United States Patent

Bullock et al.

[15] **3,679,099**

[45] **July 25, 1972**

[54] **BALANCE TYPE TONER CONCENTRATION SENSING AND MONITORING SYSTEM**

[72] Inventors: **Michael K. Bullock; Myrl J. Miller; William F. Voit, Jr.**, all of Lexington, Ky.

[73] Assignee: **International Business Machines Corporation,** Armonk, N.Y.

[22] Filed: **July 28, 1970**

[21] Appl. No.: **58,808**

[52] **U.S. Cl.** **222/55,** 222/DIG. 1, 118/7
[51] **Int. Cl.** **B67d 5/08**
[58] **Field of Search** ....222/57, 55, DIG. 1; 118/7, 118/637; 200/84 C

[56] **References Cited**

UNITED STATES PATENTS

2,852,162 9/1958 Nauta 222/57
3,137,529 6/1964 Allen et al. ....222/55 X

FOREIGN PATENTS OR APPLICATIONS

729,633 5/1955 Great Britain 222/55

Primary Examiner—Samuel F. Coleman
Assistant Examiner—James M. Slattery
Attorney—Hanifin and Jancin and D. Kendall Cooper

[57] **ABSTRACT**

A toner monitoring means including a sensor monitors the density of a mixture of toner and carrier in a developer means arranged for developing latent images in a xerographic process. The sensor in the monitoring means turns a toner feed mechanism on and off to maintain the toner concentration in the developer means at any selected density operating point.

10 Claims, 10 Drawing Figures

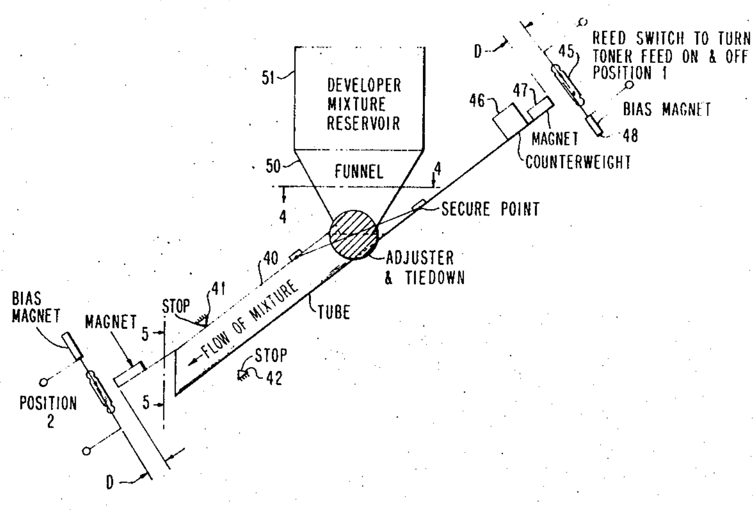


FIG. 1

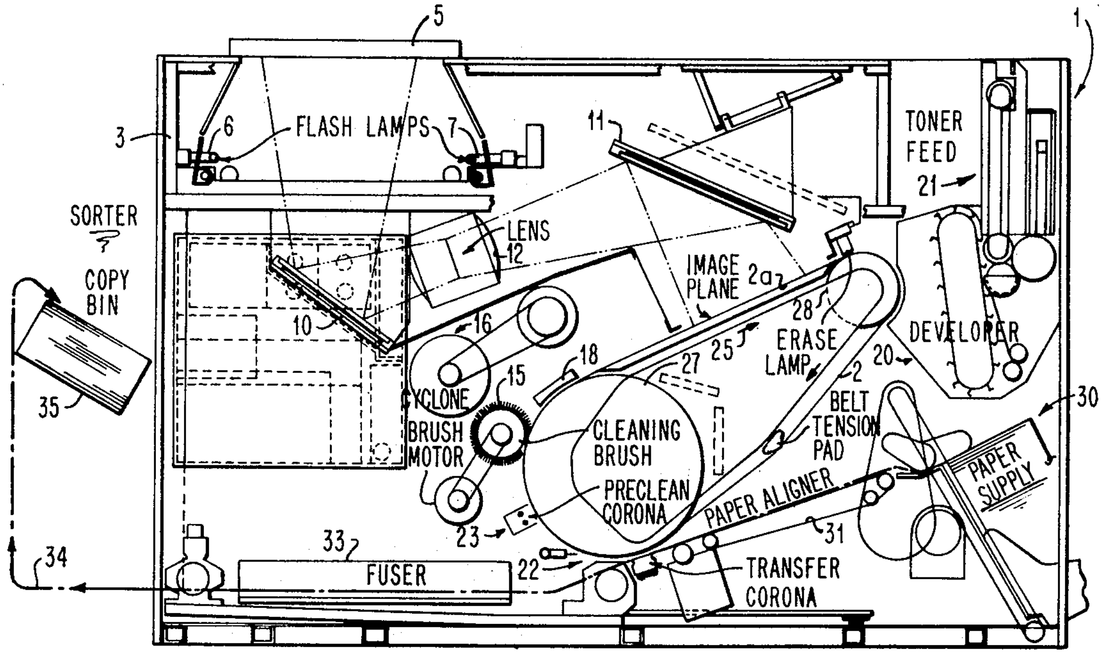
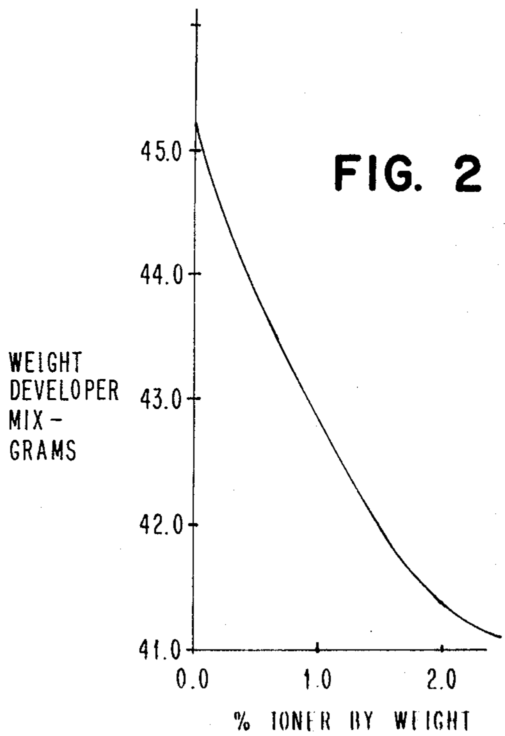


FIG. 2



MICHAEL K. BULLOCK
MYRL J. MILLER
WILLIAM F. VOIT, JR.

BY D. Kendall Cooper

ATTORNEY

FIG. 4

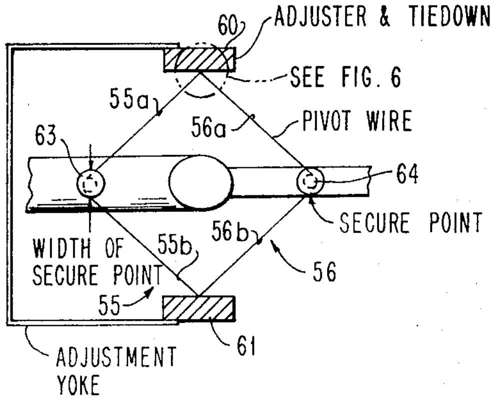


FIG. 6

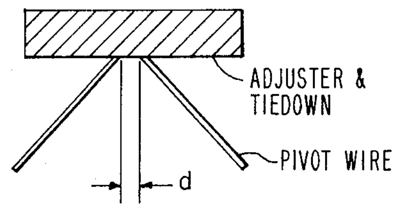


FIG. 3

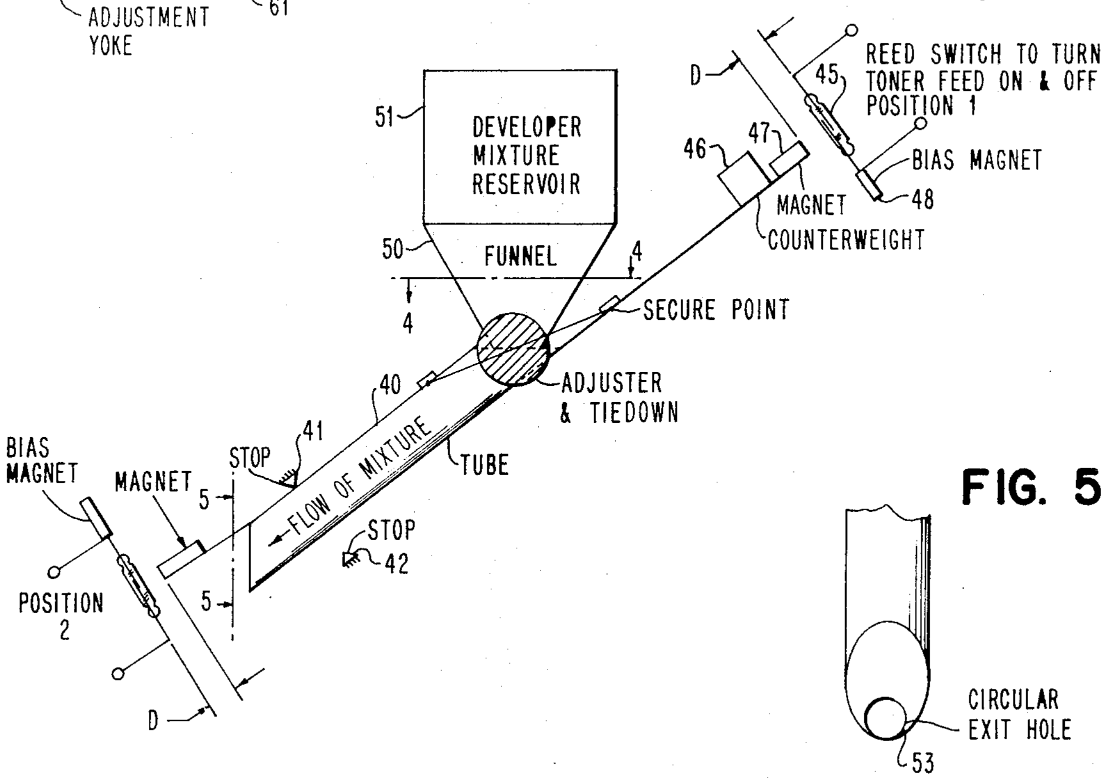


FIG. 5

FIG. 7

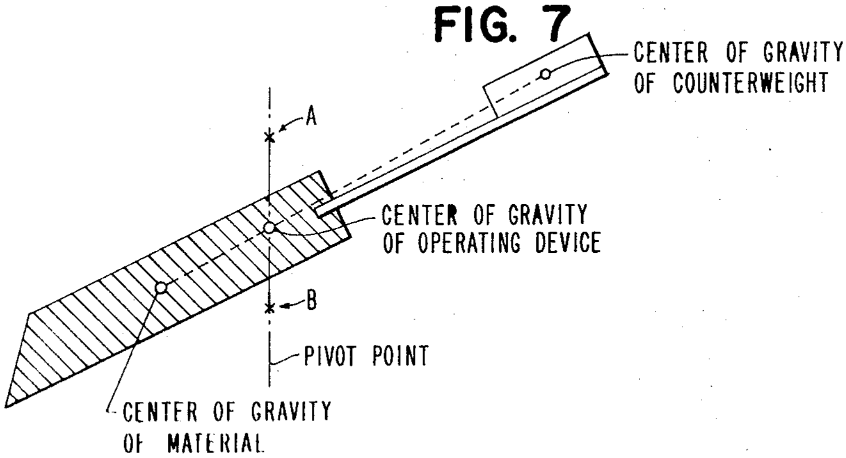


FIG. 8

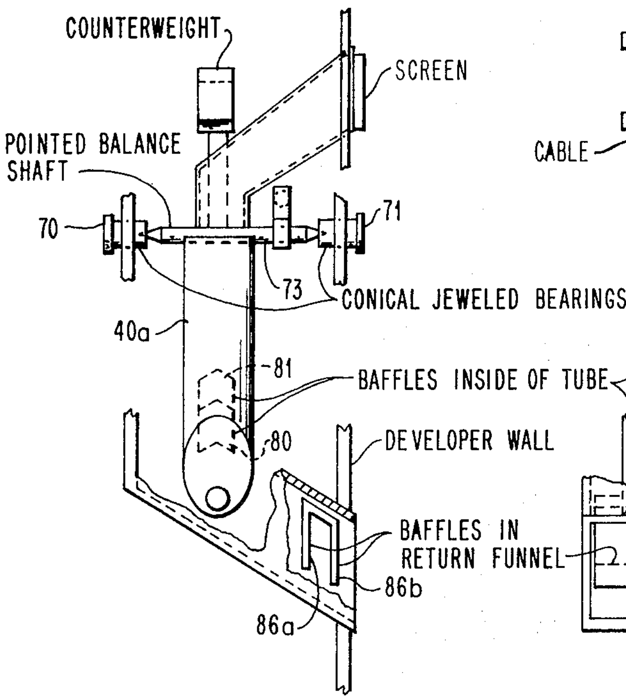


FIG. 9

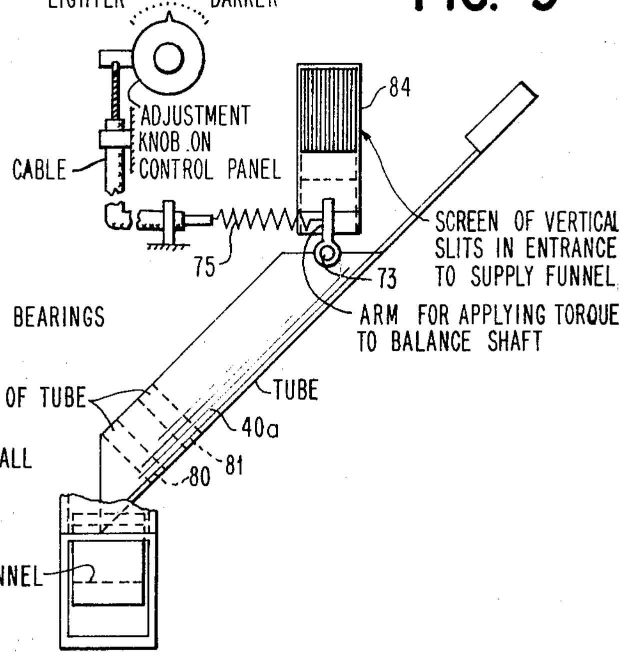
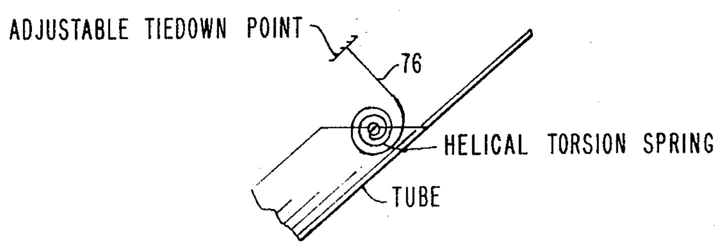


FIG. 10



BALANCE TYPE TONER CONCENTRATION SENSING AND MONITORING SYSTEM

BACKGROUND OF INVENTION AND PRIOR ART

The following U.S. Pat. Nos. are representative of the prior art: 2,956,487, 3,094,049, 3,233,781, 3,354,802, 3,361,113, 3,369,524, 3,376,853, 3,376,854, 3,399,652, 3,409,901, 3,430,606, 3,487,978.

None of the patents listed above discloses a toner monitoring system based on the density of the mixture of toner and carrier as taught in the present case.

SUMMARY OF THE INVENTION

The density of a mixture of toner and carrier, called developer mixture, is a function of the percent of toner in the mixture. Since the density of the carrier is greater than that of the toner, the more toner present in a given volume, the less the mixture weighs. This toner monitoring system uses this fact to monitor toner concentration. A sensor is preferably a two-arm balance which weighs a portion only of the developer mixture as it continuously flows through an inclined tube. If the toner concentration is high, the tube rests against a first stop. As the toner is depleted from the developer mixture, the mixture flowing through the tube becomes denser and when the density reaches the point which corresponds to a concentration where more toner is needed, the increased weight of the mixture in the tube produces a torque which causes the tube to pivot down to a second stop. This movement is used to switch a reed switch which actuates a toner dispensing means including a feed mechanism. When the developer mixture decreases in weight sufficiently, the tube pivots back up to the first stop and switches off the feed mechanism toner dispensing means.

OBJECTS

Accordingly, a primary object of the present invention is to provide a toner monitoring system that is based upon the sensing of the density of a portion of the developer mixture including toner and carrier.

Still another object of the present invention is to provide a toner monitoring system functioning with an auxiliary stream of developer mixture thereby precluding interference with the main developer stream.

The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of the preferred embodiments of the invention as illustrated in the accompanying drawings.

DRAWINGS

In the drawings:

FIG. 1 is a schematic diagram of a high speed copier system utilizing a photoconductive belt for the conveyance of images flashed thereon from an original document.

FIG. 2 is a graph illustrating the underlying principles of the invention and involving a consideration of the relationship of the percentage of toner to the weight of the developer mixture.

FIGS. 3–7 illustrate the structure and operation of a first embodiment of the invention.

FIGS. 8–10 illustrate the structures and operation of a second embodiment of the invention.

DETAILED DESCRIPTION

The High Speed Copier System

FIG. 1 illustrates a high speed copier unit 1 incorporating the present invention. The unit includes a photoconductor belt 2 and has a main frame 3 supporting various elements for producing a multitude of copies at high speeds from original documents. An original is positioned on the original document plane 5 and illuminated by flash lamps 6 and 7 in timed relation with movement of belt 2. An optical system including mirrors 10 and 11 and lens element 12 project the image of the original toward an image plane 2*a* on belt 2.

The unit in FIG. 1 includes the customary electrophotographic facilities for producing copies. These include a cleaning brush 15 with associated cyclone cleaning system 16, a charge corona station 18, the image plane 2*a*, previously mentioned, a developer means 20 and a toner dispensing means 21 including feed mechanisms operable when actuated to feed toner into the developer means 20, a transfer station 22, and a preclean corona station 23. Belt 2 is mounted for movement as indicated by arrow 25 on drum driving elements 27 and 28. A paper supply 30 accommodates a large quantity of individual sheets of paper that are fed by various devices including a belt 31 to the transfer station 22 for transfer of images in timed relation with movement of belt 2. Following such transfer, the image is fused by fuser 33, passes by transportation means 34, not shown, to a completion station, such as a sorter copy bin 35.

THE PRINCIPLES OF THE INVENTION

FIG. 2 illustrates the relationship of the percentage of toner by weight in comparison with the weight of the developer mixture in grams. The following can be deduced from the above:

1. The mass density of the developer mixture increases with decreasing toner concentration.
2. Or the weight of a given volume of developer mixture increases as the percent of toner concentration decreases.
3. The relationship between the weight of a given volume of developer mixture and the percent of toner is linear within a reasonable working region.

The present inventive arrangements are based on the foregoing observations, and toner concentration is monitored by making a weight comparison, e.g., comparing equal volumes of developer mixture which have varying amounts of toner. In the present system, monitoring means continually samples the developer mixture and has a balance sensor arrangement which is adjusted to be balanced at a desired mix density. By comparing the weight of a sample of the develop mixture against the weight of a standard volume of mixture, it effectively monitors the toner concentration. The readout can either be mechanical or electrical, as well as pneumatic, as by the use of the balance to position a spool valve. An electrical approach might use photosensing means or a strain gauge to readout the weight difference. The balance is mounted on a cantilevered flexible spring member or a low friction pivot so that a significant readout of a small weight difference can be obtained. In the embodiments disclosed herein, the sensing of the balance sensor is conveyed by the status of a reed switch influenced by a magnet carried by the balance sensor.

Of interest is the following experimental data illustrating the principles disclosed in FIG. 2. The data was compiled by weighing equal volumes of carrier and carrier with toner of two different toner concentrations, that is, 1.03 percent and 1.91 percent. A beaker containing the toner weighed 28.757 grams.

Beaker—28.757 grams

	Beaker + Carrier	Beaker + Developer (1.03%)	Beaker + Developer (1.91%)
	73.890 gms 71.744	gms	70.051 gms
	73.730 71.719		70.000
	73.923 71.659		70.100
	73.947 71.630		70.114
	73.888 71.545		70.109
Avg			
	73.875 Avg 71.659		Avg 70.075
Less			
	28.757 Less 28.757		Less 28.757
Tot	45.118 gms		
	42.902	gms	41.318 gms

The data presented above corresponds to that shown in FIG. 2.

EMBODIMENT OF FIGS. 3–7

The density of a mixture of toner and carrier, called developer mixture, is a function of the percent of toner in the mixture. The carrier, usually small steel, glass, sand, or plastic, beads, etc., is much denser than the toner which adheres to it due to triboelectric attraction. Consequently, the more toner present in a given volume, the less the mixture weighs. This toner monitoring system uses this fact to monitor toner concentration.

The monitoring neans, FIG. 3, includes a two-arm balance sensor which weighs a constant volume of mixture as it continuously flows through an inclined flow tube **40**. If the toner concentration is high, the tube **40** rests against stop **41**. Flow tube **40** is preferably mounted on developer means **20**, FIG. **1** so that a sampling portion of developer mixture passes into the upper entry portion of tube **40**, moves through tube **40** and then exits from the lower exit portion. Tube **40** is mounted in a balanced condition representative of a desired weight of developer mixture as it flows through tube **40**, with the relationship being such that tube **40** moves between first and second conditions representative of higher and lower toner concentrations in the developer mixture. As the toner is depleted from the developer mixture, the mixture flowing through the tube becomes denser and when the density reaches the point which corresponds to a concentration where more toner is needed, the increased weight of the mixture in the tube produces a torque which causes the tube to pivot down to stop **42**. This movement is used to switch sensor means reed switch **45** which turns on the toner feed mechanism, FIG. **1**. When the toner concentration reaches an acceptable level, the mixture flowing through tube **40** will have decreased in weight sufficiently to cause the tube to pivot back up to stop **41** and switch off the toner feed mechanism.

Tube **40** acts as one arm of a balance and is counterweighted either by a mass secured to the other arm, a balancing force system, a balancing torque system, or a combination of these systems. When a counterweight method is used, the counterweight **46** is positioned so that the center of gravity of the balanced system is very close to the same level as the pivot point to attain maximum sensitivity. The center of gravity may also be above the pivot point to achieve a bi-modal balancing effect.

Magnet **47** sets up a field with the reed switch **45** and a certain force is required to move the magnet out of this field. In order to decrease the force required to move the magnet, a bias magnet **48** is installed on reed switch **45**. This enables magnet **47** to switch the reed switch from a greater distance D. Since the magnetic field set up between the switching magnet and the reed is smaller, the force required to move the switching magnet is also smaller. A light and a photocell can also be used to switch the toner feed on and off where the balance interrupts a light beam.

The mouth of funnel **50** at the bottom of the reservoir **51** is smaller than and approximately flush with the entrance to the tube. This is to keep the developer mixture from overflowing the top of the tube. The small funnel exit also somewhat restricts the flow of mixture from the reservoir. This helps to keep a constant head of pressure on the mixture as it flows through the tube. The system will also work if the mixture is allowed to overflow the tube.

A circular exit aperture **53**, FIG. **5**, at the bottom of tube **40** is smaller in size than the diameter of flow tube **40** and allows the mixture to flow through the tube while restricting the flow somewhat so that the mixture will fill up the tube. The size of the exit hole must be small enough to restrict the initial flow of mixture through the tube. As the mixture flows through the tube, it becomes slightly triboelectrically attracted to the tube and tends to cling around the exit hole, thus reducing the effective size of the opening. For a given area of the exit hole, a circular shape provides the largest effective exit hole area as the mixture builds up around the exit hole. Although other exit hole shapes will work, the circular hole is best.

Tube **40** pivots about the point where the mixture is funneled into it. Wires **55–56** comprising portions **55***a*, **55***b*, **56***a* and **56***b*, FIG. **4**, are used to form the pivot because they are not influenced by any toner or carrier which may build up on them, and are practically frictionless. The pivot is made from two wires secured between two tiedowns **60**, **61** in the arrangement shown. Tie down means **60**, **61** comprise separate means positioned a predetermined distance apart to accommodate at least the cross-sectional dimension of flow tube **40**. Tube **40** is interconnected by wires **55**, **56** intermediate the tie down means **60**, **61** in a balanced sensing condition. The optimum angle the two wires make with the tiedowns is 45° in order to produce maximum stability and, with the help of the two wide secure points **63**,**64**, limit the movement of the balance to one degree of freedom.

Tiedowns **60**,**61** function as fine balance adjusters. The pivot wires are secured to the tiedowns a distance *d* apart, FIG. **6**, the central point between the pivot wires where they are attached to the tiedowns serving as a pivot point. As the adjusters are simultaneously rotated in the same direction, a biasing torque is applied to the balancing system. This bias torque may be used to fine-balance the system, and establish a desired tension and balance relationship of the pivot wires **55**,**56** and flow tube **40**.

FIG. **7** illustrates the feature concerning the location of the center of gravity of the balance tube. If the pivot points of the balance tube are located at point A, above the tube, then the tube will tend to see-saw back and forth about the pivot points with greater instability. If, however, the pivot points are located at point B below the tube, then a more positive sensitivity is obtained from the tube in the nature of a bistable action, which is more desirable if the operating system's center of gravity is only slightly above point B.

ALTERNATIVE EMBODIMENT OF FIGS. 8–10

FIGS. **8–10** illustrate modifications in the monitoring system previously discussed.

The wire suspension system described in FIGS. 3–7 is replaced by a pair of conical jeweled bearings **70**, **71** and a pointed balance shaft **73**, FIG. **8**. This provides somewhat better control of the location of the center of gravity of the system.

In FIG. **9**, structure for fine adjustment of the balance includes an adjustable spring **75** which adds a bias torque to the balance shaft **73**, and serving to provide a resilient force on balance shaft **73** that can be varied within limits. This varies the degree of sensitivity of the monitoring means. In an alternate method, FIG. **10**, the torque is varied by adjusting spring **76**. A baffle system including baffle means **80**, **81** is installed inside tube **40***a* and tends to impede the initial flow of carrier mixture, thus lowering the exit velocity of the carrier mixture, and serving to regulate the flow of mixture through the tube. Since:

$$\dot{M}/(V_1A_1)=\dot{M}/(V_2A_2)$$

where

$\dot{M}$ is mass rate of flow (a constant)
V_1 is the velocity of the carrier beads entering the tube
V_2 is the velocity of the carrier beads exiting the tube
A_1 is the entrance area of the tube
A_2 is the exit area of the tube

the exit area can be made larger and clogging problems encountered while sensing irregularly shaped carrier or foreign particles are minimized.

To keep foreign material from jamming the exit hole of tube **40***a*, a screen of vertical slits **84** is installed in the entrance to the funnel that supplies the carrier mixture to the tube. This screen keeps material large enough to jam the tube from entering it. A screen of vertical slits was chosen because a chunk of material tends to flow down these slits into the developer rather than lodging in the screen as it would if a screen of round or square holes were used. This same screening method can be used on other toner sensors.

Some toner may filter up into the return funnel of the structures shown in FIG. **8** from the associated developer mechanisms, not shown. A large build-up of toner between the tube and housing walls, such as the wall shown in FIG. **8** inhibits the required pivot motion. To alleviate this possible problem, a baffle system including baffles **86***a*, **86***b* is installed in the return funnel which returns the mixture to the developer.

In actual use, the structures shown performed well, allowing the toner feed in the toner dispensing means **21** to remain on a maximum of only 25 seconds although, in general, the toner feed was only turned on from 4–6 seconds at a time. This type of operating characteristic is very desirable because it allows the toner concentration to vary a maximum of only about ±0.06 percent.

While the invention has been particularly shown and described with reference to several embodiments, it will be understood by those skilled in the are that various changes in form and detail may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A toner monitoring system for electrophotographic apparatus incorporating a toner dispensing means for replenishing a developer mixture of toner and carrier with toner when required, comprising:

developer means for moving a predetermined quantity of developer mixture to a point of utilization in said apparatus;

monitoring means capable of storing only a sampling portion of said developer mixture, said sampling portion being relatively small in relation to said predetermined quantity of developer mixture for monitoring the density of developer mixture during its movement by comparing developer mixture weight with a reference weight;

and means controlled by said monitoring means for actuating said toner dispensing means to replenish said developer mixture in said developer means in order to maintain a desired proportion of toner and carrier in said mixture.

2. The system of claim **1**, further comprising:

a flow tube incorporated in said monitoring means, said flow tube having an entry portion and an exit portion;

mounting means for mounting said flow tube on said developer means for entry of a said sampling portion of developer mixture into said entry portion from said developer means, movement of said sampling portion through said tube and return of said sampling portion from said exit portion of said tube to said developer means, said mounting means further mounting said flow tube in a balanced condition representative of a desired weight of developer mixture as it flows through said tube, with the relationship being such that said tube moves between first and second conditions representative of higher and lower toner concentrations in said mixture; and

means for sensing the status of said flow tube to control said toner dispensing means.

3. The apparatus of claim **2**, further comprising:

a pair of tie down means comprising separate means positioned a predetermined distance apart to accommodate at least the cross-sectional dimension of said flow tube therebetween; and

pivot wire means interconnecting said flow tube and said tie down means with said flow tube positioned intermediate said pair of tie down means in a balanced sensing condition for monitoring of said sampling portion of developer mixture.

4. The system of claim **3**, further comprising:

sensing means comprising a magnet mounted on said flow tube and a reed switch operated by movement of said magnet to control said toner dispensing means.

5. The apparatus of claim **3**, further comprising:

means for adjusting said tie down means to establish a desired tension and balance relationship of said pivot wires and said flow tube.

6. The system of claim **3**, wherein said:

tie down means mounts said flow tube means above the point of tie down to establish a bistable action of said tube.

7. The system of claim **2**, further comprising:

a balance shaft mounting said flow tube means;

a pair of bearings supporting said shaft to establish a balanced relationship of said flow tube means;

means providing a resilient force on said balance shaft; and

means for varying said resilient force to control the center of balance of said flow tube and thereby the degree of said sensitivity of said monitoring system.

8. The system of claim **7**, further comprising:

baffle means in said flow tube means to regulate the flow of mixture therethrough.

9. The system of claim **7**, further comprising:

a supply funnel connected to the entry portion of said flow tube for guiding developer mixture from said developer means to said flow tube during operation; and

a screen positioned between said developer means and said flow tube for interception of developer mixture particles from said funnel to prevent entry of particles over a predetermined size into said flow tube.

10. The system of claim **7**, further comprising:

a return funnel positioned between the exit portion of said flow tube and said developer means; and

baffle means in said return funnel to regulate flow of developer mixture therethrough.

* * * * *