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Smith et al.

[11] **3,789,794**

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[54] **APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGES**

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[22] Filed: **Dec. 27, 1971**

[21] Appl. No.: **212,155**

[52] **U.S. Cl.** **118/7,** 118/602, 118/637, 137/93

[51] **Int. Cl.** **G03g 13/10**

[58] **Field of Search** 117/37 LE, 102; 118/602, 612, 118/DIG. 23, 637, 7; 137/93; 259/4, 8, DIG. 30; 355/10

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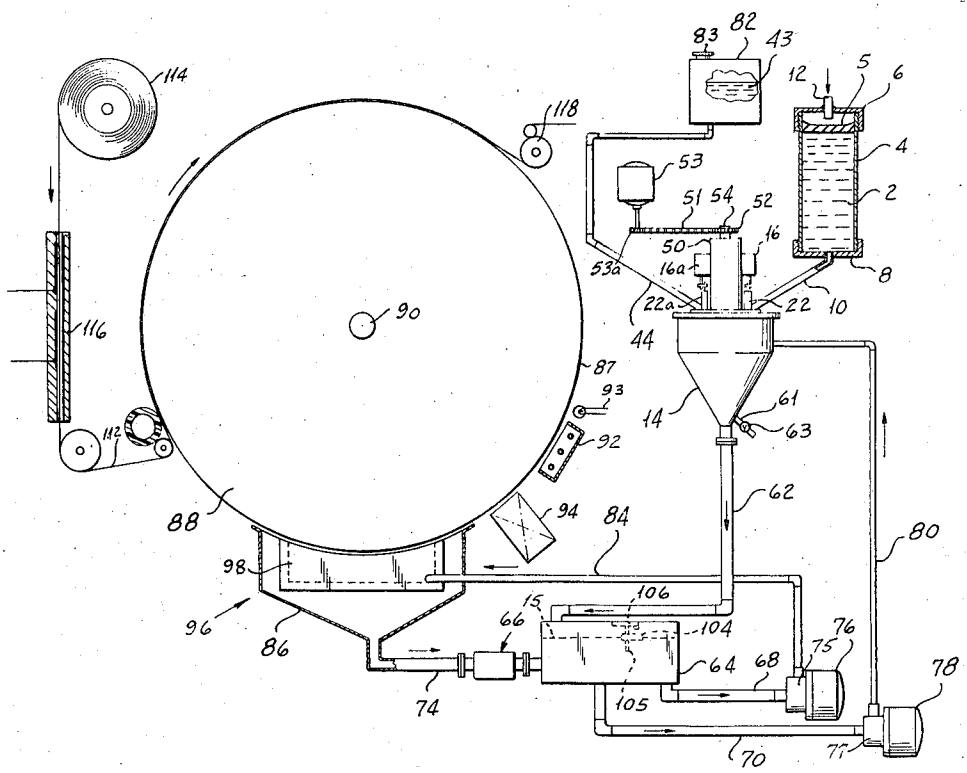
[57] **ABSTRACT**

An electrostatic copier includes means to recirculate developer comprising a diluent carrier and a tacky toner, between a developer supply tank and a developer station. A recirculation system communicates a mechanical mill with the supply tank. Means monitoring developer level in the supply tank and opacity of the developer material control the respective feeds of carrier and toner to the mill.

12 Claims, 5 Drawing Figures



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SHEET 1 OF 3

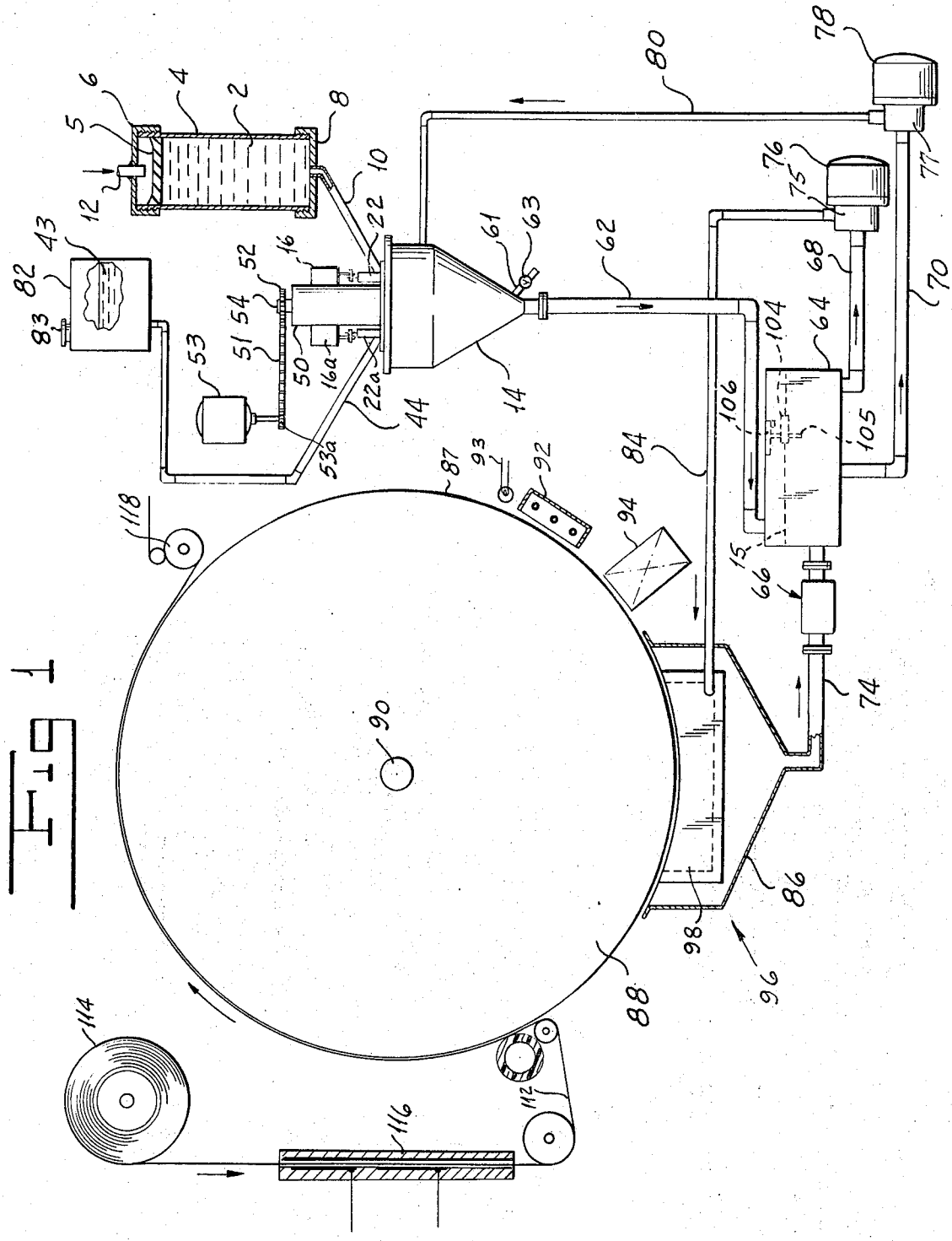

Fig 1

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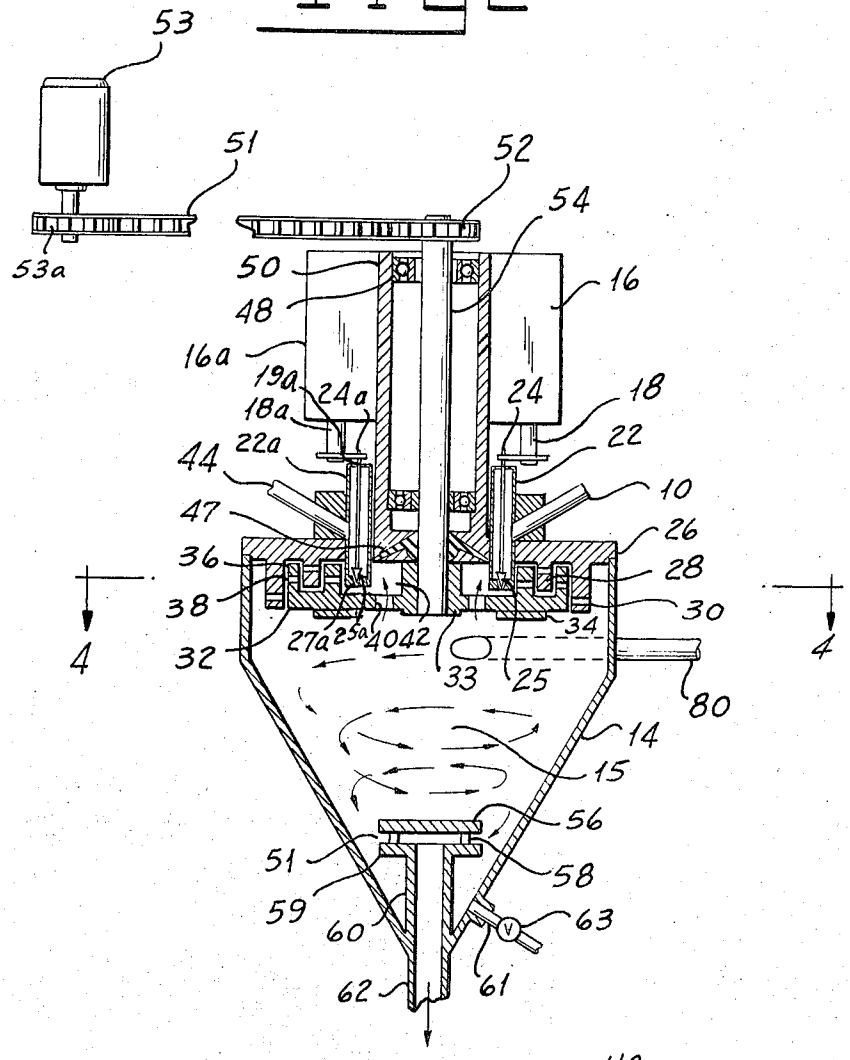
Fig 2



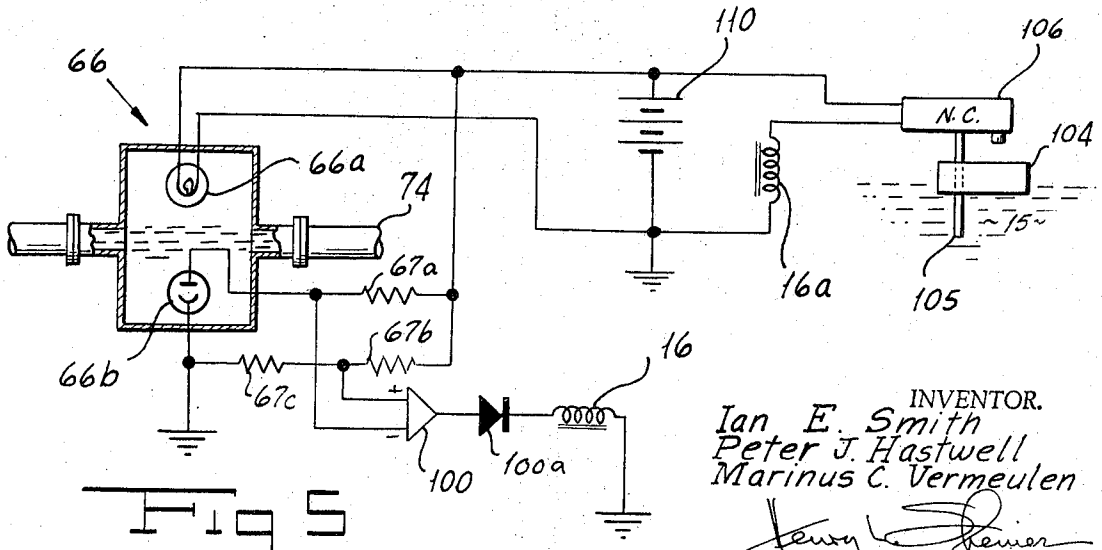


Fig 5

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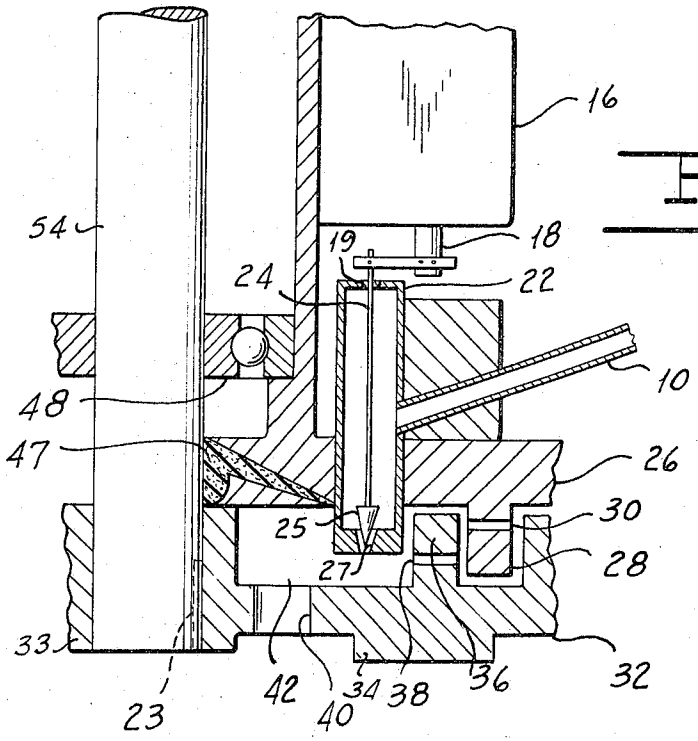

Fig 3

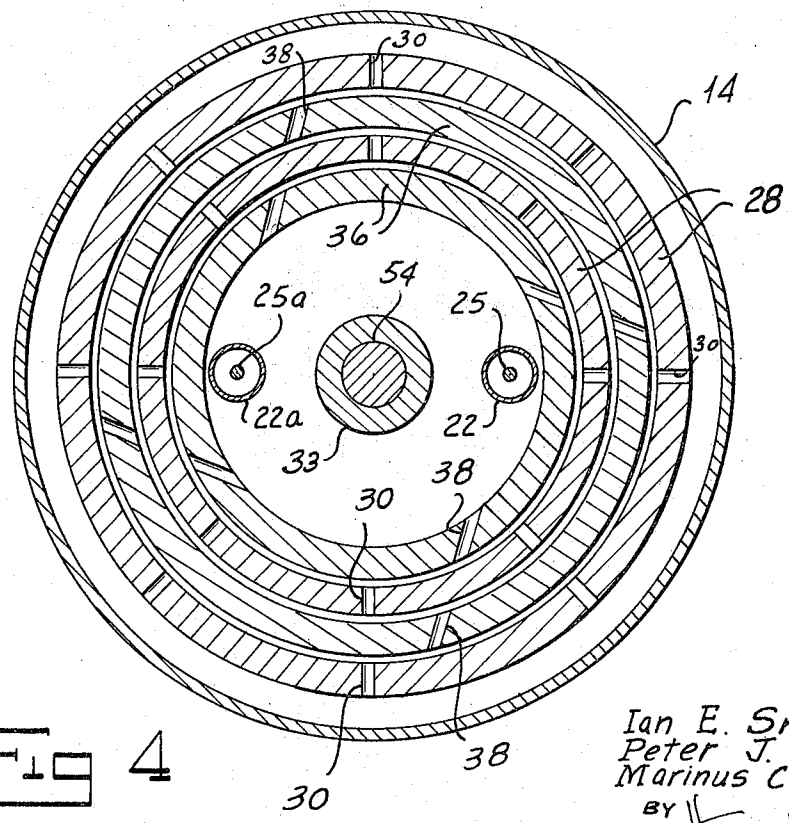

Fig 4

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APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGES

BACKGROUND OF THE INVENTION

In our co-pending application, Ser. No. 155,108, filed June 21, 1971, we disclose a novel method for contact transfer of liquid toner developed electrostatic images. The latent electrostatic image, formed on a photoconductive surface is developed by a novel liquid toner which comprises a volatile liquid which suspends a high molecular weight resin. This resin has the property of becoming tacky, so that it can be transferred from the photoconductive surface to a carrier such as plain paper by contacting the paper with the developed image. The resin is admixed with pigment and is normally insoluble in the volatile diluent or carrier component of the developing liquid. Accordingly, we form an organosol by dissolving the high molecular weight resin in a solvent and then emulsify the resultant organosol with the volatile liquid carrier within which the resin is insoluble. As developer liquid is used the toner component becomes depleted and must be replenished. The size of the equipment which would be necessary to furnish an adequate developer liquid source for extended operation would render it impractical. Attempts to replenish the organosol by direct addition to the diluent result in coagulation and flocculation rendering the developing liquid unsuitable for proper development of the image. That is, the resin upon contact with the volatile liquid vehicle tends to segregate and isolate itself within the resulting mixture.

Moreover, since the organosol tends to precipitate and settle to the bottom of the developer tank, the organosol dispersion requires continual agitation when the machine is not being operated. If this is not done, copies made after a prolonged period of machine idleness will be of inferior quality.

Not only is it advantageous to agitate the developer liquid but it is necessary to disperse the toner organosol with the diluent vehicle when either diluent or toner is added to the developer liquid.

SUMMARY OF THE INVENTION

One object of our invention is to provide a continuous supply of tacky toner liquid developer of correct composition.

Another object of our invention is to provide an efficient apparatus for replenishing the components of a tacky toner liquid developer.

A further object of our invention is to provide a liquid developer supply system of reduced volume.

Still a further object of our invention is to provide a completely self-regulating developer supply system capable of continually supplying a developer fluid of proper composition to electrophotographic apparatus.

Other and further objects of our invention will appear from the following description:

In general, we provide for a continuous and homogenous supply of tacky toner developer liquid to a developer station in an electrophotographic apparatus by providing two independent paths of developer liquid circulation each of which includes a common toner supply tank. One path continually circulates toner from the toner supply tank to an emulsifying mill, the discharge of which returns to the toner supply tank. The other path continually circulates toner liquid taken from the toner supply tank to the developer zone, the discharge of which returns to the toner supply tank. Mixing of the independently circulating rings occurs in the toner supply tank. We thus assure an uninterrupted flow of developer liquid of the proper composition to the developing station to develop the latent electrostatic image. We employ separate pumps in our two circulating rings.

We may continuously monitor the toner concentration by measuring the light transmissibility of the fluid at any desired point such, for example, as that at which liquid leaves the developer station. When the toner concentration is sufficiently low a photosensor receives a greater flux of light due to the reduced opacity of the developer fluid. When enough light strikes the sensor a solenoid valve opens to add toner concentrate to the circulating ring through the emulsifying mill.

We employ a mechanical impingement mill to apply high shear stresses to the viscous toner organosol. The injection of the concentrate into the emulsifying mill is intermittent, depending upon the rate of toner depletion in the developer zone.

The level of fluid in the apparatus is monitored by a level indicator positioned at an appropriate point such as in the toner supply tank. When the level of fluid in the supply tank reaches a predetermined low another solenoid valve activates to supply diluent carrier liquid to the emulsifying zone. The toner is maintained at a proper consistency and a supply of developer liquid is available without the necessity of employing a large and cumbersome developer liquid supply tank.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is a diagrammatic view showing electrostatic copying apparatus employing a liquid developer and incorporating one embodiment of our invention.

FIG. 2 is a fragmentary sectional view, drawn on an enlarged scale, of an impingement mill used in our invention.

FIG. 3 is a fragmentary sectional view drawn on an enlarged scale showing one of the control valves of our invention.

FIG. 4 is a sectional view drawn on an enlarged scale taken along the line 4–4 of FIG. 2.

FIG. 5 is a diagrammatic view showing the control circuitry operating the valves controlling admission of the toner concentrate and the diluent liquid.

DESCRIPTION OF THE PREFERRED EMBODIMENT

More particularly, referring now to FIG. 1 of the drawings a copy machine incorporating our developer supply system includes a drum **88** provided with a photoconductive surface **87**. The drum **88** is supported on a shaft **90** which rotates in the direction of the arrow when the machine operates. Light source **93** insures that any residual electrical charge remaining on surface **87** from a previous exposure is reduced by conduction to ground. Preparatory to forming a latent image on surface **87** an electrostatic charging device **92** charges the surface **87** of the drum, which is enclosed in a lightproof casing (not shown) as is known in the art. An exposure system **94** focuses an image of the original to be

copied on the charged photoconductive surface thus producing a latent electrostatic image on the surface of the drum. As the drum rotates, this latent image moves to the developer zone indicated generally by reference numeral **96** at which a tray and applicator means **98** subjects the latent image to the action of the developer liquid. The tacky developed image is carried by the drum into contact with paper **112** which is heated by a heater **116** as it leaves a supply roll **114.** Although the tacky toner is attracted to the photoconductive drum surface in accordance with the light or dark areas of the original, the toner, owing to its composition, exhibits a greater affinity for the paper surface **112** than it does for the drum surface **87.** After picking up the developed image the paper **112** passes to delivery rolls **118.**

To assure uniformity of this process, a developer supply pump **75** driven by a motor **76** draws developer liquid from the toner supply tank **64** and discharges it through pipe **84** into developer tray **98.** A developer applicator in tray **98** applies developer fluid to the surface **87.** Excess developer liquid leaving the photoconductive surface **87** collects in a trough **86.** A pipe **74** conducts liquid from trough **86** through the toner monitoring system indicated generally by reference numeral **66** and back to supply tank **64.** As successive images are developed toner in the developer liquid is depleted at a relatively rapid rate and carrier liquid is depleted at a relatively slower rate so that the makeup of the liquid changes slightly on each operation of the machine.

Our apparatus includes another loop of circulating fluid including the toner supply tank **64.** This second system includes a developer recirculating pump **77** driven by a motor **78.** Pump **77** continually withdraws developer fluid from the toner supply tank **64** through pipe **70** and pumps it through a pipe **80** into an impingement mill body **14.** From the body **14** liquid passes back to tank **64** through pipe **62** to complete the loop.

Now referring to FIGS. **1** and **2,** it can be seen that the fluid discharging from recirculating pump **77** passes through pipe **80** and is then tangentially injected into the impingement mill body **14** where it mixes with developer fluid **15** in the mill body. The combined fluids whirl about in the direction of the arrows and exit through pipe **62** after passing through a space **51** formed by mounting a disc-shaped cap **56** on spacers **58** carried by a flange **59** on an extension **60** from pipe **62.** The emulsion thus formed in mill **14** flows back to toner supply tank **64** through pipe **62.**

As with the circulation through supply pump **75** the consistency of the developer fluid **15** in each succeeding cycle through pump **77** is of a slightly different makeup than that in the preceding cycle. This change in fluid consistency in succeeding cycles through supply pump **75** and through recirculation pump **77** occurs during development of the successive latent electrostatic images. As has been pointed out hereinabove, there will unavoidably be some slight evaporation of the diluent during each cycle as well as depletion of toner from the developer liquid. That is, the concentration of toner in a given volume of fluid entering tray **98** will be slightly greater than that collected in return trough **86** for that same volume owing to development of the image.

Referring now to FIGS. **1, 2,** and **3,** a container **4** holds a supply of toner concentrate liquid **2.** A pipe **12,** fixed in a cap **6,** communicates with a source fluid under pressure (not shown) which supplies pressure to piston **5** to push toner concentrate through supply pipe **10.** The cap **6** of container **4** is removable so that toner paste **2** can be replenished. The pipe **10** is normally closed by a valve **25** operated by a solenoid **16.** Valve **25** which normally engages seat **27** has a stem **24** connected to the armature **18** of a solenoid **16.** Operation of solenoid **16** controls the admission of toner paste into the mill. Stuffing box **19** seals the commutating stem **24** and valve chamber **22.** The operation of solenoid **16** is controlled by a toner monitoring system indicated generally by reference numeral **66.** Actuation of solenoid **16** lifts valve **25** from its seat **27.** When this occurs paste **2** from the valve chamber **22** flows into a rotor intake chamber **42.**

Now referring to FIGS. **1** and **5,** the monitor **66** is similar to the toner monitoring system described in U.S. Pat. No. 3,354,802. We position the toner monitoring unit **66** in pipe **74.** It is to be understood, however, that the location of monitor **66** in pipe **74** is shown by way of illustration only and not by way of limitation, as the monitor may be positioned elsewhere, for example, in supply pipe **84.** Monitor **66** includes an incandescent source **66*a*** and a photosensor **66*b*.** When the toner liquid has the proper or desired concentration the voltage at the anode of photosensor **66*b*** is equal to that at the junction of resistors **67*b*** and **67*c*** so that the net input to differential amplifier **100** is zero. When toner pigment is depleted the illumination of the photosensitive element **66*b*** by lamp **66** increases because of the reduction of opaqueness of the developer liquid **15.** This reduces the resistance of the photosensitive element **66*b*** and hence reduces the voltage there across. The voltage to the "minus" input of differential amplifier **100** becomes more negative than the voltage at its "plus" input. Differential amplifier **100** accordingly, provides a positive output which is coupled forwardly through diode **100*a*** to energize solenoid winding **16.** The negative terminal of battery **110** is grounded. Lamp **66*a*** is connected between the positive terminal of battery **110** and through a resistor **67*a*** to the anode of photosensor **66*b*,** the cathode of which is grounded. Positive terminal of battery **110** is further serially connected through resistors **67*b*** and **67*c*** to ground. The junction of resistors **67*b*** and **67*c*** is connected to the plus input of a differential amplifier **100.** The anode of photosensor **66*b*** is connected to the minus input of differential amplifier **100.** We apply the output of differential amplifier **100** to the anode of diode **100*a*,** the cathode of which is connected through solenoid winding **16** to ground.

The amount of light striking photodetection element **66*b*** is a function of the light transmissibility of developer liquid **15.** When the toner concentration is increased the opacity of fluid **15** increases. The illumination of photosensor **66*b*** decreases when the toner concentration increases. When this occurs, the voltage at the anode of photosensor **66*b*** rises and the output of differential amplifier **100** decreases so that solenoid **16** is de-energized thereby closing valve **25.**

Referring now to FIGS. **1** and **2,** a supply of volatile carrier liquid **43** is stored in container **82.** Cap **83** is removable from container **82** so that diluent liquid **43** may be added as needed. Pipe **44** is normally closed by a valve **25*a*** operated by a solenoid **16*a*.** The volatile liquid **43,** under the influence of gravity, fills valve cham-

ber 22*a* and is retained therein in its normally closed position of valve 25*a*.

Valve 25*a*, adapted to seat on seat 27*a*, is operated by a solenoid 16*a* through its armature 18*a* and the valve stem 24*a*, thereby regulating the admission of volatile diluent into the mill. We provide stuffing box 19*a* at the top of chamber 22*a* to seal the valve stem. The solenoid 16a is controlled by the opening and closing of a microswitch 106 actuated by a float 104 in tank 64. Actuation of solenoid 16*a* lifts valve 25*a* from its seat 27*a*. The diluent in chamber 22*a* then flows into the rotor intake chamber 42.

Referring now to FIG. 5, the normally closed microswitch 106 is connected in series with diluent control solenoid 16a across battery 110. Float 104 slides vertically on a guide 105 so that when the fluid level reaches a predetermined point, the switch 106 opens and deenergizes winding 16*a*, permitting the valve 25*a* to close.

Referring again to FIGS. 1, 2, and 3, an electric motor 53 having a shaft to which sprocketed wheel 53*a* is keyed is energized to drive a chain 51 which drives a sprocket wheel 52 on impingement mill shaft 54. Shaft 54 is positioned concentrically within housing 50 and is free to rotate therein on bearings 48. A key 23 secures the hub 33 of the mill rotor 32 to shaft 54. Rotor 32 has apertures 40 and a pair of cylindrical vanes 36 formed with apertures 38 as can be more clearly seen in FIG. 3. As shown in FIG. 2, underbody vanes 34 are formed on the underside of rotor 32. We position rotor 32 adjacent to stator body 26 which forms the top of mill casing 14. Stator 26 supports both valve chambers 22 and 22*a*. These chambers extend through stator 26 so as to be positioned in the space between the first rotor vane and rotor hub 33, which space forms rotor intake chamber 42. Stator 26 is formed with vanes 28 having apertures 30. The entire rotor assembly is sealed about shaft 54 by means of packing 47.

When the photocopying apparatus is actuated, motor 53 through the chain drive described above will spin rotor 32. When this occurs the fluid in the rotor intake chamber 42 accelerates outwardly circulating through apertures 40. When valves 25 and 25*a* are closed the developer fluid in the impingement mill body 14 circulates through the spaces between and through the openings in rotor vanes 36 and stator vanes 28. On command from the tonor monitor toner paste flows into chamber 42. On command from developer liquid level sensor diluent 43 flows into the impeller intake chamber 42. These fluids either singly or in combination are accelerated outwardly of chamber 42.

Referring now to FIG. 4, the outward movement of the fluids occurs through apertures 38 in rotor vanes 36, and through apertures 30 in stator vanes 28. Some of the fluid traverses the narrow annular spaces or interstices between stator vanes 28 and rotor vanes 36 as well as the interstices between rotor body 32 and stator body 26. The juxtaposed relation of these vanes causes violent shear stresses which emulsifies and homogenizes the traversing fluids. The effluent mixes with developer liquid 15 in mill casing 14. Underbody vanes 34 aid the circulation of the fluids.

It is to be understood that the injection of toner paste 2 or volatile diluent 43 or both is made only when required. However, the homogenizing process is continuous while the machine is operating. After the machine has been in operation for some time, some precipitation may occur. To clear the system of precipitates, we provide tap pipe 61 controlled by valve 63, in the lower portion of mill body 14, permitting removal of any accumulated coagulants.

In use, when the electrostatic copier is energized, motors 76, 78, and 53 operate and rotate continuously while the machine is operating. Motor 76 drives pump 75 to discharge developer liquid through pipe 84 to the developing tray 98. Developing liquid returns through pipe 74 to the toner supply tank 64 from which it passes through pipe 68 for continuous circulation around the circulating ring comprising the toner supply tank 64 and the developing tray 98. Energization of motor 78 operates pump 77 which draws developer liquid from toner supply tank 64 through pipe 70 and discharges it through pipe 80 into the homogenizer 14. The discharge from the homogenizer 14 through pipe 62 returns the homogenized developing fluid to the toner supply tank 64. The operation of motor 53 drives the homogenizer rotor 32 through the chain drive 51. The organosol components of the developing fluid are thoroughly homogenized in the carrier liquid by the interaction of the stationary vanes and rotary vanes of the homogenizer, as well as by the agitation which takes place in the homogenizer body 14. When the high molecular weight components of the tacky toner composition become reduced in quantity, the optical control system 66 will insure their replenishment. This occurs when valve 25 opens allowing the air pressure upon piston 5 to deliver the toner concentrate to the homogenizer. When the concentration reaches the proper consistency, the optical control system permits valve 25 to seat. Some toner liquid adheres to the revolving drum surface 87 and evaporates. This reduces the liquid level within the toner tank 64. When this occurs microswitch 106, held open by float 104, closes energizing solenoid 16a and operating valve 25a permitting diluent from the diluent storage tank 82 to flow through pipe 44 into the homogenizing zone.

It will be seen that we have accomplished the objects of our invention. We have provided a system for maintaining the developer liquid in proper condition. We have provided a continuous supply of tacky toner liquid of correct composition to a developer station. We have provided a novel means and method for replenishing our tacky toner component of the developer liquid. Our machine is of reduced size. We have provided a self-regulated toner developer supply system which continually supplies toner fluid of proper composition to the developing zone.

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

Having thus described our invention, what we claim is:

1. In an electrostatic copier utilizing a liquid developer having a diluent constituent and a tacky toner constituent which is insoluble in said diluent, a container for holding a quantity of said developer, mechanical mill means for subjecting developer passing there-

through to shear stresses sufficiently great to maintain an emulsion of said toner and said diluent, means including a pump for circulating said developer from said container through said emulsifying means and back to said container, a developer unit, and means for supplying developer to said developer unit from said container.

2. Apparatus as in claim 1 including means for holding a supply of toner, means for monitoring the opacity of said developer liquid and means responsive to said monitoring means for feeding said toner from said supply to said mill means.

3. Apparatus as in claim 1 including means for holding a supply of said diluent, means for sensing the level of developer in said container and means responsive to said sensing means for feeding diluent from said supply to said mill means.

4. Apparatus as in claim 1 including means for holding a supply of said toner, means for holding a supply of said diluent, means for monitoring the opacity of said developer, means for sensing the level of said developer in said container, means responsive to said monitoring means for feeding toner from said toner supply to said mill means, and means responsive to said sensing means for feeding diluent from said diluent supply to said mill means.

5. In an electrostatic copier utilizing a liquid developer having a diluent component and a tacky toner component apparatus including a tank for holding a supply of said liquid developer, a developer unit, means including a first pump for circulating developer liquid from said tank through said developer unit and back to said tank, mechanical mill means for subjecting developer passing therethrough to shear stresses sufficiently great to maintain an emulsion of said toner and said diluent, and means including a second pump for circulating developer liquid from said tank through said emulsifying means and back to said tank.

6. Apparatus as in claim 5 including means for holding a supply of said toner, means for monitoring the opacity of said developer liquid and means responsive to said monitoring means for feeding toner from said supply to said mill means.

7. Apparatus as in claim 6 in which said toner holding means comprises means for maintaining said toner under superatmospheric pressure.

8. Apparatus as in claim 5 including means for holding a supply of said diluent, means for sensing the level of liquid in said tank and means responsive to said sensing means for feeding diluent from said supply to said mill means.

9. Apparatus as in claim 5 in which said mill means comprises a stator member, a rotor, means forming a narrow space between said rotor and said stator, means for directing material fed to said mill means into said space, and means for moving said rotor relative to said stator to apply shear forces to material in said space.

10. Apparatus as in claim 9 in which said space forming means comprises an annular vane on said stator and an annular vane on said rotor, said rotor vane being disposed adjacent said stator vane to form an annular space, said directing means comprising openings in said rotor vane, and means for feeding material to the rotor.

11. Apparatus as in claim 5 in which said mill means comprises a rotor and a stator, a plurality of concentric annular vanes on said rotor and on said stator, said stator and rotor vanes cooperating to form a plurality of narrow annular spaces, means for directing material fed to said mill means to said rotor, means forming openings in said vanes for directing material fed to said rotor to said spaces and means for rotating said rotor to apply shear forces to the material in said spaces.

12. Apparatus as in claim 11 in which said stator vane openings are generally radial and in which said rotor vane openings extend from inlet to outlet in a direction slanted opposite to the direction of rotation of the rotor.

* * * * *