and transported in a medium of magnetic particles, apparatus utilizable in association with a source of magnetic flux for bringing said powder into intimate contact with a surface bearing an electrostatic image to be developed by said powder, said apparatus comprising: a cylindrically-shaped member made of magnetic material, a screen secured to the surface of said member, said screen including wires made of magnetic material, said wires being aligned generally transversely to the longitudinal axis of said member, and means at each end of said member for supporting said member for rotation about its central axis.

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