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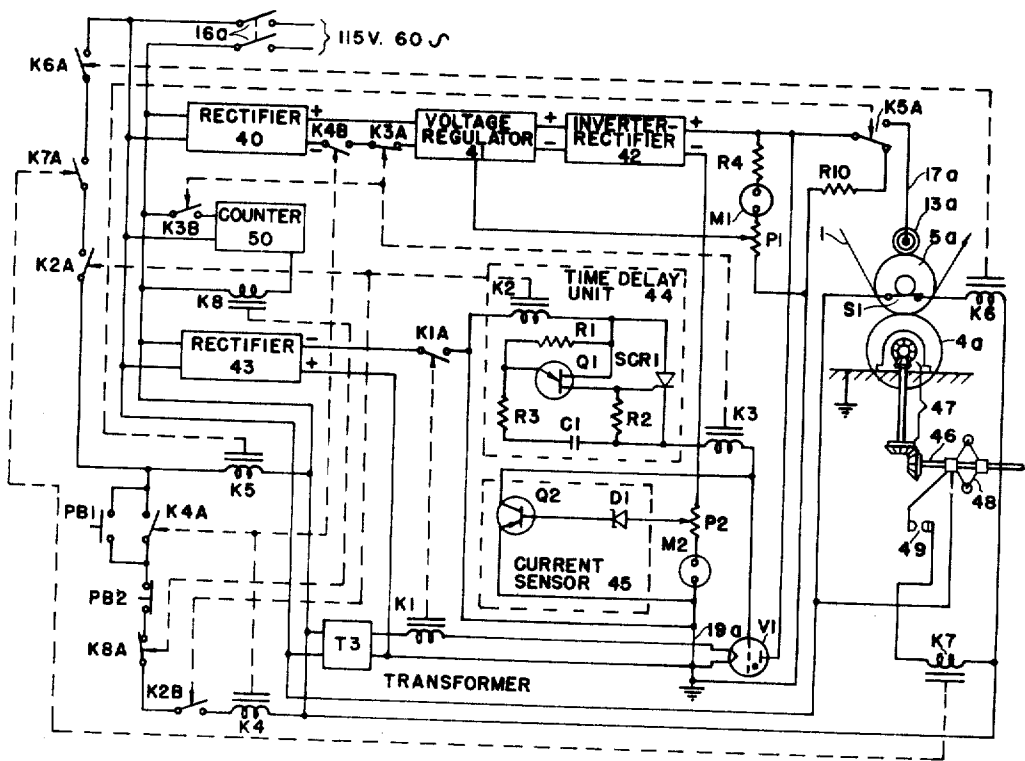
[54] **CONTROL OF COLOR DENSITIES AND TONES IN
MULTICOLOR PRINTING**
1 Claim, 5 Drawing Figs.

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101/426, 101/211, 101/152
[51] Int. Cl..... **B41m 1/10**
[50] Field of Search..... **101/151,**
152, 170, 426, 211

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ABSTRACT: In web-fed, multicolor printing operations wherein individual colors which make up the final composite copy are separately applied to the web, each at a separate printing unit or station, the invention provides a new and advantageous method of controlling the color densities and tones obtained in said composite copy, so that they closely correspond to those of the original art work or composition to be reproduced. The method provided employs electrical energy of controlled relatively high voltage and low amperage which is applied in the area of each printing unit or station wherein said individual colors are transferred to the web, whereby to effect or assist said transfer. It further provides for separately regulating the potential of the electrical energy supplied to each of the separate printing units or stations, to govern the amount of pigment there transferred to the web and thereby independently control the density of each individual color in the composite copy. By controlling the density of each individual color applied to the web, the tone values of combined colors in the copy (such as, for example, a purple formed by overprinting blue on red) may also be controlled.



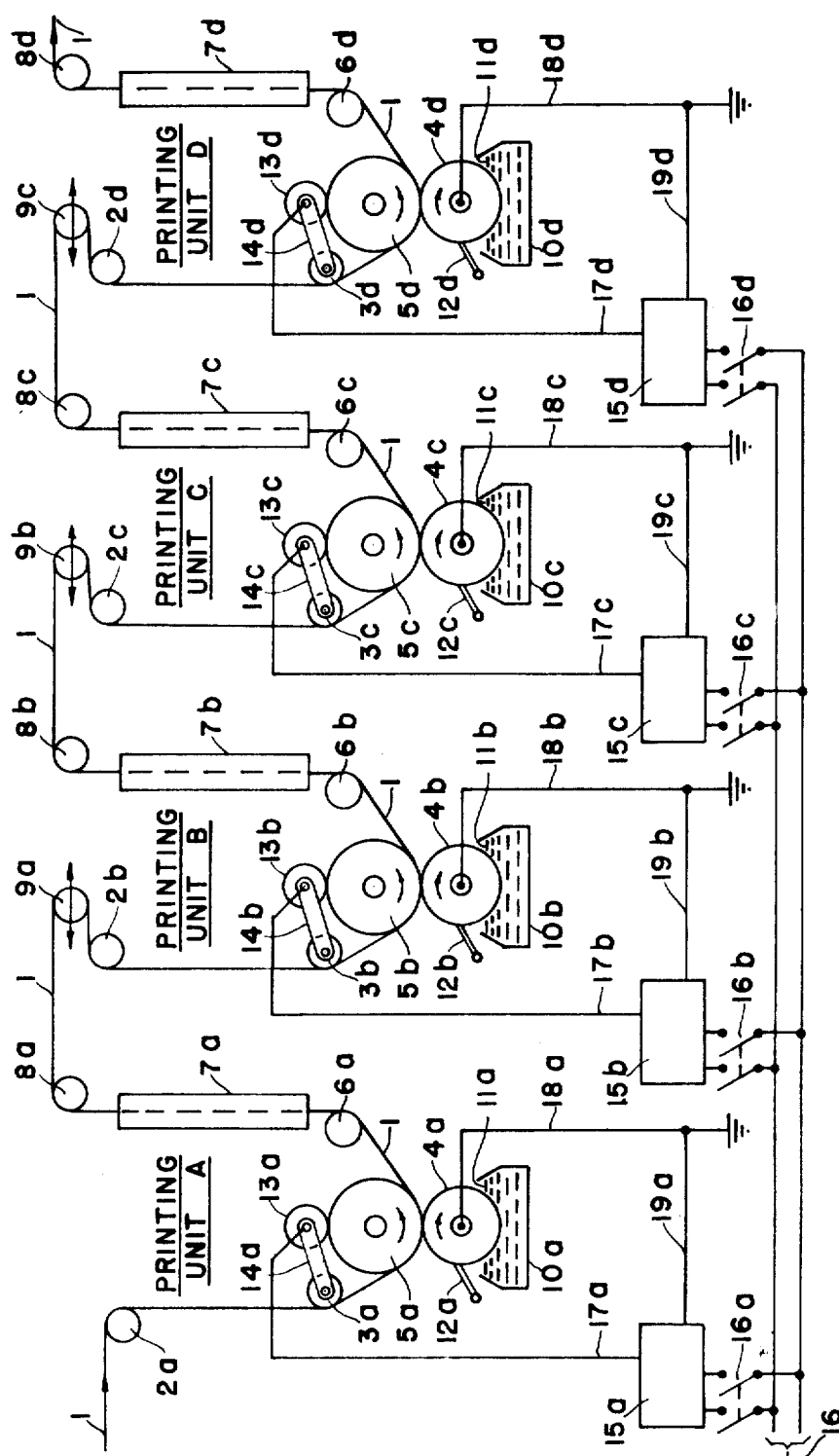


Fig. 1

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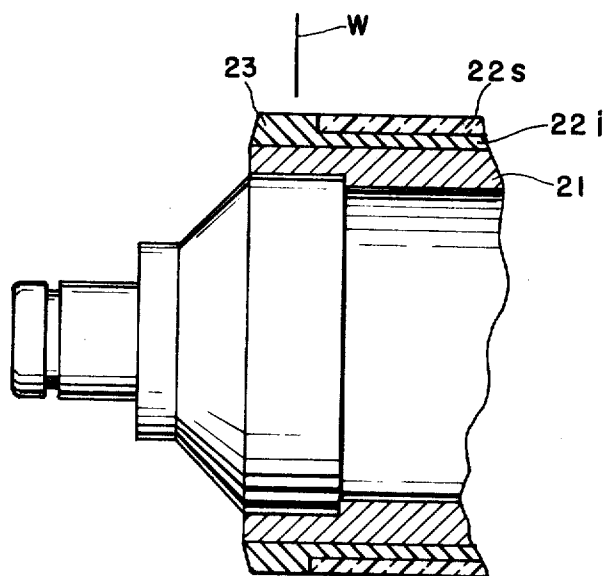


Fig. 2

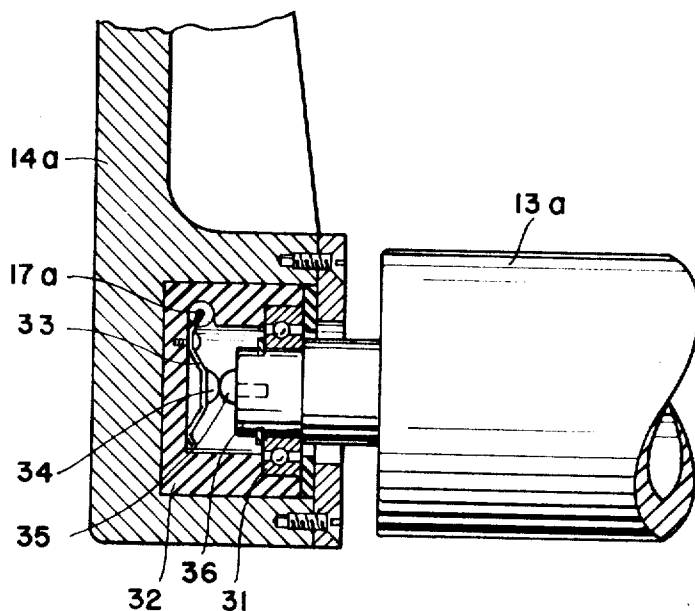


Fig. 3

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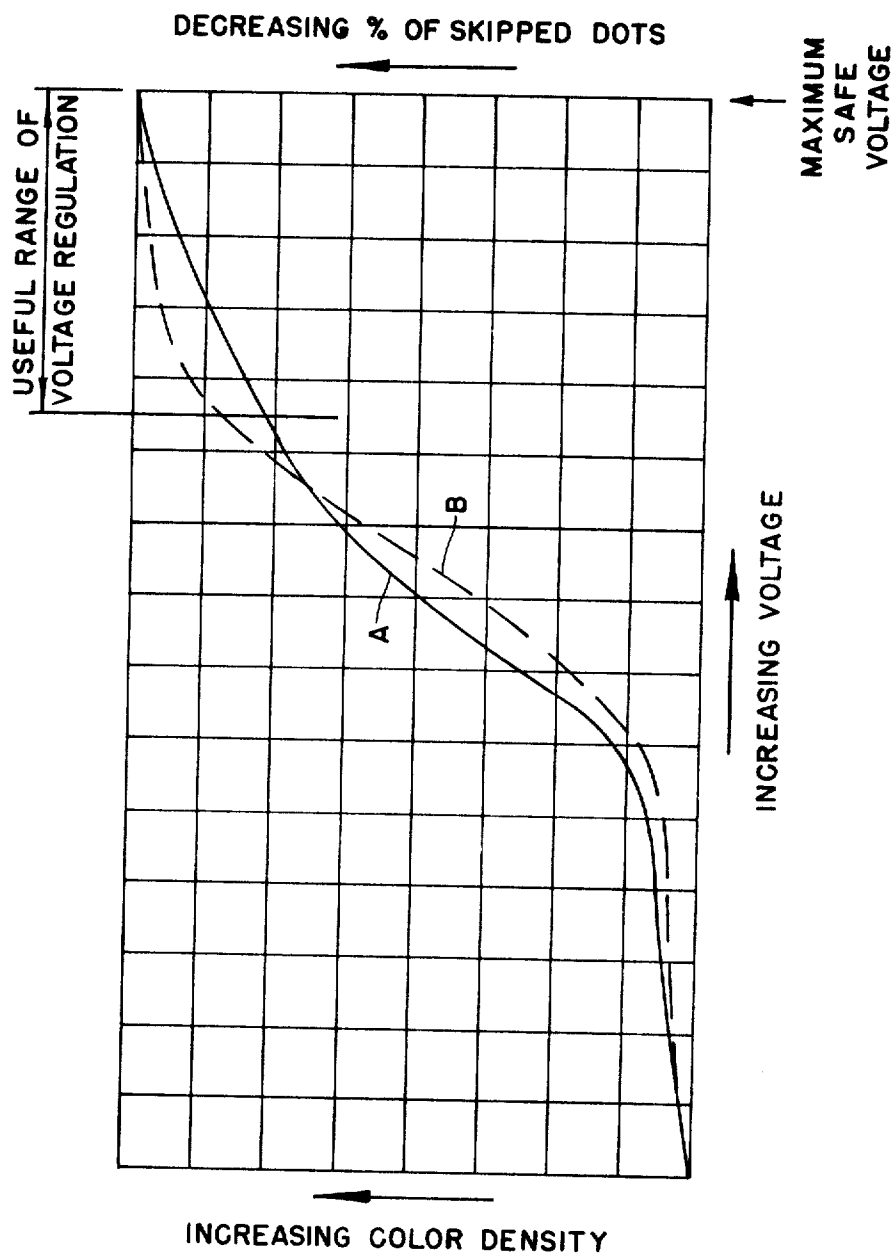


Fig. 5

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CONTROL OF COLOR DENSITIES AND TONES IN MULTICOLOR PRINTING

It is common practice, in web-fed, multicolor printing operations, to employ a limited number of differently colored inks and to apply each of them to the running web of paper or other material printed upon at a separate printing unit or station. At these separate units or stations, the printing cylinder or plate employed carries an inked pattern corresponding to only that portion of the finished copy which either consists of or contains one of the individually applied colors. Combinations of the individually applied colors are obtained by overprinting all or a part of the pattern carried by one or more plates or cylinders upon all or a part of the pattern carried by another plate or cylinder. For example, an area in the finished copy which appears green may be obtained by applying to that area both yellow and blue inks from corresponding areas of the separate cylinders which apply yellow and blue.

To properly prepare a set of color cylinders or plates is an art as well as a science. It involves making color separations from the original composition, one separation for each of the different colors to be employed in the printing, the production of a screened resist from each color separation and the careful etching, through each resist, into a printing plate or cylinder, the pattern carried by that resist. In addition to careful control of the processing conditions, this requires good judgment, based upon experience, and considerable skill. Therefore, it is not unusual, upon proofing a set of cylinders or plates to find that one or more of them must be reworked by hand or completely remade before acceptable results can be obtained in the printing.

Using rotogravure work as an example, the pattern etched into the gravure cylinder, in intaglio, consists of a multiplicity of minute cells which carry the ink to be applied to the web. These cells are of varying depth, cross-sectional area and spacing in different areas of the pattern, to give the desired shading, tone and density of color in the pattern printed by that cylinder. In general, what may be termed the texture of the inked pattern on a given cylinder or plate largely determines the quantity of ink applied to the web by that cylinder or plate, whether the type of reproduction employed be gravure, letterpress, offset, or some other variety of printing.

Heretofore, with a given set of plates or cylinders and a given choice of inks, the pressman has had little latitude in altering the density of any individual color as it is applied to the web. By the same token, he has had little control over the tone values of composite colors produced by separately applying individual colors in the same area of the copy. However, there are certain expedients which can be and are used to obtain some slight variations.

In letterpress work, shims may be inserted between the plate and the cylinder on which it is mounted to exert greater pressure between the web and the plate in areas where the ink transfer is deficient. This is a time consuming, cut-and-try procedure, usually involving prolonged down time on the press and consequent loss of production.

In gravure work, and to a lesser extent in offset printing, the impression pressure employed at each unit may be adjusted to give greater or lesser contact between the web and the gravure cylinder or offset blanket which carries the ink. However, if there is much inequality between the impression pressures carried at different units, resulting web tension variations cause misregister between the separate printings.

As a last resort, to avoid remaking plates or cylinders, one or more of the inks may be doctored by adding more of the same pigment, a little different pigment, more or less solvent, extenders, etc. However, when expedients such as mentioned are necessary, the resulting printed copy is quite apt to be a compromise between what is really wanted and what is unacceptable.

The present invention provides a convenient and effective method of controlling color densities and tone values in multicolor work, during the press run. This method does not prevent the use of previously available expedients but greatly

extends the latitude of control available to the pressman. It is not intended to obviate careful preparatory work nor the judicious choice of inks, but provides, during the printing operation, correction for minor deficiencies commonly encountered in preparing plates and cylinders. In most instances, when reasonable care and skill are exercised in the preparatory work, this new method will produce results superior to those otherwise obtainable from a given set of plates or cylinders and a given choice of inks.

The method herein provided of controlling color densities and tones involves the use of electrical energy (sometimes referred to as electrostatic energy because of the low amperage and relatively high voltage employed) to at least assist the transfer of ink or other pigment to the web from the patterned surface on which it is carried. It also provides a procedure for determining the operating conditions which may be safely employed, particularly with respect to the amperage and the range of voltage supplied to each printing unit. It further provides for separately regulating the potential of the electrical energy supplied to each printing unit, whereby to independently control the color density in the pattern of printing applied to the web at each printing unit.

The use of electrical or electrostatic energy in the transfer of pigmented materials is well known particularly as applied to spray painting. Neither is its use unknown in printing, but until quite recently it has not been applied successfully to commercial work such as publication, catalog and package printing. Most of the proposed electrostatic printing systems undertake to effect the transfer of dry, powdered pigment from a patterned surface upon which it is deposited, or through a patterned screen, to the surface to be printed upon through an ionized air gap, with no physical contact between the web and the surface carrying the pigmented pattern.

Recently, a system for electrostatically assisting the transfer of liquid ink in otherwise conventional rotogravure printing operations has been offered to the industry by the firm to which the present invention is assigned. It has enjoyed rapid and widespread adoption and has proven beneficial with a wide variety of printing stocks. While it utilizes a printing impression (i.e., physical contact between the web and the printing cylinder), it permits the use of lower impression pressure than would give acceptable ink transfer without the electrostatic assistance provided.

This electrostatically assisted system has been promoted and accepted entirely on the basis that it accomplishes more complete emptying of the ink carrying cells to give better and more uniform ink distribution on the web. This eliminates or greatly reduces the phenomenon known as snowflaking or skipped dots in the printed copy, which is a rather common fault occurring when some of the cells give up little or no ink to the web. This fault is particularly prevalent in delicate or lightly shaded areas of the copy and also occurs in more heavily pigmented areas when employing either relatively rough surfaced or relatively rigid and unyielding printing stocks, such as, for example, paperboard and uncalendered or lightly calendered stock made from ground wood pulp (e.g., newsprint). The electrostatically assisted system thus permits the use of rougher and lower priced stocks than would otherwise be suitable for the quality of printing generally demanded in publication, catalog and packaging color work.

The apparatus used in the aforementioned electrostatically assisted system is suitable for conducting the process of the present invention. Because of its much greater successful use than other proposed apparatus for electrostatically effecting or assisting printing operations, it is the form of apparatus preferably employed for practice of the method of operation herein provided and is included as a part of the accompanying drawing. However, it is not intended to limit the invention to use with this nor with any other specific form or type of apparatus, since the invention involves a method of operation, rather than a means. To the extent that other means are successfully usable in or may be readily adapted to the practice of the invention, such use falls within the intended scope of the invention.

When employed as herein provided, for the purpose of controlling color densities and tones, the way in which the apparatus is initially set up to operate and its mode of operation differ from the setup procedure and mode of operation previously contemplated. These differences have to do, principally, with setting the upper limits of voltage and amperage to be employed and with separate regulation of the voltage actually employed during the run at each of the printing units or stations. The recommended setup procedure and mode of operation will be described later, with reference to the accompanying drawing.

In the accompanying diagrammatic drawing, FIG. 1 illustrates four printing units of an otherwise conventional rotogravure printing press embodying apparatus by means of which the method of operation provided by the invention may be practiced.

FIG. 2 of the drawing is an enlarged longitudinal section of one end of the impression cylinders of FIG. 1, showing the two layer resilient covering preferably employed thereon.

FIG. 3 is an enlarged view of the end portion of one of the conductive rollers of FIG. 1, showing one way in which they may be electrically insulated from the frame of the press and one way in which electrical energy may be supplied to these rollers.

FIG. 4 is essentially a circuit diagram of a power supply usable in the practice of the invention and incorporating desirable safety features.

FIG. 5 illustrates the general form of curves obtained by plotting the voltage of the electrical energy applied to one of the printing units of FIG. 1 against (in curve A) the ink density in the printed copy produced by that unit and (in curve B) the percentage of skipped dots in the printed copy produced by that unit.

Referring now to FIG. 1, that portion of the rotogravure press here represented comprises the separate printing units A, B, C and D, which are substantially identical in construction. Corresponding parts of these separate units are designated by the same reference numbers, suffixed by the letters a, b, c and d, respectively.

The web 1, which may be paper, paperboard, plastic film, laminates of such materials, or any other substantially nonconductive material, is drawn from rolls thereof on a suitable reel or unwind stand, not shown, and passes over idler rollers 2a and 3a to the first impression formed between printing cylinder 4a and impression cylinder 5a. Carrying the pattern of color applied at unit A, the web then passes over idler roller 6a to a suitable dryer represented at 7a, where heat is applied to dry or set the ink. The web is then directed over idler roller 8a, compensator roller 9a, and thence, in succession, through printing units B, C and D, its path of travel through each unit being as illustrated and described with respect to unit A.

The compensator rollers 9a, 9b, and 9c are bidirectionally movable, as indicated by the arrows, to controllably lengthen and shorten the path of web travel between impressions and thus control circumferential register between patterns separately applied to the web at the several impressions.

At printing unit A, an ink fountain 10a is provided, into which the lower portion of gravure cylinder 4a extends, and a suitable level of ink, indicated at 11a, is maintained in the fountain. Cylinder 4a is rotated in the direction indicated by the arrow thereon, by well known drive means, not shown, and the intaglio pattern which it carries picks up ink as the cylinder rotates through the pool in the fountain. Some ink is also picked up on the smooth, unetched areas of the cylinder and is doctored (scraped) from these areas before reaching the impression, by means of a suitable doctor blade indicated at 12a. Similar fountain and doctor blade arrangements, designated in the drawing by corresponding reference numerals, serve the same purposes at units B, C and D.

For present purposes it may be considered that the portions of the printed copy consisting of and containing yellow are applied to the web at printing unit A, those consisting of and containing red, blue and black are applied to the web, respectively, at printing units B, C and D. Thus, the web leaving

printing unit D carries, on one side, a complete four-color reproduction which may include areas printed in only one of any of the four colors and areas in which one or more of the four colors is overprinted on a previously applied color.

If the web is to be printed on both sides, it is turned over upon leaving unit D, by well known means not shown, and directed to one or more additional printing units, similar or the same as A, B, C and D, wherein its reverse side is printed upon either in monotone or in two or more colors, as desired. One or more subsequent operations such as slitting, rewinding, folding, cutting and creasing, etc., are also, normally, performed on the web after it leaves the last printing unit, but these are not pertinent to the present invention and are not illustrated.

Electrically conductive, metal rollers 13a, 13b, 13c and 13d apply the electrical energy employed in electrostatically assisting each of the separate printing operations to the respective impression cylinders 5a, 5b, 5c and 5d, these conductive rollers each being connected, as will be described later, to an individual power supply.

Conventionally, the impression cylinders are loaded by means of pneumatic or hydraulic cylinders or by means of screws, not shown. This permits adjustment of the impression pressure to regulate the area of the indentation or nip, formed in a resilient covering provided on the impression cylinders, by their pressurized contact, through the web, with the printing cylinders. It also permits retraction of the impression cylinders from contact with the web and with the printing cylinders, whenever desired.

During the electrostatically assisted printing operation, the conductive roller serving each printing unit being used is in firm, rolling contact with the surface of an outer, resilient, conductive covering provided, and later described, on the impression cylinders. However, the conductive rollers are movable with vertical movement of the impression cylinders and preferably, they may also be completely retracted, whenever desired, from contact with the impression cylinders. One of the numerous suitable means of accomplishing both purposes is shown in FIG. 1 and in more detail in FIG. 3. As illustrated in FIG. 1, the end shafts of the conductive rollers are carried in one end of pivoted arms such as shown in 14a, 14b, 14c and 14d, the opposite ends of which are pivoted, in the case illustrated, about the end shafts of the respective idler rollers 3a, 3b, 3c and 3d. Suitable hand-operated levers or, when desired, remotely controlled air cylinders, not shown, may be employed to lift the conductive rollers from contact with the impression cylinders.

Each of the printing units has a power supply individual to that unit and comprising a source of low amperage, high voltage current. The power supplies for units A, B, C and D of FIG. 1 are shown in block form at 15a, 15b, 15c and 15d, respectively. Their components and circuitry preferably are identical and the diagram of a suitable circuit is illustrated in FIG. 4. The functions of this circuit will be described later with reference to FIG. 4.

As shown in FIG. 1, a two phase line 16, of any conveniently available voltage and frequency, is connected to the power supplies through individual switches 16a, 16b, 16c and 16d. Thus, any printing unit not being used may be disconnected from its primary source of electrical energy. The positive terminals of the DC output of the power supplies are connected by the conductors 17a, 17b, 17c and 17d to the respective conductive rollers 13a, 13b, 13c and 13d, which feed the current supplied thereto into the resilient, conductive covering on the impression cylinders 5a, 5b, 5c and 5d. The purpose of conductors 19a, 19b, 19c and 19d, leading from the power supplied to ground, will be explained in conjunction with the description of FIG. 4.

In the impression or nip area between each impression cylinder and the corresponding gravure printing cylinder, electrical energy passes from the conductive covering on the impression cylinder, through the web to the gravure cylinder. The gravure cylinders are at ground potential, being con-

nected to ground in the case illustrated by conductors 18a, 18b, 18c and 18d. However, no special grounding wire is normally required, since the end shafts of the printing cylinders are journaled in bearings on the frame of the press and this usually establishes a good path to ground potential.

The web 1, being of relatively nonconductive material, offers resistance to the flow of electrical energy from the impression cylinder to the printing cylinder and, with the latter grounded, a substantial difference in potential normally exists through the web at the impression. This causes ionization of the ink particles, in the cells of the intaglio pattern on the gravure cylinder, at a polarity opposite to that prevailing in the conductive covering of the impression cylinder. Consequently, the normal meniscus of the ink in the cells is deformed, attracting it to the interposed web. Thus the cells of the intaglio pattern on the printing cylinder are more completely emptied, as they pass through the impression, to deposit on the web a greater quantity of ink than otherwise would be transferred.

The increased quantity of ink transferred to the web and, hence, its color density in the printed pattern, is directly related to the difference in potential between the impression and printing cylinders in the nip area. This, in turn, is a direct function of the voltage applied to the conductive covering on the impression cylinder. Therefore, by regulating the voltage output of the connected power supply, the color density of the pattern printed at each unit may be controlled.

In accordance with conventional practice, each of the impression cylinders is made vertically movable by journaling its end shafts in a frame which slides vertically on suitable ways provided on the frame of the press. To avoid unnecessary detail in the drawing, the well-known structure comprising the press frame and the slidable mounted frames in which the impression roller shafts are journaled are not shown. However, it should be noted that this structure normally establishes an electrical path to ground potential from the impression cylinder. One way in which this may be avoided is illustrated in FIG. 2.

Referring to FIG. 2, the metal shell of the impression cylinder is indicated at 21 and is covered by two layers, 22i and 22s, of resilient material. The layer 22i is of high dielectric strength and preferably is a compound of rubber or similar elastomer, suitably bonded to the metal shell 21. The layer 22s is conductive to the extent required to transmit electrical energy from the conductive roller to the impression formed between the impression and printing cylinders. It may also be a compound of rubber or other elastomer containing sufficient carbon black or other conductive material to render it semiconductive.

Usually the width of the web is less than the length of shell 21 of the impression cylinder. The printing cylinder may also be of greater length than the width of the web. The location of one edge of the web is indicated at W in FIG. 2 and, to prevent the electrical energy employed from short circuiting from the impression cylinder to the printing cylinder at their end portions which extend beyond the web width, the insulating material 22i preferably is extended at these ends to a level which is flush with or slightly below the outer surface of the insulating layer 22s. This construction is indicated at 23 in FIG. 2.

FIG. 3 illustrates one type of construction whereby the conductive rollers are insulated from the frame of the press. The conductive roller 13a and its supporting pivotal arm 14a of printing unit A are shown in FIG. 2, the corresponding assemblies for the other printing units being of the same construction.

Both end shafts of the metal conductive roller are mounted in suitable bearings, one of which is shown at 31 in FIG. 3. Each of these bearings is mounted in a housing, indicated at 32, which is constructed of suitable high dielectric material, such as, for example, glass or cotton fabric impregnated with phenolic resin or, as an alternative, wood fibre bonded under pressure with urea-lignin resin (hardboard). The housing 32 is

encased in one end of the metal arm 14a, the opposite end of which is pivoted as indicated in FIG. 1. The conductor 17a from the power supply serving this press unit terminates within housing 32 in a spring 33, preferably of beryllium-copper, having a suitable contact button 34 which bears upon and makes contact with a hard metal contact 35 attached to the metal end shaft 36 of the conductive roller.

Referring now to FIG. 4, which is essentially a circuit diagram, it also shows in diagrammatic form the printing cylinder 4a, impression cylinder 5a, web 1, and conductive roller 13a of FIG. 1, to indicate how the circuit between these elements and the source of power for the electrostatically assisted system is connected and completed. Certain elements and subassemblies in the circuit of the power supply and its associated parts are of well-known construction and they function, individually, in a well-known manner. To avoid unnecessary complexity in the diagram, these well-known subassemblies are shown in block form. It should be understood, of course, that although FIG. 4 shows the power supply connected to the first printing unit (A of FIG. 1), it is typical of the power supplies 15a, 15b, 15c and 15d of FIG. 1, one such power supply serving each printing unit employed.

Readily available AC line current (such as 115 V., 60 cycle, for example, although other voltages and frequencies may be used) is supplied as shown on the upper left hand corner of FIG. 4, to low-voltage, full-wave rectifier 40 having, for example, an output of +50 volts DC. This low-voltage DC is supplied to the voltage regulator 41, which is essentially a three-stage transistor amplifier with an internal source of reference voltage, such as a battery, and a regulating feedback which will be later described. The regulated low-voltage DC output from 41 is fed to the DC-to-DC transistor inverter-rectifier 42, where, in accordance with well-known practice, the low voltage DC input is first converted into high-frequency, high voltage square waves, in the inverter section. The inverter-rectifier assembly also contains a bridge-type rectifier section wherein the high-voltage square waves from the inverter section are converted to high-voltage direct current.

The positive output side of the inverter-rectifier is connectable, through relay contacts K5A and, as described in more detail with reference to FIG. 3, through line 17a to the conductive roller 13a. The negative side of the inverter-rectifier output is connected through potentiometer P2, meter M2, and line 19a to ground. The printing cylinder 4a is also grounded to complete the circuit and provide energy for electrostatically assisting the transfer of ink as previously described.

The circuitry provided and illustrated in FIG. 4 makes provision for the following automatically-controlled safety features:

1. Temporarily interrupting operation of the electrical system whenever the load imposed on the power supply reaches a preselected safe limit.

2. Discontinuing operation of the electrical system until it is intentionally started after clearing the difficulty, when a persistent or frequently recurring load corresponding to the preselected safe limit is imposed on the power supply.

3. Preventing operation of the electrical system until the press reaches a predetermined operating speed (i.e., cylinder r.p.m. or linear web speed).

4. Preventing operation of the electrical system until the impression is made (i.e., the impression cylinder has been brought into firm contact with the printing cylinder).

The aforementioned safety provisions and their mode of operation are explained in conjunction with the following description of the sequence and mode of operation of the circuit components.

The aforementioned AC supply line has a main disconnect switch 16a and, with this switch closed, the line is connected with the low-voltage AC-to-DC rectifier 40. The supply line is also connected through this switch with another rectifier 43 of the same type to provide -20 volts DC, for example, which is used as will be later described. Also, the AC power line is con-

nected with a transformer T3 which provides a suitable filament voltage to the Thyatron tube V1.

As current flows through the Thyatron filament circuit from transformer T3, the current sensitive relay coil K1 is energized. This closes the corresponding contacts K1A of the relay to connect the negative side of the output from rectifier 43 with the time delay unit 44, which functions in the following manner to prevent energization of the rest of the system until the filament of the Thyatron tube warms up and renders this tube operative.

With contacts K1A closed, the capacitor C1 in the time delay unit starts charging from voltage drawn through relay coil K2 and the resistors R1 and R2. As soon as the voltage of capacitor C1 has risen to a sufficient value to cause the unijunction transistor Q1 to conduct, the resulting positive pulse of voltage generated at its unijunction base is applied to the gate of SCR 1, turning it on. Conduction through SCR 1 permits sufficient voltage to be applied to relay coil K2 to cause operation of this relay, closing its contacts K2A and K2B in a branch of the AC supply line. Until this happens, the pushbutton PB1, the relay contacts K6A and the relay contacts K7A in the aforesaid branch line are rendered ineffective to close the circuit of this branch line by virtue of the open contacts at K2A and K2B.

The function of the momentary contact pushbutton PB1 is to initiate the electrically assisted operation, but until relay contacts K2A, and K2B, K6A and K7A are all closed, no energy can be transmitted through the branch line in which these contacts are located, and the pushbutton PB1 remains ineffective. The manner in which contacts K2A and K2B are closed has been described above. The manner in which contacts K6A and K7A may also be closed, so that the operation can be initiated by pushbutton PB1, will now be described.

When the impression cylinder 5a is lowered into contact with the printing cylinder, as shown on the right hand side of the diagram, the contacts of limit switch S1 will close. This causes power from the AC supply line to energize relay coil K6, closing the corresponding contacts K6A.

After the press is started in the usual manner, not illustrated, the printing cylinder is accelerated to the desired running speed through the drive shaft 46 and the conventional gearing indicated diagrammatically at 47. A suitable speed sensitive switch which, for the sake of simple illustration, is here shown as a device 48 similar to a flyball governor attached to drive shaft 46 and having contacts 49, closes these contacts when cylinder 4a reaches a predetermined speed. Closing contacts 49 completes the circuit through relay coil K7, energizing the same to close the corresponding relay contacts K7A.

With relay contacts K2A, K2B, K6A and K7A all closed, the impression between cylinders 4a and 5a will have been made, the cylinders will be rotating at the desired speed and the time delay unit 44 will have functioned to insure that the Thyatron V1 is ready to operate. The system is thus ready to start supplying power to the conductive roller 13a. By then manually operating the momentary contact pushbutton PB1, to close its contacts, this will complete the closing of the entire series of contacts in the branch AC supply line and relay coil K4 will energize to close the contacts K4A and K4B. Contacts K4A remain closed after pushbutton PB1 is released, thus keeping the aforesaid branch line conductive until the stop button PB2 is pushed or one of the series of other contacts in the branch line drops out.

When contacts K4B close, the DC output from rectifier 40 enters the voltage regulator 41 and the latter supplies its regulated output to the inverter-rectifier 42. Meanwhile, since contacts K2A, K6A and K7A have closed, the relay coil K5 has become energized to close its contacts at K5A, which connects the positive output terminal of the inverter-rectifier with the conductive roller 13a. Its corresponding negative terminal is connected to ground, as will be later described, to complete the circuit from the inverter-rectifier through the conductive roller 13a, web 1, and printing cylinder 4a to ground, and return to the inverter-rectifier.

A portion of the positive output from the inverter-rectifier is fed to ground through resistor R4, microammeter M1, which measures voltage, and potentiometer P1. A sample voltage, the value of which depends upon the setting of the wiper arm of P1 and which is positive with respect to ground, is picked from the potentiometer by the wiper arm and fed back to the voltage regulator 41. Here the sample voltage is compared in a bridge circuit with the aforementioned reference voltage in the regulator and this comparison initiates an impedance change in the input to the inverter-amplifier from the regulator to bring the sample and reference voltages to equilibrium. Thus, changing the setting of the wiper arm of potentiometer P1 changes the proportion of the voltage fed back to the regulator and causes the latter to alter its high voltage output to the conductive roller 13a. Meter M1 indicates the voltage level selected.

The negative output terminal of the inverter-rectifier 42 is connected to ground through potentiometer P2 and meter M2. Since all load current flows through this circuit, meter M2 monitors the actual current drawn by the electrostatic assist applied to the printing operation. To prevent this current from reaching a dangerously high level, which can happen, for example when web 1 breaks or when holes in the web pass through the impression, provision is made for limiting the current drawn by the conductive roller 13a and shorting the inverter-rectifier output to ground if and when the current level becomes excessive. To accomplish this, part of the voltage drop across potentiometer P2 is picked off by its wiper arm and applied to the current sensor 45. The current sensor functions as follows.

If and when the current flowing through potentiometer P2 reaches a level at which the voltage at the wiper arm setting exceeds the threshold voltage of the zener diode D1, to which this pickoff voltage is applied, the transistor Q2, to which the diode is connected as shown, conducts and grounds the grid of Thyatron V1. This causes the Thyatron to conduct heavily (crowbar) and effectively short circuit the high voltage output of the inverter-rectifier to ground through the Thyatron.

In addition, when transistor Q2 conducts to trigger the Thyatron, the coil of relay K3 will be energized to open the relay contacts K3A and interrupt the rectifier low voltage supply to the voltage regulator. This, of course, turns off the inverter-rectifier and, when its high voltage output decays to zero, Thyatron V1 ceased to conduct, no current passes through the current sensor 45 and, with relay coil K3 thus deenergized, relay contacts K3A drop back to closed position. If the cause of the amperage surge has meanwhile been corrected or cleared, the system is then back in operation. If the fault persists or is repeated, the above described cycle is repeated.

When relay coil K3 is energized, relay contacts K3B are closed to connect a counter 50 with the AC supply line. Counter 50 is of the type which closes an internal contact when a selected count is reached and counts one digit each time relay contacts K3B close. When the count reaches the preselected number, say three or five, for example, the internal contacts complete the circuit from the AC supply line through relay coil K8, energizing the same to open the normally closed contacts K8A in the branch AC supply line. This deenergizes relay coil K4, causing contacts K4A and K4B to open and thereby discontinue the operation of the system until pushbutton PB1 is manually operated. Thus, if there is a persistent heavy drain of current or this condition is repeated for a number of times corresponding to the preselected number on the counter, the current supply to the conductive roller 13a is discontinued until operation is intentionally renewed, giving the operator an opportunity to find and correct the difficulty. When desired, a warning, such as a light or audible signal, may be turned on automatically when the counter reaches the preset count, and/or operation of the press may be stopped automatically.

Since the Thyatron tube V1 is depended upon to ground the output of the inverter-rectifier in the event of an excessive current drain, provision is made for deenergizing the system in

case the Thyatron filament fails. In this event the current through relay coil K1 collapses causing contacts K1A to open and disconnect the time delay unit 44 from the rectifier 43. This deenergizes relay coil K2, causing its contacts K2A and K2B to open, thus deenergizing relay coil K4 and opening its contacts K4A and K4B, which shuts down the system and returns all circuits to their initial inoperative condition.

It should be noted that, in FIG. 4, all relay contacts are shown with the corresponding coils in deenergized condition.

When electrical energy is applied at the impression, as described, a web of given composition, structure, density and thickness will draw an amount of current which is characteristic of that particular web. But upon the occurrence of a web break, a hole in the web or extreme porosity, so that current can flow from the conductive covering on the impression cylinder directly to the metal printing cylinder, the amperage drawn at the impression will greatly increase unless the output of the power supply is limited. A large and sudden increase in current at the impression, even though momentary, is hazardous on a gravure press, since the ink contains volatile hydrocarbon solvents and the ignition point of the hydrocarbon-air mixture in the vicinity of the impression may be low. This danger is avoided, as has been explained in greater detail with reference to FIG. 4, by setting at potentiometer P2 (see FIG. 4) an adjustable upper limit to the amperage supplied to the printing unit. Preferably this limit is set quite close to but slightly above the amperage normally drawn through the particular printing stock being run.

There is also a potential or voltage level at which the web passing through the impression will be punctured or at which excessive electrical energy will otherwise be caused to prevail in the impression area. This also varies with the composition, structure, density, and thickness of the particular printing stock employed. However, it has been assumed, heretofore, that a voltage closely approaching the maximum safely permissible is desirable. Accordingly, it previously has been recommended and has been the practice, in employing apparatus of the type illustrated and described, to set the voltage output of the power supply at only slightly less than the safe maximum. In general, this voltage setting has been selected, by trial, to suit the particular printing stock being run. For example, a relatively thin or porous stock may tolerate say 800 volts, while heavy paperboard may tolerate up to 5,000 volts, with intermediate stocks, including coated papers and lighter paperboards, falling between these extremes.

I have found that, with a given set of cylinders and inks, utilizing the highest or nearly the highest safely permissible voltage at the impression may not and, frequently, does not give the desired results with respect to color densities and tones in the printed copy. Apparently, this may be attributed to lack of exact predictability and lack of precise control in preparation of the color separations, resists, and in etching the cylinders.

I have further found that, without materially endangering the quality of the printed copy with respect to good ink distribution and a low percentage of skipped dots, there usually is a considerable range over which the voltage applied at the printing units may be adjusted and that such adjustments produce very noticeable changes in the color densities and tone values obtained in the printed copy. This is shown graphically in FIG. 5 of the drawing, which will now be explained.

In FIG. 5, the horizontal axis of the graph represents the voltage of the electrical output from the power supply, increasing from zero on the left to the maximum safe voltage for a given stock in a specific press unit on the right. In curve A, the voltage values are plotted against color density in the copy printed at that unit. In curve B, the voltage values are plotted against the percentage of skipped dots in the same copy. In general, the color density increases with an increase in voltage and the percentage of skipped dots decreases with an increase in voltage. Both curves follow a generally S-shaped pattern but they are not identical.

While the curves shown in this graph are believed to be fairly representative, it should be understood that variables in the operation, such as a change in printing stock or in the moisture content, caliper (thickness) or density of a given stock, will cause them to change. Therefore, no specific quantitative values are assigned on the graph. However, on the basis of tests conducted to date, it appears that there is little increase in color density and little decrease in the percentage of skipped dots until the applied voltage reaches approximately 40 percent of its predetermined, maximum safe value. From this point up to about 70 to 75 percent of the maximum safe voltage, the percentage of skipped dots decreases at a greatly accelerated rate and then starts to flatten out rather abruptly. The color density follows a similar pattern but does not flatten out as rapidly in its upper region.

By way of example, let us assume that, with a given stock and on a given press unit, the highest potential which may be employed, leaving some margin of safety, is 1,500 volts. In the aforementioned electrostatically assisted printing operation, not utilizing the present invention, it has been the practice to determine this maximum safe voltage for the specific printing stock being run and to operate the system at a constant voltage only slightly below this predetermined value. However, in the practice of the present invention, the following procedure is recommended:

a. At the start of the operation, the potentiometer of the current sensor (P2 in current sensor 45 of FIG. 4) is set for an amperage output to the printing unit substantially in excess of the current which the web is expected to normally draw. Let us assume, for example, that we expect the web to draw somewhere between 0.5 and 1 milliamperes and that the potentiometer is set to permit an output from the power supply of 3 milliamperes.

b. Starting with a low voltage output from the power supply, it is gradually increased (by means of potentiometer P1 in FIG. 4) until the Thyatron tube (V1 of FIG. 4) crowbars rather consistently. Again, by way of example, let us assume that this will happen when the reading on meter M1 of FIG. 4 reaches 1,600 volts.

c. The voltage output of the power supply is then slowly decreased until crowbarring ceases. In the example being used, this may happen when the reading of meter M1 decreases to 1,540 volts and, to leave a margin of safety, we select, say 1,500 volts as the maximum to be used.

d. The voltage output of the power supply is further decreased, below the point where crowbarring ceases, until skipped dots begin to be noticeable in the printed copy. Say this occurs, in the example being used, at an output from the power supply of 1,000 volts, as indicated by the voltmeter (M1 of FIG. 4). The potentiometer setting is then increased slightly, to produce copy which does not have an objectionable percentage of skipped dots. Say this setting gives an output of 1,050 volts, we may then select 1,050 volts as the minimum to be used. Thus a range of voltage regulation of 1,050 to 1,500 volts has been established in this specific example.

e. Returning to the amperage adjustment, after noting on the milliammeter (M2 of FIG. 4) the current being drawn by the web, the setting of the amperage output adjusting potentiometer (P2 of FIG. 4) is decreased until the output falls sufficiently that crowbarring is encountered. Say the web has been drawing approximately 0.65 milliamperes and crowbarring occurs at 0.58 milliamperes. To accommodate normal variations in the current drawn by the web, with changes in its structure, moisture content, thickness, etc., the potentiometer setting is increased to give a maximum output from the power supply slightly above that previously noted on the milliammeter. In this example, the maximum output may be set at say 0.75 milliamperes. It is left at the setting selected during the run, unless and until the characteristics of the web or some other factor changes sufficiently to require some readjustment. During the run the printed copy is examined periodically to compare the density of each individually applied color with an acceptable standard and the voltage employed at any unit which is not

producing the desired results is adjusted, within the limits predetermined as above described, to give optimum results.

It will be obvious that the sequence of the recommended setup procedure (steps (a) through (d) above) may be altered in some respects without violating their purpose. Also, the specific figures given as examples are intended only to be indicative of their order of magnitude. It should also be pointed out that the recommended procedure applies to each individual press unit and the power supply which serves it since there may be a slight difference in their behavior and this should be determined on any new installation.

As a general rule, when proper inks have been selected and the cylinders have been prepared with reasonable care and expertize, matching the densities of the individually applied colors (normally yellow, red, blue and black) with those of the original art work to be reproduced or with acceptable color swatches will also give the desired tone values in the areas of the copy where individually applied colors are combined. However, it should be noted that, with respect to maintaining the desired tone values of combined colors, the invention affords a choice of three procedures. This may be clarified by a specific example, such as follows:

Say a certain shade or tone value of green in the copy begins to deteriorate, taking on a cast which is too yellow. The possibilities for correcting this are (1) decrease the voltage at the unit which applies the yellow ink, (2) increase the voltage at the unit which applies the blue ink, or (3) do both. The choice will be dictated, in part, by the existing settings of the potentiometers which control the voltage to these two units. If the one controlling yellow is somewhere in mid range or near its upper usable limit, it may, of course, be reduced, but if it is near its lower limit, reducing it further is usually undesirable. Conversely, if the potentiometer controlling the blue is near its upper limit, its effectiveness is limited, but if it is somewhere in mid range or near a low limit, it can be increased with good effect. If the blue is near its upper limit and the yellow near its lower limit, a small change in both, each in the proper direction, is indicated. If neither potentiometer setting has a narrow remaining range, in the proper direction, a knowledgeable operator will also take into account what will happen to an area of the copy printed only in yellow or only in blue if he changes the potentiometer controlling that color in order to bring the green to the desired tone value.

Devices are now available for continuously monitoring

color densities and tones in multicolor printed copy, as it is produced. Such a device has special utility when used in conjunction with the method of control herein provided and such use is definitely desirable and is contemplated. However, the specific means of continuously monitoring, indicating, and/or recording changes in color tones and densities, while pertinent, is not a part of the present invention.

While the foregoing specification refers particularly to gravure printing, utilizing some impression pressure, it is not intended to limit the scope of the invention to this nor to any other specific means of reproduction. To the extent that other types of reproduction, including offset or planographic, letterpress or stereotype, flexographic (formerly called aniline), screen or stencil printing, and the like, are susceptible to improvement by the method herein provided, such use of the method does not depart from the intended spirit and scope of the invention.

I claim:

1. In the process of applying to electrically resistive material a pattern of work comprised of at least one color which is transferred to said material from a patterned, pigment-carrying surface within a transfer zone, a current diversion path being provided to bypass the transfer zone, the method of controlling the color density of said pattern which comprises supplying a relatively high direct current potential across the transfer zone in a range of from about 1,000 to 1,500 volts and adjusting the current drawn to a value which is in excess of a predetermined current within a range of from about 0.5 to 1.0 milliamperes which said material is expected to normally draw, diverting current through the current diversion path by increasing the potential across the transfer zone to a value sufficient to effect current diversion, inhibiting current diversion by adjusting the potential across the transfer zone to a value below that which effects negation of current diversion, further adjusting the potential across the transfer zone while observing a printed copy to a value below the last named value whereat the printed copy possess a suitable color density to establish a potential adjustment range between the two last-named values, readjusting the current delivered to the transfer zone to a value immediately below that which effects current diversion through the current diversion path, and adjusting the potential across the transfer zone within said potential range while observing the printed copy to vary the colored density during printing.

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