AUTOMATIC TONER CONCENTRATE DETECTOR AND CONTROL DEVICE

Inventor: Stanley A. Gawron, Arlington Heights, Ill.

Assignee: Addressograph-Multigraph Corporation, Cleveland, Ohio

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Primary Examiner—Michael Sofocleous
Attorney, Agent, or Firm—Sol L. Goldstein; Russell L. Root; Ronald J. LaPorte

ABSTRACT
Apparatus for monitoring and controlling the ratio of toner to carrier particles of a dry developer mix includes an inductive sensing coil positioned in contact with the developer mix. The voltage output of circuitry connected electrically to the sensing coil changes in response to a change in the inductive reactance of the sensing device due to changes in the ratio of toner to iron particles in the mix. A toner dispenser replenishes toner material to the mix in response to a predetermined change in the voltage output of the circuitry.

5 Claims, 2 Drawing Figures
This is a division of application Ser. No. 65,902 filed Aug. 21, 1970, now U.S. Pat. No. 3,707,134.

BACKGROUND OF THE INVENTION

This invention relates generally to apparatus for monitoring and controlling the ratio of toner-to-carrier particles of a developer mix used in electrostatic copying machines for developing copies, and more particularly to apparatus of the above-described type which monitors an electrical property of the developer mix to maintain the ratio of toner-to-carrier particles substantially constant.

Various types of apparatus are known for monitoring and controlling the ratio of toner-to-carrier particles in dry developer mix used in electrostatic copiers. Some of the types of apparatus monitor the developer mix for changes in resistance as toner is depleted in the development of copies, while others use optical sensing devices to measure light reflectance of toner deposited on a probe to determine and control the ratio of toner-to-carrier therein. Still others monitor capacitive changes in a capacitor device placed into the developer mix.

While the above-described type of apparatus function satisfactorily for the most part to maintain the toner-to-carrier ratio in a dry developer mix substantially constant, there are drawbacks which detract from the desirability of using the apparatus. For instance, the various apparatus described tend to be complex and require frequent inspection so as to be maintained in working order. Some of the heretofore known types of monitoring apparatus function best in developer mixes wherein the ratio of toner-to-carrier particles is in a restricted range.

SUMMARY OF THE INVENTION

Accordingly, it is a primary object of the present invention to provide new and improved apparatus for monitoring and controlling the ratio of toner-to-carrier particles in a dry developer mix used for developing copies in an electrostatic copying machine.

It is another object of the present invention to provide apparatus of the last-described type which is simple in construction, efficient in operation and can be used satisfactorily in dry developer mixes of various ratios of toner-to-carrier.

It is still another object of the present invention to provide an improved method of developing electrostatic images by monitoring and controlling the ratio of toner-to-carrier particles.

Briefly, a preferred embodiment of the apparatus for monitoring and controlling the ratio of toner-to-carrier particles of a dry electrostatic developer mix comprises an inductive sensing coil having an iron core. The coil is placed in the surroundings of the developer apparatus of an electrostatic copying machine so as to be in contact with the dry developer mixture containing toner and magnetizable carrier particles. The inductive reactance of the coil is a function of the amount of magnetizable particles per toner particles in the mix. Thus, as the toner is depleted, the inductance of the coil changes. The frequency of an oscillator circuit connected to the coil changes as the inductance of the coil is varied. The change in frequency produces a corresponding output of additional circuitry which in turn operates a toner dispenser unit, causing toner to be added to the mix to restore the toner-to-carrier ratio to a predetermined level.

DESCRIPTION OF THE DRAWINGS

A better understanding of the present invention and its organization and construction may be had by referring to the description below in conjunction with the accompanying drawings. Wherein:

FIG. 1 is a schematic diagram of a preferred embodiment of the circuitry used in the monitoring and controlling apparatus of the invention; and

FIG. 2 is a side sectional view of a magnetic brush type developer arrangement employing the inductive monitoring and controlling apparatus.

DETAILED DESCRIPTION

Referring now to the drawings in greater detail, FIG. 1 thereof illustrates a preferred embodiment of the apparatus according to the invention for monitoring and controlling the ratio of toner-to-carrier particles of a dry electrostatic developer mixture including a schematic representation of the control circuitry 10 and inductive sensing means 12 employed therein.

The control circuit 10 comprises several stages connected in tandem and shown enclosed in dotted lines. A first Variable Frequency Oscillator stage (VFO) 14 is connected to an Amplifier and Discriminator stage 16, which in turn is connected to a Buffer stage 18. Outputs 20, 22 of the last-mentioned Buffer stage 18 are connected to interconnected switching networks 24, 26, respectively, which in turn operate a toner replenisher drive 28 and an out-of-toner indicator arrangement 30, respectively. A voltage regulating circuit portion 32 connected to the Buffer stage 18 serves to stabilize the control circuit and compensates for voltage variations in the input voltage.

A more detailed description of the control circuit 10 including its various stages will now be presented.

Power to the control circuit is provided at input electrode 34. The positive potential side of a 26 volt DC power supply (now shown) is connected thereto to power the circuit 10. A ground connection is made at ground point 36.

The VFO stage 14 consists essentially of a standard Colpitts Oscillator circuit including a transistor 38 connected in an emitter follower configuration. Input voltage to the transistor 38 is provided through resistors 41, 43 connected to the base electrode 45 of transistor 38. The collector electrode 40 of the transistor is connected through a "tank" circuit including a tuneable inductor 42 and capacitors 44, 46. The capacitors are connected via lead 48 to one side of the inductive sensing means 12 and the tuneable inductor 42 is connected via lead 50 to the other side of the sensing means 12. The last-mentioned sensing means comprises an inductive sensing coil 13 preferably having an iron core. A preferred embodiment of the sensing coil will be discussed when referring to FIG. 2 wherein such a coil is illustrated.

The primary frequency determining portion of the VFO stage 14 is the "tank" circuit arrangement including capacitors 44, 46 and tuneable inductor 42. In practice the inductor 42 can be adjusted to permit a matching of the oscillator circuit 14 to the sensor coil 13 which thereafter is placed into the environment of a de-
developed mix including a predetermined ratio of toner and magnetizable particles, such as iron. A voltage divider network 52 comprising resistors 54, 56 is connected via capacitor 62 to the base electrode 64 of a transistor 60 connected as a common emitter amplifier portion of the adjoining Amplifier and Discriminator stage 16 of the control circuit according to the invention. The transistor amplifier 60 is connected in the usual common emitter configuration. The base electrode 64 of the amplifier configuration is connected through a first resistor 68 to the positive potential lead 70 and through a second resistor 72 to ground lead 74, and at its emitter 76 through a parallel connected resistor 78 and capacitor 80 to ground lead 74. Connected at the collector electrode of transistor 60 is a tuned network 84, comprising a capacitor 86 and coil 88, the latter of which serves as the primary winding of a transformer 90. The network in practice is tuned to a normal operating frequency of about 15 KH.

The primary winding 88 is loosely coupled inductively through a pair of secondary windings 92, 94 of the Discriminator portion of stage 16. Capacitors 96, 98, connected in parallel configuration with respective secondary windings comprise "tank" circuits 100, 102, tuned to frequencies of approximately 16 KH and 14 KH, respectively.

The diode and capacitor combinations 104, 106, and 108, 110, connected to the respective "tank" circuits 100, 102, rectify and filter the outputs, respectively, taken across respective capacitors 96, 98. Resistors 105, 107 are connected in parallel with "tank" circuits 100, 102, respectively.

In a normal situation, prior to placing the sensing coil 13 in the toner-carrier mixture, the outputs across the respective capacitors 106, 110, are equal but opposite in polarity and cancel out. Consequently, the output of the Discriminator circuitry is zero.

Upon placing the coil 13 into the environment of the toner-carrier mixture, the frequency of the oscillator circuit decreases due to the magnetizable character of the carrier particles in the mix. As the frequency decreases, the coupling of the primary winding 88 to the secondary windings 92, 94, causes a greater coupling with the 14 KH secondary "tank" circuit since the oscillator frequency drops from its original 15 KH setting, and a lesser coupling with the secondary winding "tank" circuit. Since the positive charge on the capacitor 106 is greater than the opposing negative charge on capacitor 110, the output of the Discriminator circuitry is positive and of a magnitude that depends upon the relationship of the frequency of the VFO stage to the 14 KH frequency of the "tank" circuit 100.

A thermometer device 112 is connected in parallel across capacitor 110 to provide stability to the circuit regardless of temperature changes. The thermometer compensates for temperature variations essentially between 40° to 160° F.

Connected to the output leads 114, 116 of the Amplifier - Discriminator stage 16 is a Field Effect Transistor 118. A Zener diode 120 connected in series with a resistor 122, is connected across the output of the Amplifier - Discriminator stage at leads 118, 116, to protect the voltage follower transistor by limiting the voltage supplied to the latter.

A resistor-capacitor combination 124, 126, connected to the gate electrode 128 of the Field Effect Transistor 118 serves as a Time Delay Network 130, to delay the voltage output impressed on the transistor 118, thereby to prevent the latter transistor from being subjected to instantaneous changes in the voltage caused by frequency changes detected by coil 13. In this manner, a relatively smooth change in voltage is impressed on the transistor 118.

The Field Effect Transistor 118 or Darlington transistor as it is sometimes called, is connected in an emitter follower configuration with the "drain" electrode 132 connected to the positive DC voltage lead 70 and the "source" electrode connected through a pair of series connected resistors 136, 138, across which outputs to the Switching Networks 24, 26, to be described, are taken at leads 20, 22, respectively.

The Field Effect Transistor 118 acting as an emitter follower avoids further amplification of the output from the Amplifier - Discriminator stage 16 and converts the high output impedance into a low output impedance, high power signal which can be used to operate the Switching Networks 24, 26.

As mentioned heretofore, Voltage Regulator circuit 32 stabilizes any voltage variations occurring in the DC voltage source. The Voltage Regulator 32 includes resistor 140 connected to the positive potential electrode 35 and in series with a parallel connected Zener diode 142 and capacitor 144. The regulator circuitry maintains the voltage at approximately 22 volts DC.

Referring now to Switching Network 24, there is included therein a conventional solid state switching arrangement comprising first and second transistors 146, 148. The voltage from output 20 is impressed at the base electrode 150 of transistor 146. A resistor 152 is interposed between the base electrode and output 20 of the Buffer stage 18 of the control circuit. Base electrode 150 is also connected to a capacitor 157, in turn connected to ground at 36. The emitter 147 of transistor 146 is connected via Zener diode 154 to ground 36. The collector 155 is connected to a pair of current limiting resistors 156, 158, and to the base 160 of transistor 148. The Zener diode 154 establishes the operating voltage for the transistor 146. The voltage at the base of transistor 146 must exceed the Zener break down voltage of diode 154 plus the voltage drop across the emitter 147 before transistor 146 will conduct. In practice the break down voltage of diode 154 is approximately 9.1 volts and the voltage drop across the emitter 147 is approximately 0.5 volts.

The emitter of transistor 148 is connected to the positive potential lead 165, connected itself to the positive electrode 34 of the DC power supply (not shown). The collector 164 of transistor 148 is connected to an electric clutch 166 of toner replenisher drive 28 which drives an auger (FIG. 2) in a toner dispenser reservoir (FIG. 2) for the purpose of dispensing toner to the developer unit containing developer mix. A resistor 169 is connected between the base 150 of transistor 146 and the collector electrode 164 of transistor 148. A Zener diode 168 is connected in parallel relation with the clutch 166 to prevent damage to transistor 148 upon the cessation of operation of clutch 166 after sufficient toner is replenished in the developer mix.

The voltage output taken across resistor 138 at output 22 is impressed on Switching Network 26 at 22. Switching Network 26 also includes a pair of transistors 170, 172. The emitter 174 of transistor 170 is connected via lead 175 to emitter 147 of transistor 146 of Network 24 and to diode 154, and the base electrode...
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176 of transistor is connected through a capacitor 178 to lead 180 connected to the opposite side of diode 154. The collector 182 of transistor 170 is connected through a pair of current limiting, series connected resistors 184, 186, to the positive potential lead 165.

Base electrode 188 of transistor 172 is connected between resistors 186, 184. The emitter electrode 190 of the last-mentioned transistor is connected to the positive potential lead 165, and the collector 192 of transistor 172 is connected through a resistor 194 of a pair of resistors 194, 196, to which base 176 of transistor 170 is also connected. The resistor 196 is in turn connected to the output 22 of Buffer stage 18.

A toner-out indicator lamp 198 is connected via lead 200 to the collector 192 of transistor 172, and a fault signal producing circuit arrangement 30, comprising series resistors 202, 204, is connected to collector 192 for producing a signal over lead 206 to interrupt the operation of the copying machine in which the apparatus is used.

A resistor 208 connected between the switching networks 24, 26, in parallel relation thereto at lead 165, 175, establishes a common reference voltage for both Networks. Zener diode 154 is used for both networks, and transistor 170 will also not operate until the voltage at input 22 at the base 176 of transistor 170 exceeds the breakdown voltage of the Zener diode 154 plus the voltage drop across emitter 174. This will be explained in greater detail when the operation of the apparatus, including control circuit 10 is described.

Turning now to FIG. 2 of the drawings, there is illustrated therein a sectional view of a developer unit 210 of the type shown in copending patent application, Ser. No. 9316, filed Feb. 6, 1970, now U.S. Pat. No. 3,626,898, used in a high speed electrostatic copier.

The developer unit 210 comprises a hollow cylinder or drum 212 rotatably mounted on a fixed shaft 214, and suitably supported on the shaft by bearing members 216.

Affixed to the shaft 214 is a magnetic flux generating assembly 218 including an array of permanent magnets, such as 220, disposed within the cylinder 212 for magnetically arranging the outer surface of the cylinder. A developer 221 is provided with aperations of the mix. The magnets, while being of sufficient Gauss strength to attract developer mix, are not sufficiently strong to attract developer mix to the coil end 237. If the latter occurs, a failure indication of the ratio of toner to carrier particles of the mixture is provided.

An iron core coil arrangement is preferred for use as a sensing means since the iron core provides a greater sensitivity to change in the inductance of the coil due to the outside influence of the mix. An air core coil does not provide as great a sensitivity for efficient appraisal of the iron-to-toner ratio in a dry developer mix. For purposes of affording a more complete understanding of the invention, it is advantageous to provide a functional description of the mode in which the component parts thus far described cooperate.

As described heretofore, upon placing the sensing means 12 (coil 13) in the vicinity of the dry mixture comprising toner and iron particles in a predetermined ratio, a positive output voltage is produced at 20 and 22 of Buffer Stage 18. The output voltages, however, are normally less than required to cause the conduction of transistors 146, 170.

As copy material passes through the developer unit for development, toner is applied thereto and removed from the mixture, changing the ratio of toner to carrier particles of the latter.

As the ratio of toner-to-iron particles changes, leaving a greater amount of iron in the mix per toner particle, the inductance of coil 13 changes to in turn vary the frequency of the Variable Frequency Oscillator Stage 14. The frequency change is amplified and produces a decreased frequency in the primary winding "tank" circuit 84. The inductive coupling of the secondary winding is increased and hence greater voltage outputs at 20, 22 are realized. The output voltage at 20, however, is approximately 2 volts greater than that at 22.

When the voltage at point 20, which is fed into the base of transistor 146 of Switching Network 24,
reaches a predetermined value, i.e., the Zener breakdown voltage of diode 154 (9.1 volts) plus the voltage drop of approximately 0.5 volts across the emitter 147 of the transistor, transistor 146 is rendered conductive or is turned on. The conduction of transistor 146 causes transistor 148 to conduct also. The last-mentioned transistor in turn operates electric clutch 166.

In the case of the developer unit illustrated in FIG. 2, when the clutch 166 is operated, auger 234 is rotated to dispense toner from hopper 230 into the vicinity of the rotating cylinder 212, thereby to reinstate the predetermined ratio of toner-to-ion particles of the mix.

Upon replenishing sufficient toner material to the mix, the inductance of the sensing coil 13 changes to a value, whereat the output voltage at point 20 falls below the 9.6 volts required to operate transistor 146, and the operation of clutch 166 is discontinued.

In the event the supply of toner in the replenishing hopper 230 is depleted so that no toner is added to the mix, the clutch 166 continues to turn the auger 234. Within a short time, however, the inductance of the sensing coil 13 has changed to such a degree that the voltage taken at point 22, which as mentioned heretofore, is approximately 2 volts less than that taken at point 20, reaches the predetermined voltage value, i.e., 9.6 volts, and transistor 170 of Switching Network 26 conducts, causing transistor 172 to conduct also.

The operation of transistor 172 lights lamp 198, indicating to the operator of the copying machine in which the developer unit is housed, that the toner replenisher hopper is depleted of toner. In addition, a signal at lead 206 is provided which may be used to interrupt the operation of the copying machine itself until toner is replenished in the hopper.

Upon replenishment of toner in hopper 230 which dispenses it into the developer mix in the trough, Switching Network 26 shortly ceases to operate and lamp 198 is turned off. Any interruption to copying machine operation is likewise withdrawn. Switching Network 24, however, remains operable until sufficient toner is replenished in the developer unit to restore the mix concentration to normal rating. When the predetermined ratio of toner-to-ion particles is reinstated, the last-mentioned Switching Network 24 also is rendered inoperative until a further change in toner-to-ion particle concentration is detected.

The use of the toner-to-carrier ratio monitoring and controlling apparatus of the invention insures that copies made in an electrostatic copier in which the apparatus is used, will be of uniform density and contrast and of high quality. The apparatus of the invention is especially useful in new high speed electrostatic copying machines in which toner is depleted rapidly and in great quantities. The apparatus is designed to provide fast replenishment of toner to maintain easily the ratio of toner-to-carrier particles in the mix substantially constant regardless of the speed in which toner is removed from the mix.

While a particular embodiment of the invention has been shown and described, it should be understood that the invention is not limited thereto since many modifications may be made. It is therefore contemplated to cover by the present application any and all such modifications as fall within the true spirit and scope of the appended claims.

What is claimed is:

1. The method of automatically maintaining a developer mix comprising toner particles and magnetic carrier particles in a weight ratio representative of an optimum performing developer mix for developing high quality electrostatic images comprising the steps of:
   a) moving the developer mix along a path from a supply chamber onto the surface of a rotating magnetic brush cylinder and back to the supply chamber,
   b) contacting said developer mix with a sensing device, at a point where it is forming the brush on the surface of the cylinder, said sensing device forming part of an electric circuit and exhibiting to the circuit an inductance responsive to changes in the weight ratio of said toner to said carrier,
   c) detecting said changes in inductance, and
   d) when the sensed inductance increases above a predetermined value, dispensing toner powder from a toner dispensing unit into said supply chamber and mixing the same with said developer mix until the reading of inductance given by said sensor is restored to said predetermined value.

2. The method as set forth in claim 1 which includes the step of attracting the developer mix towards the sensing device by a magnetic force sufficient to provide a substantially predetermined contact with the sensing device without causing adherence thereto.

3. The method as set forth in claim 2 which includes providing guidance for the brush surface so as to obviate any tendency of the developer mix to accumulate adjacent the sensing device.

4. The method as set forth in claim 1 which includes providing guidance for the brush surface so as to obviate any tendency of the developer mix to accumulate adjacent the sensing device.

5. The method of automatically maintaining a developer mix comprising toner particles and magnetic carrier particles in a weight ratio representative of an optimum performing developer mix for developing high quality electrostatic images comprising the steps of:
   a) moving the developer mix along a path from a supply chamber onto the surface of a rotating magnetic brush cylinder and back to the supply chamber,
   b) at some point in said path, so manipulating the developer mix as to place it in a predetermined readily repeatable degree of compaction,
   c) at said point contacting said developer mix with a sensing device which forms part of an electric circuit and exhibiting to the circuit an inductance responsive to changes in the weight ratio of said toner to said carrier,
   d) detecting said changes in inductance, and
   e) when the sensed inductance value increases above a predetermined value, dispensing toner powder from a toner dispensing unit into said supply chamber and mixing the same with said developer mix until the reading of inductance given by said sensor is restored to said predetermined value.

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