In a copying machine employing two conductive rollers to which zinc oxide coated copy paper is fed, the power source provides a DC voltage between the rollers that is derived from a frequency (of 25 kilocycles, for example) which is relatively high compared to line frequency. The relatively high frequency ripple that is on the DC output eliminates much of the problem with discernible lines on the end product. One of the two rollers has a rubber sleeve which is selected to provide a low capacitance such as 75 microfarads. The resistance of the sleeve is such that a current flow of 50 microamperes is obtained with a 3,000 volt potential between the two rollers. The low capacitance means that when a sheet of copy paper is fed between the rollers, the change in the potential across the rubber sleeve and the change in current flow will occur very rapidly so that an even charge is applied on the copy paper. Because of the relatively high frequency employed, the ripple factor is kept low and the voltage magnitude applied is kept down to a point where the amount of ozone generated is minimized.

17 Claims, 7 Drawing Figures
3,778,690

ELECTROSTATIC COPYING MACHINE

BACKGROUND AND OBJECT OF THE INVENTION

This invention relates in general to electrostatic copying machines and more particularly to an improvement in the manner in which an electric charge is placed on the copy paper.

Most commonly employed techniques of applying an electrostatic charge on zinc oxide coated copy paper in electrostatic office copying machines is through the use of what is called a corona. This corona is essentially two sets of spaced apart parallel wires across which 15,000 volts are applied. The paper is passed between the two sets of wires and a discharge across the gap between the two sets of wires carries an electric charge that is picked up in part by the paper. The discharge is of a sort that is known as a corona discharge. Thus, this part of the equipment has been termed the corona.

Among the disadvantages of the corona are the generation of appreciable amounts of ozone; the high voltages required; the high power required; the variability of charge applied as a function of ambient conditions and in particular as a function of humidity; and the substantial amount of servicing required for the corona. For all of these reasons and further in order to provide a smaller, lighter and less expensive office copying machine, it has been proposed to substitute for the corona two conductive rollers, one of which has an insulating sleeve on it. These rollers are in contact with one another and copy paper is fed through the rollers. A voltage between the two rollers results in a small current flow across the high resistance sleeve, thereby applying an electrostatic charge to the paper passed between the rollers. U.S. Pat. No. 2,980,834 issued in April of 1961 to Tregay and U.S. Pat. No. 3,521,126 issued in July of 1970 to Granzow et al both illustrate this two-roller type of design. Although the basic two-roller design has been known for over a decade, it has not achieved any widespread application because this design, although it solves many of the problems of the corona design, has certain problems of its own.

For example, the two roller design has required a sufficiently high voltage that some ozone is generated. Although the rate of ozone generation may be considerably less than when a corona is employed, it is sufficient to deteriorate the high resistance, rubber-type sleeve employed on one of the two rollers. Furthermore, the even and repeatable application of a charge across the entire sheet of copy paper is a problem when a two-roller design is employed particularly when relatively high copy paper feeding speeds are employed.

Accordingly, it is a purpose of this invention to provide an improved two-roller design from which superior performance will be obtained, and by which improvements will be achieved in the areas of cost, weight, evenness with which charge is applied, repeatability of charge application and limiting of ozone generation. More particularly, it is a purpose of this invention to provide a design in which lower voltages and lower currents are required and in which a much more efficient use of the power supply is effected.

It is an important purpose of this invention to obtain these particular results while at the same time providing a technique for applying a charge to copy paper whereby the results will be repeatable from sheet to sheet and the result will be uniform so far as density and contrast are concerned.

BRIEF DESCRIPTION OF THE INVENTION

In brief, this invention is an improvement in a two-roller type of copier. The dielectric sleeve on one of the two rollers is selected to have a capacitance and resistance that will provide a sufficiently low time constant that when paper is introduced between the rollers, the change in the voltage distribution across the dielectric sleeve will occur quickly and will thus avoid a gradually varying magnitude of charge laid down on the copy paper. Yet, the resistance of the sleeve is high enough that a very low level of DC current is provided. The DC power supply has a high frequency ripple that permits easy filtering so that the amplitude of the ripple can be kept at a low level. The frequency of the ripple is sufficiently high that a series of discernable lines in the end product, that are a result of a varying level of charge laid down on the copy paper, are avoided.

Pressure adjustment between the rollers together with proper selection of the material for the dielectric sleeve on one of the rollers in the context of a high frequency, low level ripple on the output of the DC power supply makes possible a long life copying machine with minimum sleeve degradation that provides a uniform and repeatable product at a reasonably high rate of speed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective, fragmentary view, illustrating copy paper feeding through two rollers, one of which is provided with a rubber sleeve.

FIG. 2 is an elevation view of one embodiment of this invention.

FIG. 3 is a left side view of FIG. 2.

FIG. 4 is a right side view of FIG. 2.

FIG. 5 is a longitudinal cross sectional view of FIG. 2.

FIG. 6 is a schematic representation of the invention.

FIG. 7 is an electrical schematic of the power supply.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The drawings all relate to the same embodiment. Basically, this invention involves, as shown in FIG. 1, passing copy paper 10 between two rollers 12, 14. The machine can be designed to employ either sheet or roll fed copy paper. The rollers 12 and 14 are electrically conductive, preferably made of metal. The roller 14 is surrounded by a high resistivity di-electric sleeve 16 which in one embodiment is a one-sixteenth inch thick, 10 inch long, rubber sheet. Two springs 18 bias the two rollers 12, 14 toward one another so that when in operation, the sheet 10 is in physical contact with the periphery of the roller 12 and the sleeve 16.

A DC power supply 20 provides a positive voltage to the roller 12 and a negative voltage to the roller 14. For convenience, safety and to maintain minimum charge on the paper 10, the roller 12 is preferably held at zero potential and the roller 14 has a negative potential. What counts is that the rollers 12, 14 have a DC potential between them. As a consequence when copy paper is passed between the rollers, a small leakage current flows between the two rollers through the high resistance rubber sleeve 16.
In one embodiment with the DC power supply providing a voltage of approximately 3,000 volts, the amount of current flow is in the range of 50 microamperes. In that embodiment, the paper 10 is a standard zinc oxide coated copy paper in which the coated surface 10c is in contact with the rubber sleeve 16 of the negative roller 14. In that embodiment, the rubber sleeve is Buna N with a thickness of approximately one-sixteenth of an inch and provides a very high resistance and a low capacitance between the roller 12 and the roller 14. The resulting 50 microamperes leakage current provides an adequate electron supply to negatively charge the coated surface 10c of the copy paper 10. Thus, as contrasted with the use of a corona, this invention not only substantially reduces the voltage level required but also greatly reduces the amount of current required.

The embodiment illustrated in the Figures, with reference to an actual reduction to practice of the present invention, shows a 3/8 inch diameter metal roller 12 and a 10/16th inch diameter metal roller 14, both mounted for rotational movement about their respective axes in bearings 21a, 21b, respectively. The bearings 21a are directly mounted in electrical insulating end plates 22R, 22L which in turn are connected to supporting framework (not shown). The bearings 21b, which support the lower roller 14, float in the end plates 22R, 22L and are supported by the springs 18. The ends of each spring 18 are connected to respective projections 22p of the end plates 22L, 22R. Thus, the springs 18 hold the roller 14 and tend to cause the rubber sleeve 16 to bear against the roller 12.

A gear 26 on a shaft extension 28 of the upper roller 12 provides coupling to a mechanical drive mechanism (not shown) so that the roller 12 can be rotated. Because of the frictional contact, due to the rubber sleeve 16 and copy paper 10, rotation of the roller 12 will result in rotation of the sleeve 16 and thus rotation of the roller 14. Thus it may be seen that the rubber sleeve 16 provides not only the electrical function of limiting the current flow between rollers 12 and 14, but also traction that aids in pulling the copy paper 10 between the two rollers 12, 14. This rubber sleeve 16 also provides a cushioning contact against the coated surface 10c of the paper 10 to avoid damage to the coating.

The DC power supply 20 has its positive terminal connected through a lead 30 and terminal 32 to the right bushing 21a which is in contact with the upper roller. Similarly, the negative terminal of the DC power supply 20 is connected through lead 34 and contact 36 to the right bushing 21a, which bushing is in contact with the lower metal roller 14.

Certain features of the embodiment illustrated are preferred relationships in order to provide an optimum result. For example, it is important that the coated surface 10c of the copy paper 10 face toward the negative roller 14 so that the coated surface will receive an electron or negative charge. This is the polarity of the charge that is required in order to operate properly with the standard copying machines for which this invention is an improvement.

Furthermore, it is desirable that the roller with which the copy paper 10 is in direct contact (that is, the roller 12) electrically floats relative to the chassis so that the copy paper 10 will not become so charged relative to the chassis as to be difficult to handle. With the known copiers, this background voltage level for the copy paper 10 will mean a minimum background shading of the copy paper 10 when it is inked.

FIG. 6 is a schematic representation of how the invention operates and provides an explanation of some of the more significant operating aspects of the invention that result in the objectives stated above.

The power supply 20 provides 3,000 volts which is applied to the inner surface of the dielectric sleeve 16. The dielectric sleeve 16 presents a resistive parameter R and a capacitive parameter C to the circuit. The outer part of the dielectric sleeve is in direct contact with the coated upper surface 10c of the paper 10. The lower surface 10b of the paper 10 is in direct electrical contact, through the roller 12, with the other side of the power supply 20. Preferably, the power supply 20 and roller 12, 14 combination is electrically substantially isolated from the rest of the chassis.

The capacitive and resistive parameters of the sleeve 16 are represented as a resistor R and capacitor C in parallel between the negative terminal of the power supply 20 and the upper surface 10c of the paper 10. Assuming an ideal DC power supply 20 (and thus no ripple) there will be a current flow to and from the two surfaces of the paper 10 in much the same fashion as there is when the plates of a battery are being charged from a power supply. The DC current will flow through the resistor R from the top surface 10c to charge the top surface 10c negative and will flow to the lower surface 10b from the power supply 20 to charge the lower surface 10b positive. As the copy paper 10 is moved, as to the right, the portion of the surfaces 10c and 10b in contact with the dielectric sleeve and lower roller, respectively, continuously changes and new charge is laid down on the paper so that there is a continuous current flow.

In one embodiment, the DC current flow is 50 microamperes and the voltage at the positive surface of the paper 10 is approximately 500 volts. Thus there is a 2,500 volt drop across the sleeve 16 and the resistance of the sleeve 16 is 50 megohms.

When the paper 10 is not between the rollers, the capacitor C becomes effectively charged to a voltage level of 3,000 volts. When a sheet of copy paper 10 is introduced between the rollers, that sheet of paper is equivalent to applying another capacitor in series with the capacitance C. As a result, the charge and thus the voltage drop is divided between the capacitance C and the effective capacitance of the paper 10. The transient conditions that will exist until a stable charging condition is obtained will produce a non-uniform charge on the paper 14. Thus it is important that the value of the capacitance C be as low as possible so that it can discharge from 3,000 volts across the sleeve to 2,500 volts across the sleeve as rapidly as possible. Because the sleeve in one embodiment has a 75 micro-microfarad capacitance parameter, this discharge occurs very rapidly and permits rapid movement of the paper through the rollers while applying a uniform charge on the paper. A linear speed of 275 inches per minute is employed in this embodiment.

In one embodiment the rubber sleeve 16 is molded onto the roller 14 from a butadiene acrylonitrile rubber, commonly known as Buna N, a material which may be purchased from the Dyco Rubber Company of Belleville, N.J. However, a number of materials can be employed as long as they provide the required resistive and capacitive properties. It is preferred that the sleeve...
be resilient so that a surface rather than a line contact between rollers is established and so that the tension of the spring 18 can be adjusted to obtain the amount of area contact which will provide the required current flow. In addition, a resilient sleeve 16 has the advantage of providing traction to assure proper feed through of the copy paper 10.

The DC power supply 20 is preferably variable to some extent so that once a machine has been set up and adjusted, the voltage can be varied to adjust the current flow and thus adjust the charge on the copy paper 10 to affect the intensity of the image.

The sleeve 16 resistance is preferably in order of magnitude greater than the copy paper 10 used so that most of the voltage drop is across the sleeve 16 and it is the resistance of the sleeve 16 that primarily controls charging current magnitude.

Power Supply (FIG. 7)

The nature of the power supply 20 is an important factor in the proper operation of this invention. FIG. 7 illustrates one embodiment of a power supply that constitutes part of this invention. Briefly, FIG. 7 power supply converts a 50 or 60 Hz, 110 volt AC line input to a 3,000 volt DC output that has a relatively low level of ripple (2 percent) at a relatively high frequency (25KHz.). Furthermore, the FIG. 7 design for a power supply provides an impedance output (specifically, sufficiently low capacitance) from power supply to the roller system so that meaningful efficiency is obtained.

The 100 ohm variable resistor R1 is a dropping resistor that provides the ability to manually adjust the output voltage level. The diode D1, resistor R2 and capacitor C1 constitute a rectifying circuit. The capacitor C2 and small inductor L1 tune the primary P1 of the transformer T1 to 25 KHz. Similarly, the capacitor C3 is selected to tune the secondary of the transformer T1 to 25 KHz. The capacitor C2, inductor L1 and transformer primary P1 constitute the tank circuit for the transistor Q1, thereby providing an oscillator at 25KHz. A few turns of primary winding P2 are connected to the base of transistor Q1 to provide regenerative feedback. The number of turns of this feedback coil P2 are selected as a trade-off between degree of regulation and magnitude of DC output.

The diode bridge 40 provides full wave rectification of the 25,000 Hz output of the step-up transformer T1. Because of the high impedance of the load consisting of the sleeve 16 and paper 10 between the two rollers, efficient operation of this power supply 20 requires that the output impedance of this bridge must also be high. Accordingly, diodes were selected that have a 4,000 peak inverse voltage rating; and thus a peak inverse voltage rating above that of the DC output voltage. Furthermore, in order to provide an efficient impedance match, it is important that the capacitance of the diodes be small as possible. However, a small capacitor C5 of about 5,000 micro-microfarads is employed in order to reduce the magnitude of the ripple.

One of the important aspects of this FIG. 7 power supply design is that its design arises out of a recognition that the capacitance as well as the resistance of the dielectric sleeve must be considered in designing an efficient, fast operating copying device.

Among the major problems that are faced in the design of an efficient, fast operating copying device is that the occurrence of AC ripple in the DC power supply output causes such a variation in the instantaneous voltage applied that an uneven charge is applied so that the resultant product has a series of alternating darker and lighter lines laid out over the actual information that is copied. This undesirable effect can be eliminated by so filtering the power supply output that there is no ripple. However, such an approach is uneconomical in that it requires larger current levels in the power supply. In part in order to overcome the effect of the ripple, and in particular to overcome the cancellation of the DC by the AC ripple at its negative peak, there is a tendency to increase the voltage output of the power supply which again is uneconomic and inefficient and further tends to produce excessive ozone because of the high voltage levels required.

In order to provide a design in which minimum current and voltage levels are required, the device of this invention provides a very substantial increase in the frequency of the signal that is rectified to produce the DC output. Accordingly, as shown in FIG. 7, a 25 KHz input is applied to the rectifier 40 so that the ripple output is at a high frequency. This high frequency alone means that the lines mentioned above that are created in the copy paper tend to be much more closely spaced and thus that the copy paper can be run through more quickly than otherwise might be the case. Perhaps more importantly, this high (25 KHz) frequency makes it much easier to filter the output so that the magnitude of the ripple is very substantially reduced. In one embodiment, this ripple is as low as 2 per-cent of the DC level.

FIG. 7 does not show a ground connection in the power supply. This is on purpose, since the device of this invention makes possible isolating the power supply output from the chassis of the copying machine. As a consequence of so isolating the power supply, the potential charge between paper and chassis is minimized and the electrostatic charge that causes the paper to hang up in the machine and makes the paper more difficult to handle is minimum. This advantage is made possible only because of the very low current level required by the device of this invention. Since the power supply's output current capacity is in the range of 50 to 100 microamperes, physical contact by a user with the roller having the sleeve 16 is in effect a contact through a very high impedance. The resultant voltage drop and current level in the body of the person making such contact is completely harmless.

Although one specific embodiment has been described, there is a preferred range of values over which many of the parameters mentioned may vary. The preferred ripple frequency range is from 10 KHz to 100 KHz. The preferred power supply output voltage range is from 1,500 volts to 4,000 volts. The preferred range of sleeve 16 capacitance is from 25 micro-microfarads to 150 micro-microfarads. A preferred RC time constant for the LED 16 in use is less than 5 milli-seconds. A preferred current level is one that is less than 60 microamperes.

Protection by Letters Patent of this invention in all its aspects as the same are set forth in the appended claims is sought to the broadest extent that the prior art allows.

What is claimed is:
1. In a two-roller mechanism for applying a charge to coated copy paper wherein the copy paper passes between a first conductive roller and a second conductive
roller having a di-electric sleeve thereon, the improvement comprising,
pressure means to apply pressure between said first roller and said sleeve,
the material of said sleeve being such that substantial area contact is established between said sleeve and whatever paper is fed between said sleeve and said first roller under said pressure established by said pressure means,
said area of contact being sufficiently great to provide a current path that substantially eliminates the generation of ozone,
the capacitance and resistance of said sleeve when positioned between the rollers and when subject to said pressure providing an electrical time constant sufficiently short in duration that the introduction of copy paper between the rollers results in a sufficiently rapid adjustment of the voltage division between the sleeve and the copy paper that the charge density in the leading portion of the copy paper is substantially equal in magnitude to the charge density in the trailing portion of the copy paper,
said sleeve being mounted on said second roller such that said second roller applies a uniform potential at any one moment to the surface of said sleeve in contact with said second roller.

2. The improvement of claim 1 wherein said time constant is no greater than 5 milli-seconds.

3. The improvement of claim 1 wherein said resistance of said di-electric sleeve is great enough to limit the DC current level between said rollers to no more than 60 microamperes.

4. The improvement of claim 2 wherein said resistance of said di-electric sleeve is great enough to limit the DC current level between said rollers to no more than 60 microamperes.

5. The improvement of claim 1 wherein the material of said sleeve is a butadiene-acrylonitrile.

6. The improvement of claim 2 wherein the material of said sleeve is a butadiene-acrylonitrile.

7. The improvement of claim 3 wherein the material of said sleeve is a butadiene-acrylonitrile.

8. The improvement of claim 4 wherein the material of said sleeve is a butadiene-acrylonitrile.

9. The improvement of claim 1 further comprising: a DC power supply having its output across the rollers and having a relatively high frequency ripple current on its DC output, the relationship between
a. the output capacity of said power supply,
b. the capacity of the di-electric sleeve when subject to said pressure and
c. the amplitude and frequency of the ripple providing a substantially even charge density along the surface of copy paper introduced between the rollers.

10. The improvement of claim 9 wherein the frequency of said ripple current is at least 10 kilohertz.

11. The improvement of claim 10 wherein the magnitude of the ripple is less than 5 percent of the DC voltage level.

12. The improvement of claim 9 wherein said time constant is no greater than 5 milli-seconds.

13. The improvement of claim 12 wherein said resistance of said di-electric sleeve is great enough to limit the DC current level between said rollers to no more than 60 microamperes.

14. The improvement of claim 13 wherein the frequency of said ripple current is at least 10 kilohertz.

15. The improvement of claim 14 wherein the magnitude of the ripple is less than 5 percent of the DC voltage level.

16. The improvement of claim 13 wherein the material of said sleeve is a butadiene-acrylonitrile.

17. The improvement of claim 15 wherein the material of said sleeve is a butadiene-acrylonitrile.

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