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**Smith et al.**

[11] **3,825,191**

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[54] **CENTRIFUGAL MILL FOR CONTACT TRANSFER ELECTROSTATIC COPIER**


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[52] **U.S. Cl.** ..... **241/46.11,** 241/79.1

[51] **Int. Cl.** ..... **B02c 13/14**

[58] **Field of Search**..... 241/39, 46 R, 46.02, 46.11, 241/46.17, 79.1, 79.2, 80, 101 R



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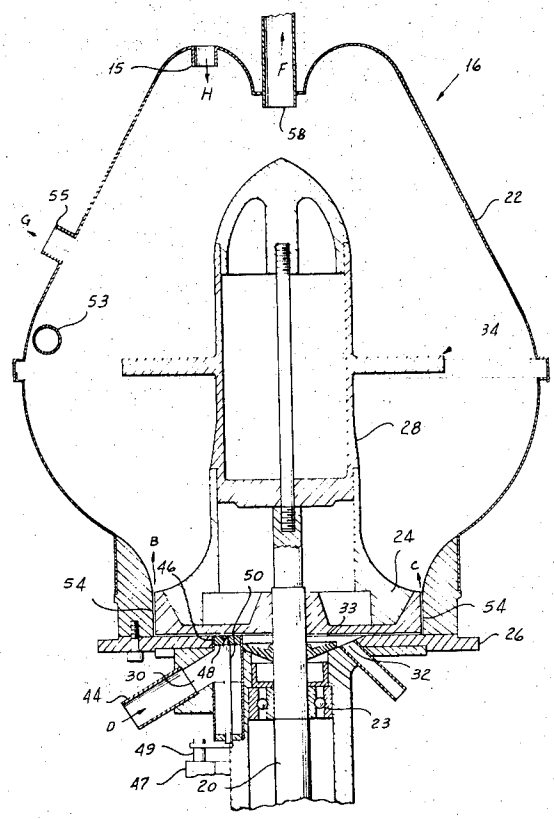
[57] **ABSTRACT**

A centrifugal impingement mill and developer supply system for an electrostatic copier using a developer made up of particles of tacky toner suspended in a carrier liquid in which a cylindrical spindle having a conical apex is provided with an annular radially extending vane located in the bulbous generally pear-shaped cavity of a housing and is provided with a relatively broad cylindrical base disposed in relatively closely spaced relationship to the wall of a shallow cylindrical recess in the housing below the cavity to form a vortex of developer liquid in the cavity above the recess and in which a first circulating path for developer containing relatively fine toner particles is provided from a point above the major diameter of the cavity to a developer applicator and back to an orifice adjacent to the top center of the housing and in which a second circulating path is provided for developer containing relatively coarse toner particles from a point adjacent to the major diameter of the cavity to the space between the spindle base and the housing recess wherein shear forces are applied to the toner particles and thence to the cavity. Means are provided for allowing air trapped in the form of bubbles in the developer liquid contained in the cavity to escape to the ambient atmosphere.


**13 Claims, 2 Drawing Figures**



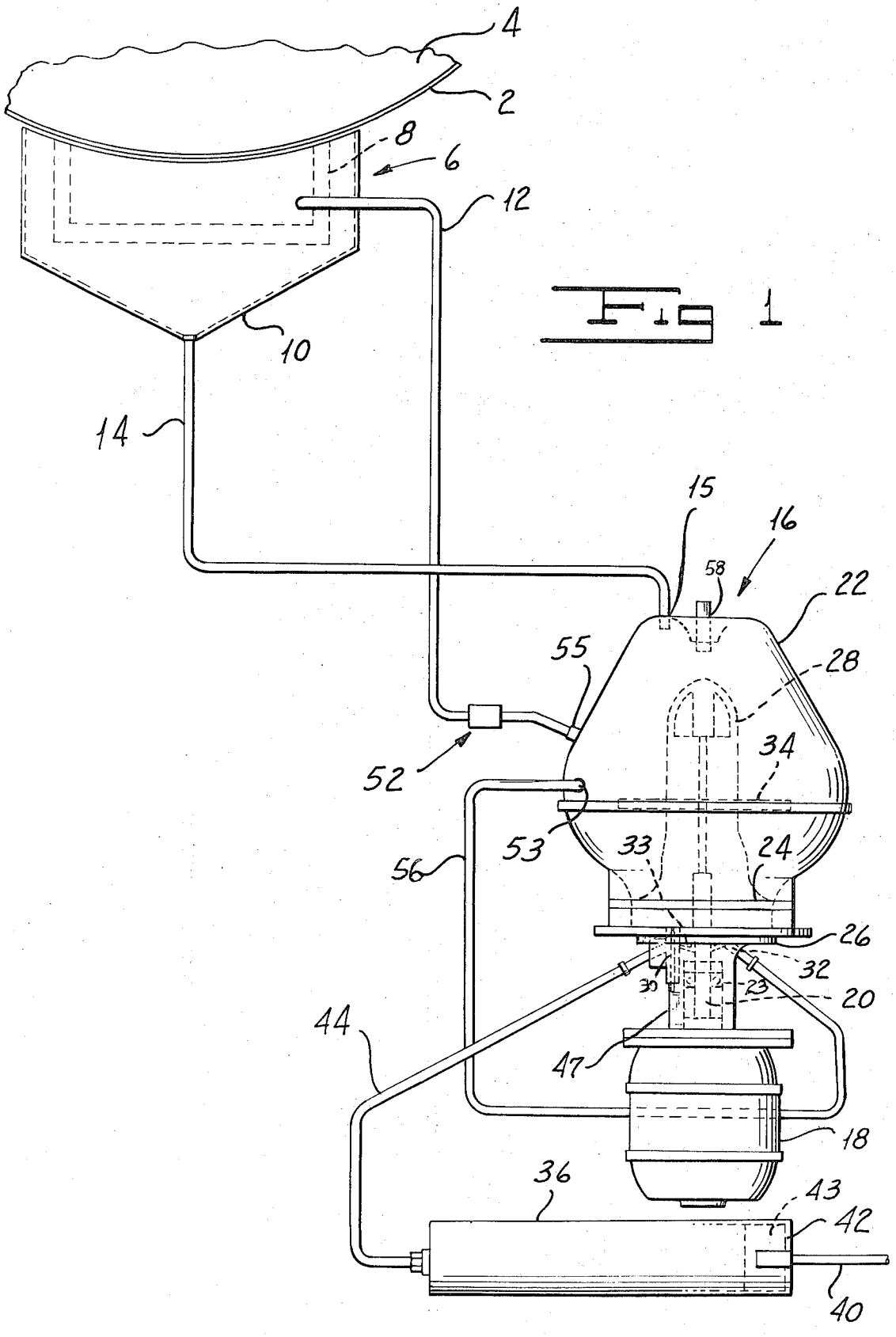

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Fig 1

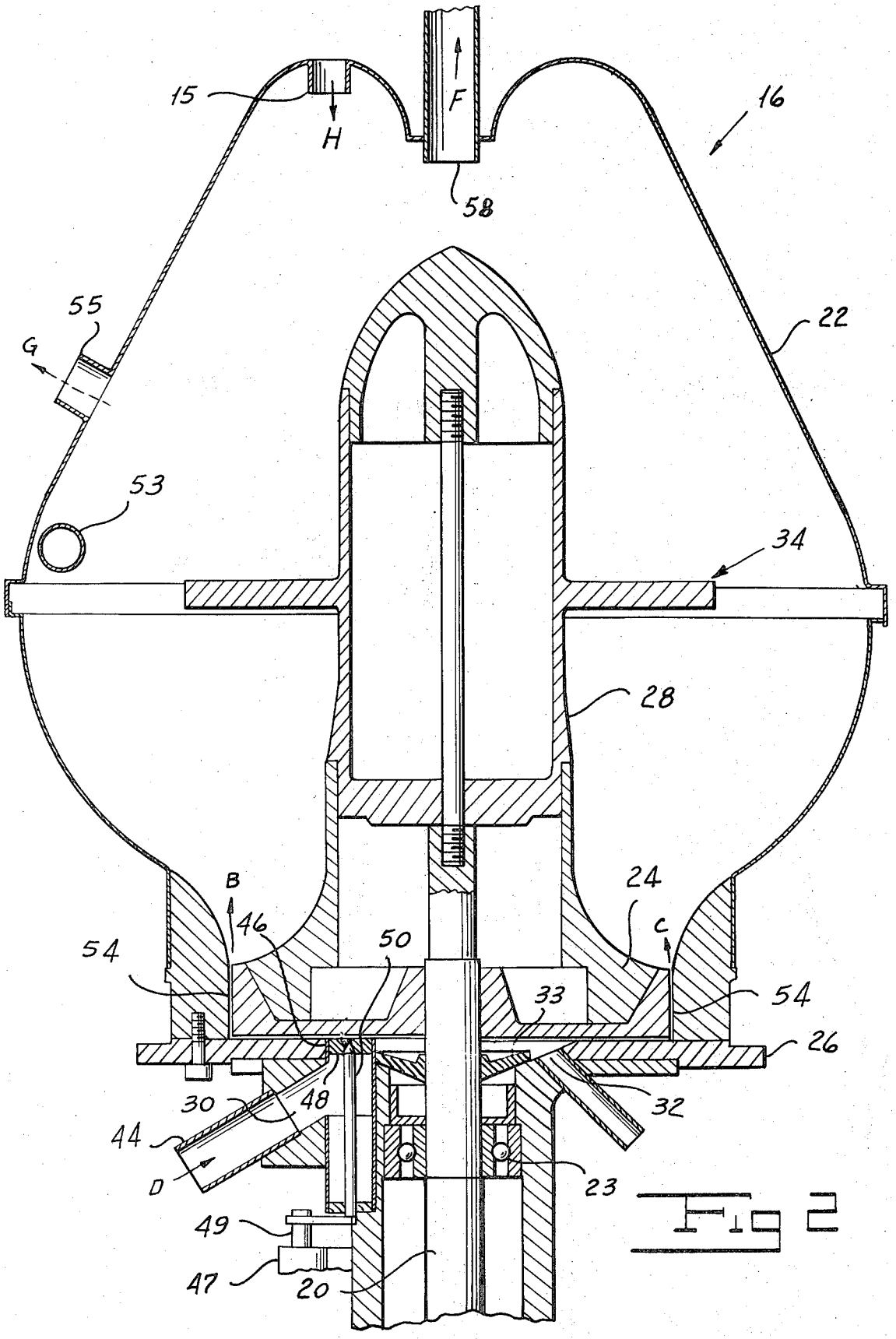
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Fig 2

# CENTRIFUGAL MILL FOR CONTACT TRANSFER ELECTROSTATIC COPIER

## BACKGROUND OF THE INVENTION

Our invention relates to an improved method and apparatus for continually replenishing a liquid developer which employs a tacky toner to develop images on a photoconductive surface. The properties of this form of liquid developer are disclosed in the copending application of Smith, et al., for "Apparatus for Developing Electrostatic Images" (I), Ser. No. 212,155, filed Dec. 27, 1971, now U.S. Pat. No. 3,789,759, and in the application of Smith, et al., (II) for "Method of Contact Transfer of Developer Electrostatic Images and Means for Practicing Same," Ser. No. 155,108, filed June 21, 1971. Briefly, the liquid developer comprises two prime components, a toner paste and a volatile, light hydrocarbon, carrier liquid. The toner paste is an admixture of an adhesive resin, a pigment, solvents, and may include a deflocculating agent, which toner component is in the form of a paste-like organosol which is insoluble in the carrier liquid. For proper development of the latent electrostatic image and its subsequent transfer to a copy medium the organosol or toner paste must be suspended in the carrier liquid. The fine particles of toner paste migrate to the charged regions of the latent electrostatic image under the influence of the electric fields incident thereto. The toner particles adhere to the image areas of the photoconductive surface and are later contact-transferred to a copy medium for which they possess greater adherence affinity, thereby transferring the developed latent electrostatic image from the photoconductive surface to the copy medium. Excess developer liquid is removed from the photoconductive surface and returned to a developer liquid trough by squeegee rollers, an air knife, or other liquid removal apparatus. There are some small losses of the carrier liquid by adherence to the photoconductive surface and by evaporation, but these losses are extremely small relative to the quantity of toner paste used over the many copy cycles by adherence to the charged regions of the photoconductive surface. For this reason toner paste must be added to the carrier liquid on a regular basis in accordance with the rate of toner particle depletion, or on a demand basis in order, for instance, to darken the copy image. Because the toner paste is insoluble in the carrier liquid, merely mixing the paste with the carrier is entirely insufficient to produce a suitable developing liquid.

We provide an improved means for mechanically emulsifying the toner paste in the developing liquid. Additionally, we provide means for filtering and pumping to the developing zone the portion of the resultant emulsion which contains the finest, most evenly dispersed toner particles. At the same time, we provide means for selectively drawing off the larger toner particles for further remilling and redispersing throughout the volume of the carrier liquid in the mill cavity.

The application of Smith, et al., (II) discloses a milling device and liquid developer circulation system designed to supply to the developing zone a tacky toner liquid developer in a well dispersed state. The circulatory system employs two circulating loops; one from an intermediate toner supply tank to the developing zone and back, the other from the intermediate toner supply tank to an emulsifying and mixing mill and back. Two



independently driven pumps maintain the fluid flow in each of the two circulation loops. On command from monitoring devices in the toner supply tank and in the toner supply tank-developing zone loop more carrier or paste is admitted to the mixing mill to be emulsified with the developer liquid present in the mill cavity. Emulsification is accomplished in the mill by subjecting the toner paste to severe shearing forces created in a series of concentric interstices between rotating and stationary vanes, into which the toner paste is injected. The resultant effluent is mixed with developer liquid present in the mill cavity. The structural arrangement of the mill is such that the rotor and stator vanes are located near the top of the mill housing and the emulsified liquid developer is drawn off from an opening at the bottom of the mill from which it is pumped to the developing zone. The entire mill assembly is located at a height above that of the developing zone. In use of that apparatus we discovered that while accomplishing its main objective, the mill incorporates two principal deficiencies. In its operation the mill churned air bubbles into the developer liquid, which, owing to the rotor placement, remained trapped therein. These air bubbles impaired effective pumping of the developer liquid to the developing zone and deteriorated the liquid's developing properties. It was also found that when not in use, excess liquid developer in the mill flowed to the developing zone, where, by gravitational drainage, during the time the copier was idle, the toner particles tended to congeal and settle. Once agglomerated the mass of toner sediment could not entirely be pumped back to the mill for further mixing and agitation.

Our improved centrifugal mill overcomes the defects of the prior art. It is arranged so that air bubbles rise out of the emulsion present in the mill cavity and are released to the atmosphere through a suitably located port. Our improved mill is arranged to receive liquid developer by gravitional drainage from the developing zone during periods of machine idleness. In this manner any toner particles which congeal and settle in the liquid developer do so in the mill cavity rather than in the developing zone tank. When the copy machine is again switched on the mill is activated and the sediment which has collected therein is emulsified and distributed throughout the carrier liquid in the mill cavity.

## SUMMARY OF THE INVENTION

One object of our invention is to provide a continuous supply of extremely well mixed tacky toner liquid developer of correct composition, free from flocculates and air bubbles.

Another object of our invention is to provide a method of replenishing components of a tacky toner developer liquid as these components are depleted.

A further object of our invention is to restore the desirable properties of a tacky toner liquid developer after they have been lost during periods of copy machine idleness.

A still further object of our invention is to provide a wholly self-regulating developer supply system capable of continuously supplying a developer fluid of proper composition to a developing zone.

In one embodiment of our invention, we provide a continuous and homogeneous supply of tacky toner liquid developer to a developing zone by providing a single closed loop circulatory path between the developing zone and our centrifugal impingement mill. The de-

veloping zone generally comprises a trough into which developing liquid is pumped, and an application instrumentality which transfers the developer from the tank to the latent electrostatic image on the photoconductive surface. Examples of such application instrumentalities are endless belts, polyurethane rollers, and spray devices. Our centrifugal impingement mill performs three functions. It serves as a reservoir for the tacky toner liquid developer. It serves as a liquid developer emulsification apparatus. It serves as a pump which continuously circulates the liquid developer between the developing zone and the impingement mill. In this configuration well-mixed tacky toner liquid developer of proper composition is pumped up to the developing zone and then discharges back to the mill by gravitational drainage.

## BRIEF DESCRIPTION OF THE DRAWINGS

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

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

FIG. **2** is a fragmentary sectional view of our centrifugal impingement mill used in our toner liquid developer circulation system.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. **1** of the drawings, we have shown a schematic view of our liquid developer circulation system and centrifugal impingement mill, in which a photoconductive surface **2** on a rotating drum **4** moves past a developing station indicated generally by the reference numeral **6.** The drum **4** and the developing station **6** are two components of a copy machine whose other components have been omitted from FIG. **1** since they do not per se form part of our invention. The developing station **6** comprises an applicator tank **8** and overflow trough **10.** The developer liquid flows into the applicator tank **8** from a pipe **12** and is applied to the latent electrostatic image formed on the photoconductive surface by an application instrumentality (not shown) of any suitable type known to the art. Excess liquid developer on the photoconductive surface is collected in the trough **10** and returns, by way of a pipe **14** to an aperture **15** in a centrifugal impingement mill, indicated generally by the reference character **16.** We arrange an electric motor **18** to drive an impingement shaft **20.** The shaft **20** is positioned concentrically within a bulbous, pear-shaped mill housing **22** of spun aluminum, for instance, and is free to rotate therein on bearings **23.** The shaft **20** is suitably secured to a rotor **24** which forms the base of a concentrically mounted hollow spindle **28.** We position the cylindrical milling rotor **24** adjacent the walls of a recess in a correspondingly shaped stator body **26** which forms the bottom of the mill casing **22.** The stator body **26** supports a valve chamber **30** and a "coarse" fluid re-entrant chamber **32.** These chambers extend through the stator body **26,** opening into a space **33** between the cylindrical milling rotor **24** and the stator body. We concentrically mount about the spindle **28** a vortex forming vane **34** having the shape of a thin right circular annulus.

As will be explained hereinafter with greater particularity, the cavity of the mill casing serves as a tacky toner liquid developer reservoir. The mill continuously emulsifies and filters the liquid developer therein and pumps back to the developing station a liquid developer containing fine and evenly dispersed toner particles.

Referring now to both FIG. **1** and FIG. **2,** a container **36** holds a supply of toner paste or concentrate. A threaded rod **40** or the like is adapted to be screwed into one end **42** of container **36** to position a piston **43** to apply pressure to the toner concentrate which is conducted to chamber **30** by pipe **44.** The pipe **44** is normally closed by a valve **46** operated by a solenoid **47.** A valve stem **50** normally engages a seat **48** to close the valve, and is actuated by an armature **49** of the solenoid **47** to which it is connected. Operation of the solenoid **47** controls the admission of toner paste into the mill by lifting the stem **50** from its seat **48.** The operation of the solenoid **47** is controlled by a toner density monitoring system indicated generally by the reference numeral **52.** When this occurs, the paste **38** from the valve chamber **30** flows into the space **33.**

The spindle **28** and radially extending vane **34** rotate at about 2,800 revolutions per minute to form a vortex of developer liquid within the mill casing. Centrifugal forces within the fluid vortex accelerate the suspended toner particles outwardly toward the walls of the mill casing. The heavier toner particles and flocculates tend to collect near the walls of the mill casing while the lighter and finer toner particles tend to remain close to the spindle. The walls of the mill casing are especially shaped to take advantage of the selective filtration process performed by the centrifugal forces within the vortex. The mill casing is "pear shaped," bulging outwardly in the vicinity of the vane **34** and tapering inwardly toward the top. An emission aperture **55** is placed at a point above the major diameter of the mill, where the walls of the mill casing slope inwardly toward the conical apex of the spindle to tap the portion of the fluid vortex nearer the spindle which contains the finer and lighter toner particles. This point may be empirically determined after parameters such as the liquid developer's composition, the rotational speed of the vane, and the vane's diameter have been set. The situs of the emission aperture reflects a balance between fineness of toner particles tapped and the pressure needed to drive this portion of the liquid developer through the developer feed pipe **12.** While finer toner particles accumulate near narrower mill radii, vortex pressure decreases with decreasing radius. The vortex pressure pumps this optimum tacky toner emulsion to the developing station through the pipe **12.** We locate at a point on the mill housing adjacent to the major diameter and on the outwardly bulging surface near the vane **34,** a coarse toner particle outlet **53** to tap that portion of the fluid vortex containing the heavier toner particles and flocculates. These heavier particles are driven by vortex generated pressure through a coarse return pipe **56** which communicates with the re-entrant chamber **32** in the stator body **26.** The heavier particles entering the chamber **32** are admitted to the milling zone **54** to be reground by shearing forces generated therein and sprayed back into the fluid volume in the mill cavity. This jet of highly emulsified, fine toner particles breaks up and scatters toner sediment which may have congealed in the vicinity of the rotor during periods of ma-

chine idleness. This sediment is thrust toward the coarse outlet **53** by vortex generated pressure and enters the coarse return pipe **56** to be reground and sprayed back into the fluid body in the mill cavity.

In this manner our invention causes coarse toner particles and flocculates to be continuously removed from the fluid vortex within the mill and recirculated to the milling zone between the rotor and stator where they are reground and injected to the fluid body in a finer state. Simultaneously developer fluid containing evenly dispersed fine toner particles is pumped through the feed pipe **12** to the developing station by vortex generated pressure.

Experience obtained by the use of other emulsifiers, known to the prior art, indicates that air frequently becomes churned into the developer fluid present in the mill cavity. Air trapped in the form of bubbles in the fluid vortex in our mill rises above the fluid meniscus to escape through an air escape orifice **58** located at the top of our mill and which communicates with the atmosphere.

We continuously monitor the toner particle concentration by measuring the light transmissibility of the fluid at any desired point such, for example, as that at which the liquid developer leaves the developer station, or alternatively, at the emission aperture **55** in the casing of the impingement mill as shown in FIG. **1.** When the toner particle concentration is sufficiently low a photosensor receives a greater flux of light owing to the reduced opacity of the developer fluid. When a predetermined quantity of light strikes the sensor, the armature **49** of the solenoid **47** is actuated to move valve **50** out of engagement with seat **48** to admit toner paste to the emulsifying zone of the centrifugal impingement mill. The details of the circuitry of my optical monitoring system are explained in the copending patent appliation of Smith, et al., (I).

In the preferred embodiment illustrated in FIG. **1,** our impingement mill serves as a reservoir for the light hydrocarbon carrier liquid with which the toner paste is emulsified. The cavity of the mill **16** is normally filled with carrier liquid to a height slightly above the conical apex of the spindle **28.** In use, when the electrostatic copier is energized, the motor **18** operates to rotate the cylindrical milling rotor **24** and the vane **34.** The fluid vortex formed by this rotation begins to pump the liquid developer to the developing station in the direction of arrow G, by way of the pipe **12.** Simultaneously, the coarse toner particle filtration circuit is activated, as explained hereinabove, and a jet of fine toner particles, moving upwardly in the direction of arrows B and C, from the emulsification zone, breaks up any toner sediment which may have accumulated above the rotor during periods of machine idleness. The discharged liquid developer, depleted in toner particles, returns from the overflow trough **10** of the developing station to the mill cavity by way of the pipe **14** and the inlet **15** in the direction of the arrow H in FIG. **2.** Bubbles which may form in the liquid developer fluid are displaced upwardly to the air region above the fluid meniscus and escape to the atmosphere as explained hereinabove, through the air escape orifice **58,** arrow F in FIG. **2.** Our centrifugal impingement mill is adapted to overcome the deterioration of the transfer properties of the liquid developer resulting from overmilling. In its optimum state a tacky toner liquid developer exhibits great cohesiveness and anti-fracture strength, while exhibiting only limited adhesive affinity for the photoconductor to which it is applied. In this state the tacky toner liquid developer will uniformly and completely transfer to the copy medium with which it is contacted, leaving no residue on the photoconductor surface. A tacky toner liquid developer's transfer properties depart from this optimum state over many milling cycles and the toner begins to gel. The overmilled developer loses cohesiveness and becomes increasingly adhesive. This deterioration in transfer properties is manifested by soiled and spotty copies. To counter the undesirable effects of overmilling, we may alter the configuration of the milling zone between the base **24** and housing recess so that the developer liquid passes through fewer emulsifying stages. Alternatively, we may reduce the vane radius by providing interchangeable vanes of reduced radius, for mounting about the spindle **28.** In addition we may, within limits, reduce the speed of rotation of the rotor and the spindle-vane assembly.

It will be seen that we have accomplished the objects of our invention. We have designed a system of extreme simplicity and flexibility for maintaining and supplying a liquid developer in proper condition for the development of electrostatic images. Our invention has eliminated the need for the dual circulation loops between the emulsifying station, the developing station, and the intermediate liquid developer storage tank, as disclosed in the patent application of Smith, et al. (II). Concurrently, our invention has eliminated the need for the pumps which maintained the fluid flow in those loops. Our centrifugal impingement mill serves as the fluid storage tank and provides the pumping action needed to maintain fluid flow in a single circulation loop. Of course, our centrifugal impingement mill may be used in the dual circulation loop system or in a multi-loop circulation system and still achieve the objective of providing an extremely well mixed liquid developer. It is clear that the motor **18** may be arranged in a number of different configurations, to impart motion to the cylindrical milling rotor **24** and the vane **34.** For example, the motor may be located above the mill to directly drive the cylindrical milling rotor **24** and the vane **34** through a shaft secured to the spindle at its apex, or the motor may rotate the assembly from a more remote location, through appropriately arranged gear chains.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of our claims. It is further obvious that various changes may be made in details within the scope of out 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.** Apparatus for supplying liquid developer made up of toner particles suspended in a liquid carrier to the developer applicator unit of an electrostatic copying machine including in combination, a housing forming a bulbous cavity having a major diameter, means forming a vortex of developer liquid in said housing, milling means adapted to exert shear forces on developer liquid fed thereto, means for feeding developer liquid from said vortex at a location adjacent to said major diameter to said milling means and for conducting devel-

oper liquid from said milling means to said vortex, and means for conducting developer liquid from said vortex to said developer applicator unit.

**2.** Apparatus as in claim **1** in which said milling means is in said housing below said cavity.

**3.** Apparatus as in claim **1** in which said milling means includes a cylindrical recess in said housing below said cavity, a cylindrical rotor portion disposed in said recess in closely spaced relationship thereto and means for driving said rotor to exert shear forces on said developer liquid in the space between said rotor and the wall of said recess, said conducting means conducting developer liquid from said housing at a location adjacent to said major diameter to the space between said rotor and said recess wall.

**4.** Apparatus for supplying liquid developer made up of tacky toner particles suspended in a carrier liquid to the developer applicator unit of an electrostatic copying machine including in combination, a housing forming a bulbous cavity having a major diameter and a cylindrical recess below said cavity, a rotor in said housing, said rotor comprising a vortex forming portion located in said cavity and a cylindrical portion in said recess in closely spaced relationship to the wall thereof, means for driving said rotor to cause said vortex forming portion to form a vortex of developer liquid in said cavity and to cause said cylindrical portion to exert shear forces on said developer liquid in the spaces between the cylindrical portion and the wall of the recess, means for conducting liquid from said vortex to said developer unit and back to said housing, and means for conducting developer from said housing at a location adjacent to said major diameter to the space between said cylindrical rotor portion and the wall of said recess.

**5.** Apparatus as in claim **4** including means providing communication between the interior of said housing and the surrounding space.

**6.** Apparatus as in claim **4** including means for introducing concentrated toner into the space between the cylindrical rotor portion and the wall of said recess.

**7.** Apparatus as in claim **4** in which said vortex forming portion comprises an annular vane in the region of said major diameter.

**8.** Apparatus as in claim **4** including means mounting said housing below said applicator unit.

**9.** A centrifugal impingement mill and developer supply system for an electrostatic copier using a developer made up of particles of tacky toner suspended in a carrier liquid, including in combination, a cylindrical spindle having a conical apex, radially extending vane and broad cylindrical rotor base, a stator formed with a cylindrical recess disposed at the bottom of a cavity within a bulbous, generally pear-shaped housing and forming a narrow space between said rotor base and said stator, means for feeding toner material into said space, means for moving said rotor base and said spindle relative to said stator to apply shearing forces to material in said space and to form a vortex in liquid developer contained in said cavity, means forming a first circulating path for developer containing predominantly fine toner particles from a point above the major diameter of said housing to a developer applicator unit and back to an orifice adjacent the top center of said housing, and means forming a second circulating path for developer containing predominantly coarse toner particles from a point adjacent the major diameter of said housing to a re-entrant chamber in said stator opening to said space between said stator and said rotor, and thence to said mill cavity.

**10.** An apparatus as in claim **9** in which said housing forms a surface symmetric about a longitudinal axis and has a radius which varies along the longitudinal direction of said axis to extend outwardly in the vicinity of said vane and taper inwardly toward said conical apex and said rotor base of said spindle.

**11.** An apparatus as in claim **10** in which said housing contains an air-escape orifice at a location on its surface above the meniscus of the developer fluid contained therein, an emission orifice above the major diameter of said housing through which said developer containing predominantly fine toner particles enters said first circulating path, and a coarse outlet on the portion of its surface adjacent the major axis of said housing through which said developer containing predominantly coarse toner particles enters said second circulating path.

**12.** An apparatus as in claim **9** in which said spindle and said housing cooperate to form a fluid vortex in liquid developer contained in said cavity comprised of a first fluid region containing predominantly fine toner particles in a generally annular region about said spindle and a second fluid region containing predominantly coarse toner particles in an area generally contiguous to the interior wall of said housing adjacent the major diameter of said housing.

**13.** An apparatus as in claim **9** in which said space forming means comprises disposing said cylindrical rotor base in a relatively close spaced relationship with walls of said recess formed in said stator, said directing means comprising a toner valve chamber in said stator opening on said space through which toner concentrate is admitted and a re-entrant chamber in said stator opening on said space through which liquid developer containing predominantly coarse toner particles is admitted from said second circulating path.

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