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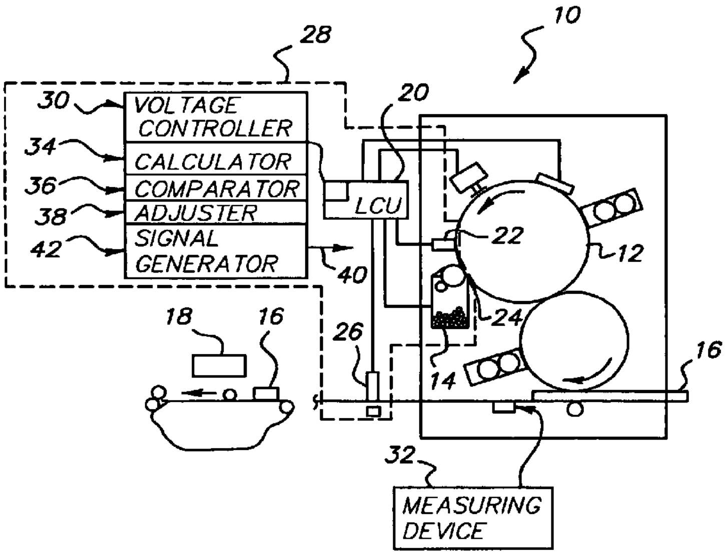
(54) Title: PRINT QUALITY MAINTENANCE METHOD AND SYSTEM



(57) Abstract: A system and related method for maintaining print quality based on development potential measurements that include comparing the current process measurements to a toner concentration related set-point; calculating a quality adjustment range based on current process measurements and the toner concentration related set-point, or a derivative thereof, indicative of print quality; and adjusting current process conditions related to the current process measurements to trend towards a new set point within the quality adjustment range so that a rate of change is proportional to the difference between the current process measurements and the set point.

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PRINT QUALITY MAINTENANCE METHOD AND SYSTEM

FIELD OF THE INVENTION

The invention relates to electrographic printers and apparatus thereof and more particularly to an apparatus and method for controlling print quality using the development voltage.

BACKGROUND OF THE INVENTION

Electrographic printers and copiers utilizing developer comprising toner, carrier, and other components use a developer mixing apparatus and related processes for mixing the developer and toner used during the printing process. The term "electrographic printer," is intended to encompass electrophotographic printers and copiers that employ dry toner developed on an electrophotographic receiver element, as well as ionographic printers and copiers that do not rely upon an electrophotographic receiver. The electrographic apparatus often incorporates an electromagnetic brush station or similar development station, to develop the toner to a substrate (an imaging/photoconductive member bearing a latent image), after which the applied toner is transferred onto a sheet and fused thereon.

As is well known, a toner image may be formed on a photoconductor by the sequential steps of uniformly charging the photoconductor surface in a charging station using a corona charger, exposing the charged photoconductor to a pattern of light in an exposure station to form a latent electrostatic image, and toning the latent electrostatic image in a developer station to form a toner image on the photoconductor surface. The toner image may then be transferred in a transfer station directly to a receiver, e.g., a paper sheet, or it may first be transferred to an intermediate transfer member or ITM and subsequently transferred to the receiver. The toned receiver is then moved to a fusing station where the toner image is fused to the receiver by heat and/or pressure.

In the electrographic process, a dielectric member, such as a photoconductive element, is initially uniformly electrically charged. The electrostatic latent image charge pattern is formed on the dielectric member by exposing the dielectric member to a suitable exposure source. For example, if the dielectric member is a photoconductive element, the photoconductive element is exposed by an exposure source such as a laser scanner or an LED array. The latent image charge pattern is developed into a visible image by bringing the electrostatic latent image charge pattern into close proximity to a developer material such as contained in a magnetic brush or other known type of development station.

The developer material is typically formed of two or more components that include non-marking, magnetic, carrier particles and marking, non-magnetic toner particles. Because of the triboelectric interaction between the toner and carrier particles, the two types of particles develop charges of opposite polarity and the toner particles electrostatically adhere to the carrier particles. The development station delivers the developer in close proximity to the latent image charge pattern present on the dielectric member and the charged toner particles are attracted to and develop the latent image charge pattern.

Using an electrostatic field to urge the toner particles in the direction of the receiver member subsequently transfers the resulting toner particle developed image to a receiver member, such as paper or plastic sheet. The electrostatic field is commonly applied in one of several ways. For example, charge can be sprayed on the back of the receiver member using a corona device. However, it is frequently preferable to use an electrically biased transfer roller to apply the field. Upon completion of the transfer of the toner particle developed image to a receiver member, the developed image is fused to the receiver member by application of heat and/or pressure.

One of the larger contributors to image quality problems is the variation in environmental conditions that occurs in and around the development station. Warmers, driers, humidifiers and additives have been used to combat and control this problem, all with an eye to controlling the effect of the ambient environment on image quality. U.S. application publication number 2004/0042815, published on March 4, 2004 shows a humidification system for a development station to control charge on toner particles for developing a latent image charge patterns. Humidification is provided by adding water vapor to an airflow directed into the developer station. The addition of a humidification system is costly and also difficult to control. It would be preferable to have a developer station that did not need a humidification system to maintain image quality through the ambient environment range but instead adjusted a parameter internal to the development subsystem to maintain image quality.

SUMMARY OF THE INVENTION

The invention is for an apparatus and method to assist an electrographic printer in controlling print quality. More specifically, a method for maintaining print quality based on development potential measurements, said method including the steps of comparing the current process measurements to a toner concentration related set-point; calculating a quality adjustment range based on current process measurements and the toner concentration related set-point, or a derivative thereof, indicative of print quality; and adjusting current process conditions related to the current process measurements to trend towards a new set point within the quality adjustment range so that a rate of change is proportional to the difference between the current process measurements and the set point.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic front view of a portion of an electrographic reproduction apparatus including a development station according to one aspect of the invention.

Figure 2 is a schematic plan view of the portion of development station according to one aspect of the invention.

Figure 3 is a flowchart for the process for controlling image quality.

Figures 4-5 are graphical representations showing the process for controlling image quality according to one aspect of the invention.

Figure 6 is a graphical representation showing the print control process according to one aspect of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present description will be directed in particular to elements forming part of, or cooperating more directly with, apparatus and methods in accordance with the present invention. It is to be understood that elements not specifically shown or described may take various forms well known to those skilled in the art

Figures 1 and 2 show, generally schematically, a portion of an electrographic printer 10. The printer includes a moving electrographic imaging member shown here as a photoconductive drum 12, which is driven by a motor to advance the drum thus advancing the receiver 16 in the direction indicated by arrow P. Alternatively, drum 12 may be a belt that is wrapped around a drum or it may be a belt that is wrapped around one or more rollers. In the electrographic printer 10, a toner development station is provided for storing a supply of toner particles 14 and selectively depositing the toner particles on the photoconductive drum 12, which is also sometimes referred to as a photoconductor. When the charge on the toner particles is at a proper level, the particles will develop the latent image charge patterns into a high-quality visible image that is the correct charge level for the subsequent transfer step. Thereafter, the visible toner particle image is transferred to a receiver member 16, which is often referred to as a substrate or receiver, and is fixed to the receiver member by a fuser 18, to form the desired image. One skilled in the art understands that the receiver could be paper that is printed or non-printed or a non-paper, such as metal, ceramics, photoconductor, textile, glass, plastic sheet, metal sheet, paper sheet and other bases that are capable of receiving a toner or toner related material.

The electrographic printer 10 incorporates a printing quality controller device or apparatus 22 and system in accordance with the methods and systems described below. The electrographic printer 10 includes a controller or logic and control unit (LCU) 20 that is programmed to provide closed-loop control of printer 10 in response to signals from various sensors and encoders. Aspects of process control are described in U.S. Patent No. 6,121,986 incorporated herein by this reference.

The quality controller device, generally indicated by 22, works in conjunction with the electrophotographic printer to control the charge on toner particles 14 which are mixed with charge carrying particles in the development station of the electrographic printer 10, in order to assure high quality development of the latent image charge pattern carried by the latent image charge pattern carrying member, here after referred to as the photoconductive drum 12, prior to transfer of the toner particle 14 developed image to a receiver member 16 transported in association therewith by any suitable transport mechanism. It has been determined that modifying the charge on the toner particles by adjusting a toner concentration 24 will maintain the development potential in a desirable range and achieve the required output print density for the desired high-quality image print without the need for a humidification system.

A print quality apparatus 28 operates in conjunction with an electrophotograhic printer without a humidification system. The quality control device 22 is a device for maintaining print quality based on development potential measurements (Vdev). The apparatus 28 includes a power supply 26 for charging a photoconductor to a photoconductor voltage (Vzero); a voltage controller 30 for determining and maintaining an aim Vzero, thereby causing, over the course of a specified time interval, a voltage control of the Vzero; one or more measurement devices 32 measure a first information including a photoconductor discharge speed and a residual voltage (toe voltage) of the Vzero as well as other environmental information such as temperature and humidity, a processing system calculation device 34 for calculating a quality adjustment range 27 based on current process measurements and the toner concentration related set-point 29, or a derivative thereof, which is indicative of print quality, such as the Vdev.

A comparator 36 is also included wherein the first information, or a derivative thereof, is compared to the calculated quality adjustment range, or a derivative thereof, so that they are indicative of print quality; as well as an adjuster 38 to adjust the current conditions so they trend towards a new set point within the quality adjustment range in a controlled manner and a signal generator 40 for generating a signal based on the comparator and/or the adjuster, thus resulting in a better quality print.

This apparatus 28 generates the signal 40 with the signal generator 42 that is controlled by a measuring device. One embodiment of a method 44 is represented by the flowcharts in Figures 3-5, for measuring at least one value related to said Vdev of said photoconductor during a time interval in which said Vdev is changing. The generated signal 40 is used to control toner concentration

24 by adding toner 14 or withholding toner and thus varying toner concentration based on one or more environmental factors including humidity, temperature, and air quality. A computer, which incorporates a control to activate the power supply, the adjuster, the comparator, and a toner, supply so that wherein the changes to the current set of conditions in a controlled manner related to a rate of change. This rate of change can be controlled by a set of rules that optimize performance.

Adjustment of the aim toner concentration based on toning potential

One preferred method 44 for maintaining print quality based on development potential measurements includes the steps of generating a print control patch 31 related to a toner concentration related set-point, which is an aim value that represents a desired or possibly, but not necessarily an ideal quality; receiving current process measurements including a measured toning potential related value and a measured toner concentration related (TM_ref) value; comparing the current process measurements to the toner concentration related set-point and calculating a difference; calculating a quality adjustment range based on current process measurements and the toner concentration related set-point, or a derivative thereof, indicative of print quality; adjusting current process conditions related to the current process measurements to trend towards a new set point within the quality adjustment range so that a rate of change is proportional to the difference; and generating a signal based on the comparison.

This method 44 sets the set point so that the quality adjustment range has a minimum and maximum. In a preferred embodiment, one important aspect is that the adjustment is made at a controlled rate of change such that the controlled rate of change is optimized based on a set of rules that are chosen based on current process conditions. The system will generate the signal based on a number of variables, including Vdev, which is used to control toner concentration 24 by adding toner or withholding toner. The signal generated would be able to change toner concentration based on one or more environmental factors including humidity, temperature, and air quality.

This method 44 will include the normal steps of charging the photoconductor 12 to Vzero and exposing the photoconductor to two light exposures (Ezero) to estimate photoconductor discharge speed and residual voltage (toe voltage) before generating the print control patches. Then print control parameters are adjusted, including the Vzero and Ezero. When the current process measurements are received for information, including the Vzero, Ezero, and residual voltage, a processor calculates development potential (Vdev) using this information and Vdev, or a derivative thereof, is then compared to a range of stored voltages indicative of print quality so that these variables can be reset to improve print quality based on the comparison.

There are many factors that influence the charge-to-mass of the toner 14. The factors of interest, such as the temperature and humidity, are measured by the measurement device(s) 32. In this example, but not limited to this example, since the water content of the toner 14 is dependent on the water content of the air to which the toner is exposed, the removal of a humidity control mechanism and thus exposure to greater humidity levels in the vicinity of the toner can result in an increase in the charge-to-mass range of the toner and thus increase the external noise and thus quality problems to which the system is exposed. Humidity-insensitive toners may not sufficiently limit the charge-to-mass to a range and thus effectively control the formation of transfer artifacts and other quality problems. The quality controller can control toner concentration to partially counteract the effect of variations in humidity. That is, when the humidity is low and the toner charge-to-mass increases the toner concentration 24 is increased so that the toner charge-to-mass is reduced. When the humidity is high and the toner charge-to-mass is low, the toner concentration is decreased so that the toner charge-to-mass increases. Toner charge-to-mass tends to be inversely proportional to both toner concentration and humidity.

In order to adjust the toner concentration 24 to compensate for the toner charge-to-mass, the toning potential is used as a substitute for the toner charge-to-mass, as the toner charge-to-mass cannot be directly measured in the digital press. The toning potential is the process parameter that is used by process control to control the image density. However, the toning potential is also not directly measured or controlled but must be inferred from measured photoconductor properties and other process control parameters. The photoconductor parameters are determined in the manner described by Buettner (US 6,647,219). The photoconductor is uniformly charged to a voltage of –500V. Then exposures of 1.63 and 5.00 ergs/cm^2 are given to the photoconductor and the corresponding exposed voltages are measured by an electrostatic voltmeter. These two expose voltages are used to estimate the photodischarge speed and the residual voltage (toe voltage) of the photoconductor. Once the photoconductor speed and toe are known, the process control system prints density control patches and adjusts the photoconductor initial voltage (Vzero), the exposure, and the toning bias to provide the aim output density. From the process control parameters of Vzero, photoconductor toe, and the toning bias, the toning potential that is required to produce the aim output density under the current process conditions is calculated.

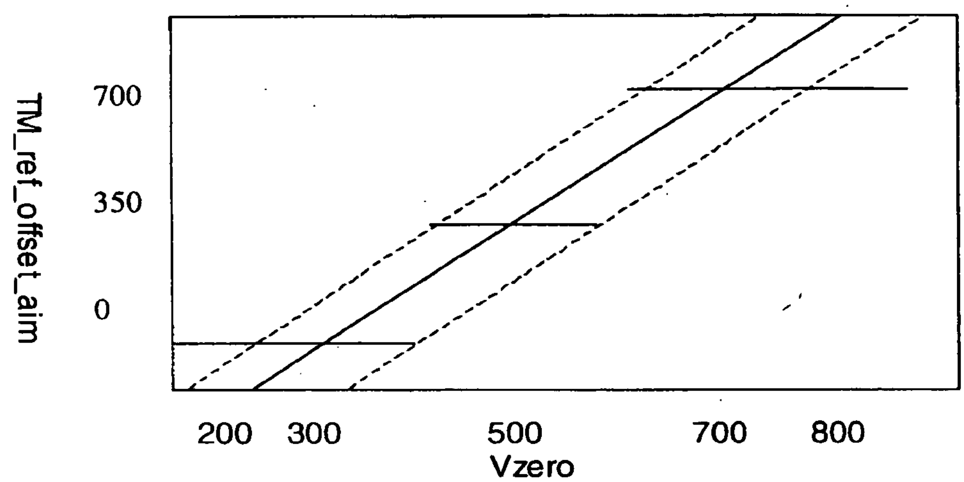
The toning potential is then tested to determine if it falls into a range that is consistent with a toner charge-to-mass that will not produce transfer artifacts or drive Vzero to values that are outside of the process control operating range. For example, the upper limit of the toning potential could be 400 V and the lower limit could be 200 V. If the toner concentration adjustment algorithm finds that the toning potential is greater than 200 V and less than 400 V, then the toner concentration will be adjusted to its nominal value (6% as an example). If the toning potential is greater than 400 V, the TC will be incrementally increased until the toning potential is equal to 400V or until an upper limit of the toner concentration is reached. If the toning potential is less than 200V, then the toner concentration will be decreased until the toning potential is equal to 200V or a lower limit for the toner concentration is reached. This algorithm is shown schematically in Figure 3. The steps enclosed in the dashed rectangle are only executed at machine power up or after the machine has been on for 10 hours. The steps outside the box are executed every process control cycle and the process control cycle is initiated every transport web revolution during active printing.

The toner concentration 24 is controlled by enabling addition of toner or refraining from adding toner to the development station based on the difference between a toner monitor signal voltage and a reference voltage that is stored in the toner concentration control system. The toner monitor is adjusted so that the reference signal is 2.5 V, for example. The toner concentration adjustment algorithm does not change the toner monitor reference signal to effect the adjustment but rather increments or decrements a toner monitor offset parameter. The parameter is adjusted by a defined increment on each process control cycle where an adjustment of the toner concentration is to be executed. Two differently sized increments are allowed. After the addition of a new developer mix, a larger increment or decrement of the toner monitor offset parameter is allowed for a selected number of process control cycles. After the selected number of process control cycles has been executed the increment reverts back to the smaller size that is normally used for the toner concentration control adjustment.

A schematic diagram of this method 44 is shown in Figure 3. More detail of the toner monitor offset adjustment and example values of the adjustable parameters of the method are described here and represented in Figure 4. The minimum value of the toner monitor offset is –1.00V. This allows the toner concentration to increase by 3% approximately. The maximum value of the toner monitor offset is +0.45V and this allows the toner concentration to decrease by 1.5% from its nominal value of 6%. The larger adjustment of the toner monitor offset used for fast toner concentration adjustment is 30mV per process control cycle. This larger adjustment is used for the first 50 process control cycles following a developer addition. The smaller adjustment of the toner monitor offset is 10mV per process control cycle.

In one preferred embodiment it is desirable to have asymmetric control to prevent the tendency for TC to rise with life as seen with previous developers in high humidity conditions. Given this characteristic, this embodiment starts with a toner concentration (TC) that is used as the minimum TC so that the controller adds toner to the aim concentration when needed, but never allows concentration to drop below this initialized level. This is done as follows:

a. TM_ref will be defined as the initialized value following a developer replacement procedure as always.
b. The aim value for TM_ref will be shifted to 2800 mV to account for the asymmetric TC control (previously 2500 mV is the target value).
c. TM_ref_offset_anchor will be defined as an offset to TM_ref which is valid at Vzero_initial. Vzero_initial is the photodischarge corrected starting points established during an automated process setup (APS). Vzero_initial generally corrects for photoconductor toe variation. The value of TM_ref_offset_anchor can have a range of 0 to 1000 mV, default is equal to 350 mV (1% over nominal concentration, and would apply to nominal 500 v Vzero, +/- 50 volts due to toe considerations).
d. TM_ref_offset_slope is the nominal adjust rate used to calculate the instantaneous TM_ref_offset_aim. This parameter is expressed as microvolts per Vzero volts and can have a range of 0 to 10,000, with a nominal value of 1,700 (results in 1% TC change over 200 Vzero range).
e. TM_ref_offset_min is a parameter to prevent the offset from exceeding a minimum value, which determines how low the minimum TC is offset from the build TC. The range for this parameter is –1000 to +1000, with a nominal value of 0. A value of zero means that the build TC is the minimum TC.
f. TM_ref_offset_max is a parameter to prevent the offset from exceeding a maximum value, which determines how high the maximum TC is offset from the build TC. The range of this parameter is –1000 to +1000, with a nominal value of +700.



In this embodiment the TC is proportional to Vzero, but not allowed to change rapidly using the following steps:

a. TM_ref_offset_aim is defined as a Vzero dependent calculation which sets the aim TM_ref_offset_aim = ...slope x (Vzero_aim – Vzero_initial) + TM_ref_offset_anchor. The value of this is allowed to adjust strictly according to the above relationship and is not subjected to min or max limits or step changes.
b. TM_ref_offset_actual is the operating TM_ref_offset, which is designed to converge on the TM_ref_offset_aim slowly by limiting the rate of adjustment in any one process patch cycle. This value is subjected to min and max limits as established by those parameters defined in e and f above.
c. TM_ref_offset_step_limit is the maximum allowed change to single TM_ref_offset_actual adjustment. This value is expressed as an absolute value, limiting positive and negative adjustments equally. The range for this parameter is 0 to 50, with a nominal value of 4, which leads to a maximum TC adjustment rate of 1% TC in 1925 prints (350 mV/%, 88 adjust cycles, 22 prints between adjustments).

In order to have a new developer converge on a mid-range TC before beginning any real-time control the additional steps are used:

a. When a developer is loaded, it is first stirred for a fixed time interval, then the fine tune electronic adjustment is made to drive TM_live to 2800, then the monitor is sampled for 20 seconds and an averaged monitor signal is stored as TM_ref.
b. Following this the TM_ref_offset_aim and TM_ref_offset_actual will be set equal to the TM_ref_offset_anchor.
c. The "add toner" service routine will then run to drive TM_cur to be adjusted to converge on the TM_ref - TM_ref_offset_actual. This action will nominally add 1% TC to this new developer. The starting TC could be based on feed-forward from an Rh sensor.

TC catch-up is scheduled when Vzero is near the values that correspond to the toning potential limits because when Vzero approaches the limits of control, it may be desirable to allow the TC to more rapidly catch up to the TM_ref_offset_aim. We have acknowledged that on the low side, when Vzero is below 300 volts that we are in a degraded quality regime. Therefore the potential instability effects of rapid TC catch up may be less objectionable than sustained operation in that condition. Likewise when Vzero exceeds 700 volts transfer artifacts are quite likely and generally the system is less stable. In these areas of operation, TC is allowed to adjust more rapidly using the following steps:

a. TM_ref_offset_Vzero_min and TM_ref_offset_Vzero_max are defined as threshold Vzero levels where catch up behavior kicks in. The range for these parameters is 250 – 800, the nominal min value is 300, and the max value is 700.
b. TM_ref_offset_step_limit_catchup is a step limit value which applies to adjustments made when Vzero is operating below the min or above the max values described by 5a. The allowed range for this parameter is 0 to 50, with a nominal value of 35. This leads to a potential rate of TC adjustment of 1% within 220 prints.

The implementation of a check on whether a large adjustment of the toner concentration is necessary is described here. For example, this might be needed if the humidity was low as indicated by the system monitor(s) 32, on Friday afternoon at the end of the day and high on Monday morning at machine startup. The need for the adjustments described in the following is yet to be determined. In order to execute the check, the toning potential from the previous setup would need to be stored and compared to the needed toning potential calculated during an automated process setup (APS) that would be executed at machine startup. If the change in required toning potential exceeded a threshold value, e.g. 200V, then the machine operator would be warned that process control limits were likely to be exceeded and color reproduction might be compromised unless the toner concentration 24 is adjusted. The operator would be led to service routines to execute either a rapid addition of toner 14 to the development station or a rapid removal of toner from the development station. The removal of toner 14 would be designed to collect a minimum amount of waste toner in the front side web cleaner.

As discussed above, the environment changes such as those detected by the system monitor 32, can change the charge-to-mass of the developer and this change in charge-to-mass can affect the bulk density of the aerated developer, including toner 14, in front of the toner monitor – the net affect being that TC tends to rise at high dew point and drop at low dew point, and this effect further challenges the system dynamic range and thus performance. The Vzero feedback to toning potential, as described in co-pending application Serial No. 11/453, 218 entitled "Print Quality Maintenance Method and System", filed June 14, 2206, by Slattery, et al., which is incorporated by reference, acts to counteract this basic affect. Sometimes, the effects due to environment are large the following embodiment is effective. For example, a black only job-stream could result in climbing Vzero even though humidity is constant at a nominal or high level. This could drive toner concentration (TC) 24 to be at such a high level as to cause a failure mode where the developer cohesiveness overcomes the magnetic agitation and compressed developer sticks to the image cylinder, leading to destruction of the image cylinder and dry ink station.

One embodiment of the toner concentration control system and method adds a check as to whether a large toner (monitor) offset is justified by the ambient conditions in the room. Figure 6 is a graphical representation showing this embodiment of the control system. This graph shows toner concentration (TC) % (100) versus V2zero (110). The temperature and humidity (Rh) sensors, as shown in Figure 1 are part of the system monitor(s) 32, and produce signals 40 that are available to the electrophotographic printer through the EP module control unit, also referred to as the control device 22. This allows for more complete toner concentration control rates and offsets by checking to see whether a calculated toner monitor offset is justified by the water content of the air and by inference, the charge-to-mass of the toner. A large toner monitor offset is only allowed if the calculated request is consistent with the environmental condition(s). The temperature and humidity (Rh) sensor(s) are not used to directly control the toner concentration 24, but as a check of the validity of a toner concentration adjustment.

<u>Toner concentration control system and method</u>

Two sets of TM_ref_offset_min and max are created as represented in Figure 6. The selection of which limit to use will be determined based on a dew point calculation.

TM_ref_offset_min_high_DP = -175
TM_ref_offset_min_low_DP = +175
TM_ref_offset_max_high_DP = + 525
TM_ref_offset_max_low_DP = + 875

The ambient temperature and humidity sensor readings from the system monitor 32 can indicate that the temperate and humidity readings in the vicinity of the machine if the monitor(s) are located locally, that is in the vicinity of the machine. These readings can be stored locally or remotely and accessed to enable corrections to be made, using a simple formula to estimate dew point (DP) as follows:

$$DP = K_1 + (K_2 * Temp) + (K_3 * Rh)$$

$$K_1 = -50.3$$

$$K_2 = 0.88$$

$$K_3 = 0.79$$

The calculated dew point will influence which TM_ref_offset min and max limits to use. Additional PIDs will dictate the Dew-Point Threshold to determine if the Dew Point is high or low.

TM_ref_offset_min_DP_threshold = 50 (120)
TM_ref_offset_max_DP_threshold = 34 (130)

For each min / max offset limit, the active limit will be determined by comparing the current calculated dew point to the respective TM_ref_offset_xxx_DP_threshold. If the calculated DP is higher than the threshold, the TM_ref_offset_xxx_high_DP value is used, and if it is lower the TM_ref_offset_xxx_low_DP is used.

The full range of TM_ref_offset is now 50% larger than it was. The original design drove TC 1% over a 200 v Vzero range. Due to the larger range, the slope is increased 50% to drive TC 1.5% over a 200 v Vzero Change.

TM_ref_offset_slope is the nominal adjust rate used to calculate the instantaneous TM_ref_offset_aim. This parameter is expressed as microvolts per Vzero volts and can have a range of 0 to 10,000, with a nominal value of 2,550 (results in 1.5% TC change over 200 Vo range).

The sensor measured inputs for temperature and humidity can be checked for plausibility, and if values are found outside of a reasonable range, the dew-point shall be assumed to be "nominal" of 42. If temperature is not within the range of 60 – 90 F, or Rh is not within the range of 5 – 80 %, the dewpoint shall be defaulted to 42.

A warning can be generated that the measured temperature and/or humidity, sometimes measured as relative humidity; are well outside of the expected range resulting in non-optimized imaging control.

This system and related method thus controls the toner concentration response by setting the min and max offsets for the two dew points to be equal to each other and the previous values, and by restoring the slope parameter.

CLAIMS:

1. Method for maintaining print quality based on development potential measurements, said method comprising the steps:

a. receiving environmental information;
b. receiving current process measurements including a measured toner concentration related value;
c. comparing the current process measurements to one or more toner concentration related ranges, each range having a related minimum and maximum toner concentration or derivative thereof;
d. determining the appropriate toner concentration related range, comprising a minimum and maximum toner concentration, or derivative thereof, indicative of print quality for the current environmental information; and
e. generating at least one signal based on the determination.

2. Method of Claim 1, wherein said environmental information comprises local information comprising at least one of temperature and /or humidity.

3. Method of Claim 2, wherein said environmental information further comprises other toner concentration effecting factors comprising one or more of the following: energy levels, time, location, printer type, operator, time, sound, and job type.

4. Method of Claim 1, further comprising adjusting the toner concentration at a controlled rate of change that is optimized based on a set of rules that are chosen based on current environmental information.

5. Method of Claim 1, wherein said generated signal, based on Vdev, is used to control toner concentration by adding toner.

6. Method of Claim 1, wherein said generated signal, based on Vdev, is used to control toner concentration by withholding toner.

7. Method of Claim 1, wherein said generated signal is used to decrease toner concentration by withholding toner, based on one or more environmental factors including humidity, temperature, and air quality.

8. Method of Claim 1, wherein said generated signal is used to increase toner concentration by adding toner, based on the environmental information.

9. An electrophotographic printer without a humidification system, including an apparatus for maintaining print quality based on development potential measurements (Vdev), said apparatus comprising:

a. a power supply for charging a photoconductor to a photoconductor voltage (Vzero) related to a toner concentration;

b. a voltage controller for said Vzero, thereby causing, over the course of a time interval, voltage control of said Vzero;

c. at least one measurement devices to determine current measured environmental information;

d. a processing device for determining a toner concentration range with a minimum and a maximum toner concentration, or a derivative thereof, from one or more toner concentration related ranges, or a derivative thereof, based on the current measured environmental information;

e. a comparator wherein the toner concentration, or a derivative thereof, is compared to the toner concentration range;

g. an adjuster to adjust the toner concentration to within the minimum and a maximum toner concentrations; and

f. a signal generator for generating one or more signals based on the comparator and/or the adjuster.

10. Apparatus of Claim 9, wherein said environmental information comprises local information comprising at least one of temperature and /or humidity.

11. Apparatus of Claim 10, wherein said environmental information further comprises other toner concentration related factors comprising one or more of the following: energy levels, time, location, printer type, operator, time, sound, and job type.

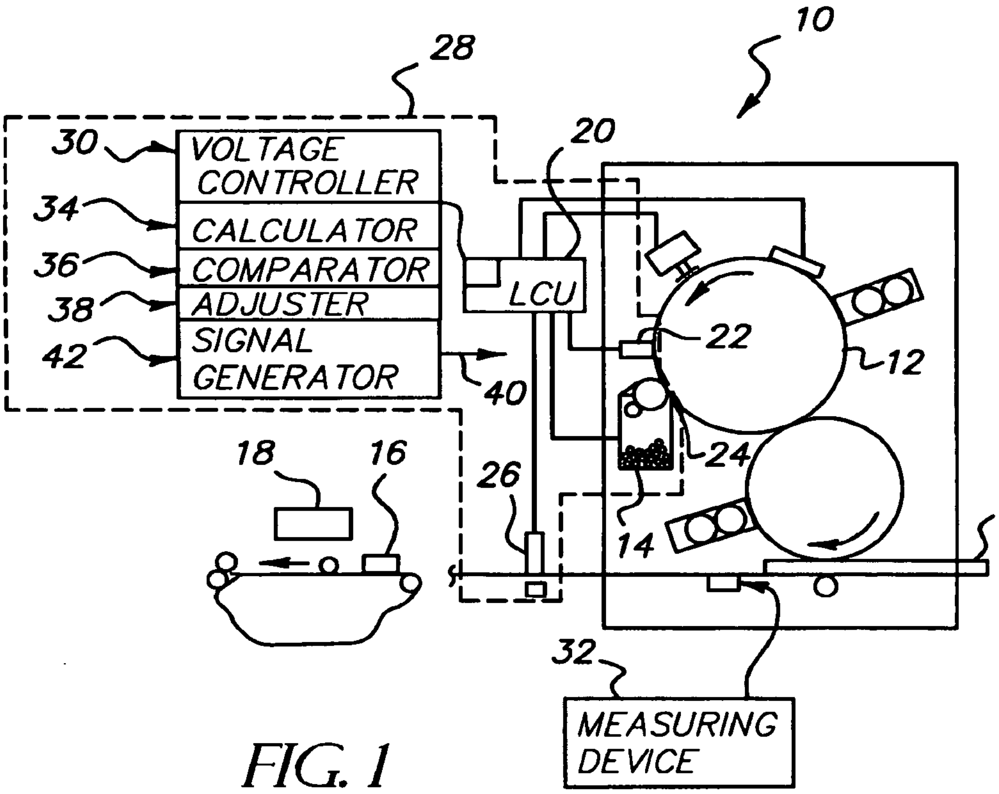
12. Apparatus of Claim 9, wherein said generated signal is used to control toner concentration by adding toner.

13. Apparatus of Claim 9, wherein said generated signal is used to control toner concentration by withholding toner.

14. Apparatus of Claim 9, wherein said generated signal controls toner concentration, based on one or more environmental factors including humidity, temperature, and air quality.

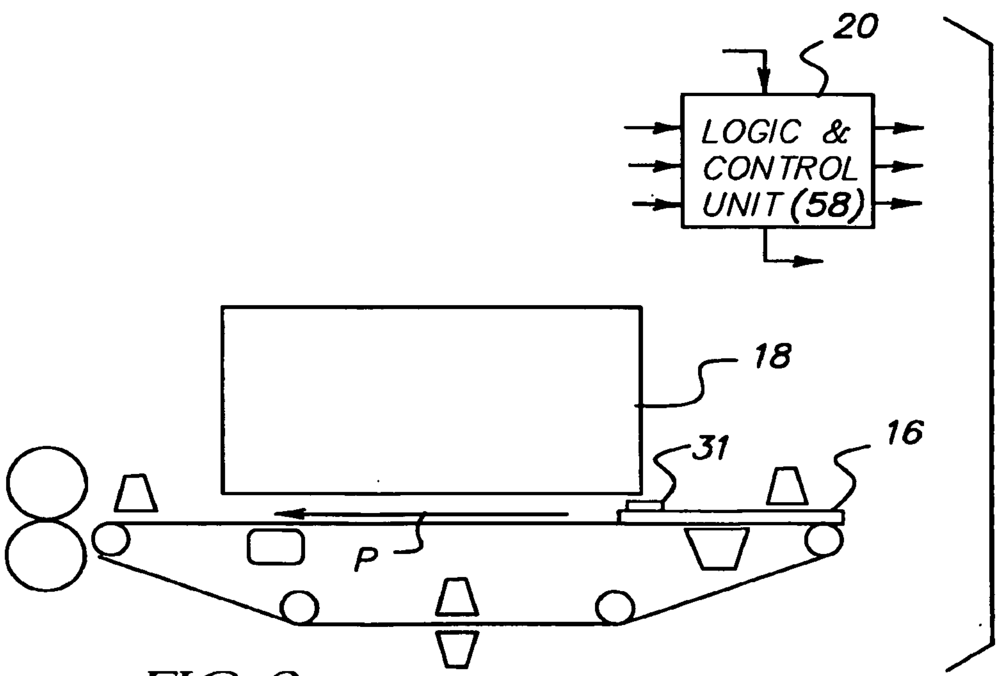
15. Apparatus of Claim 9, including a computer, which incorporates, said means for activating said power supply, the adjuster, the comparator, and said means for activating or deactivating a toner supply.

16. Apparatus of Claim 9, wherein said toner concentration range has a plurality of ranges, each with a minimum and a maximum.



10
28
30
VOLTAGE CONTROLLER
34
CALCULATOR
36
COMPARATOR
38
ADJUSTER
42
SIGNAL GENERATOR
40
20
LCU
22
12
24
14
26
18
16
16
32
MEASURING DEVICE

FIG. 1



20
LOGIC & CONTROL UNIT (58)
18
31
16
P

FIG. 2

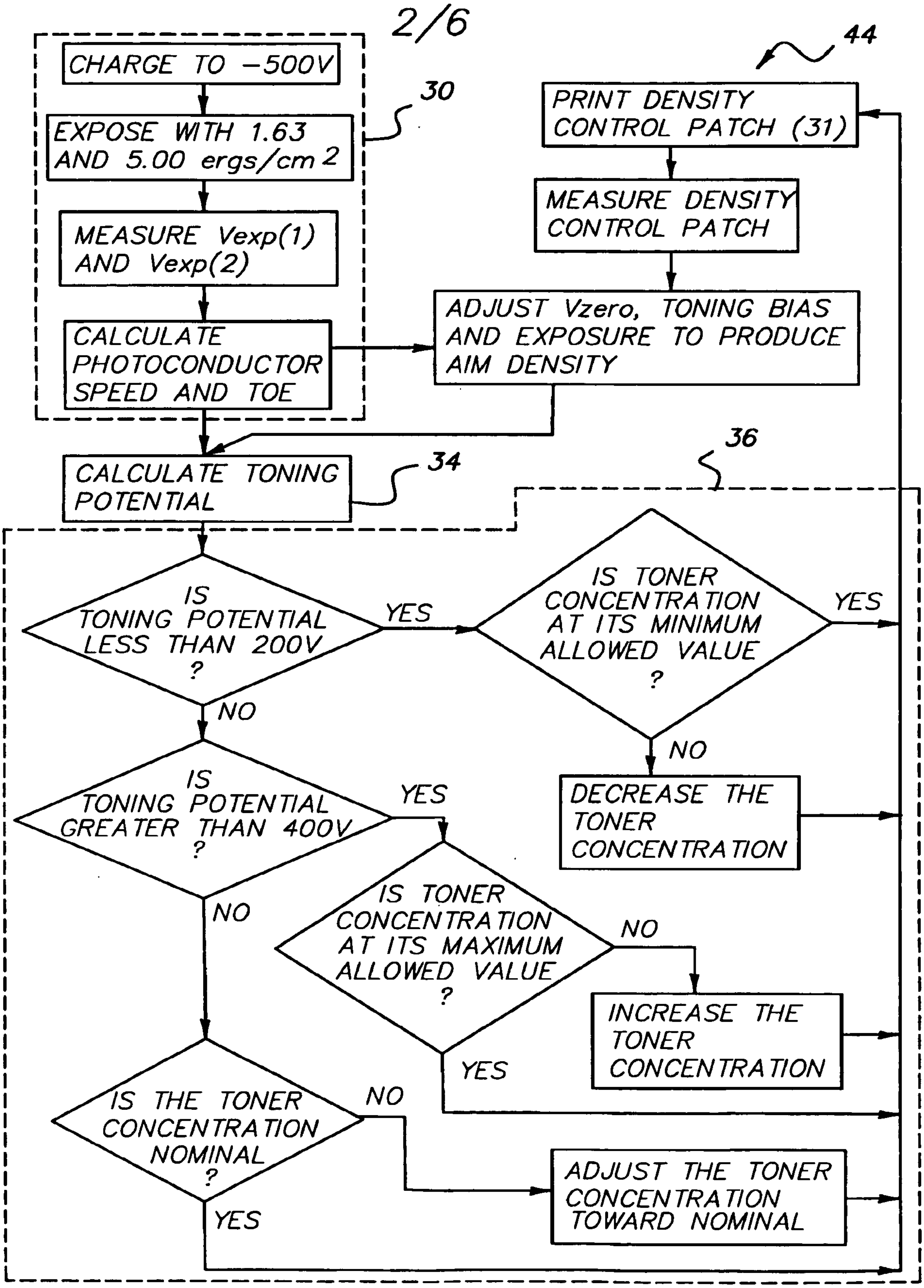

44
30
CHARGE TO -500V
EXPOSE WITH 1.63 AND 5.00 ergs/cm 2
MEASURE Vexp(1) AND Vexp(2)
CALCULATE PHOTOCONDUCTOR SPEED AND TOE
PRINT DENSITY CONTROL PATCH (31)
MEASURE DENSITY CONTROL PATCH
ADJUST Vzero, TONING BIAS AND EXPOSURE TO PRODUCE AIM DENSITY
CALCULATE TONING POTENTIAL
34
36
IS TONING POTENTIAL LESS THAN 200V ?
YES
NO
IS TONER CONCENTRATION AT ITS MINIMUM ALLOWED VALUE ?
YES
NO
DECREASE THE TONER CONCENTRATION
IS TONING POTENTIAL GREATER THAN 400V ?
YES
NO
IS TONER CONCENTRATION AT ITS MAXIMUM ALLOWED VALUE ?
NO
YES
INCREASE THE TONER CONCENTRATION
IS THE TONER CONCENTRATION NOMINAL ?
NO
YES
ADJUST THE TONER CONCENTRATION TOWARD NOMINAL

FIG. 3

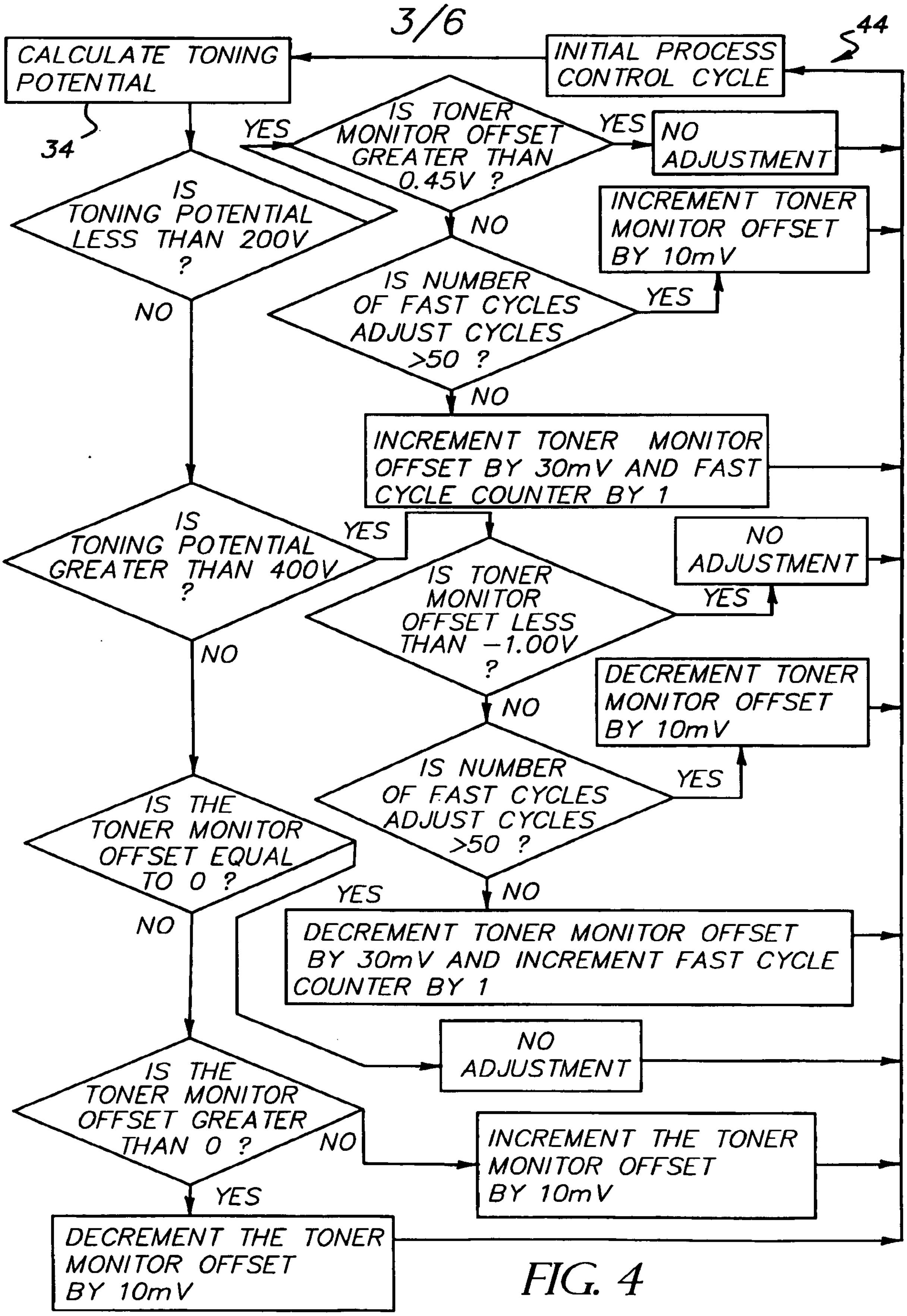

CALCULATE TONING POTENTIAL
34
INITIAL PROCESS CONTROL CYCLE
44
IS TONING POTENTIAL LESS THAN 200V ?
YES
NO
IS TONER MONITOR OFFSET GREATER THAN 0.45V ?
YES
NO ADJUSTMENT
NO
IS NUMBER OF FAST CYCLES ADJUST CYCLES >50 ?
YES
INCREMENT TONER MONITOR OFFSET BY 10mV
NO
INCREMENT TONER MONITOR OFFSET BY 30mV AND FAST CYCLE COUNTER BY 1
IS TONING POTENTIAL GREATER THAN 400V ?
YES
NO
IS TONER MONITOR OFFSET LESS THAN −1.00V ?
YES
NO ADJUSTMENT
NO
IS NUMBER OF FAST CYCLES ADJUST CYCLES >50 ?
YES
DECREMENT TONER MONITOR OFFSET BY 10mV
NO
DECREMENT TONER MONITOR OFFSET BY 30mV AND INCREMENT FAST CYCLE COUNTER BY 1
IS THE TONER MONITOR OFFSET EQUAL TO 0 ?
YES
NO ADJUSTMENT
NO
IS THE TONER MONITOR OFFSET GREATER THAN 0 ?
NO
INCREMENT THE TONER MONITOR OFFSET BY 10mV
YES
DECREMENT THE TONER MONITOR OFFSET BY 10mV

FIG. 4

4/6

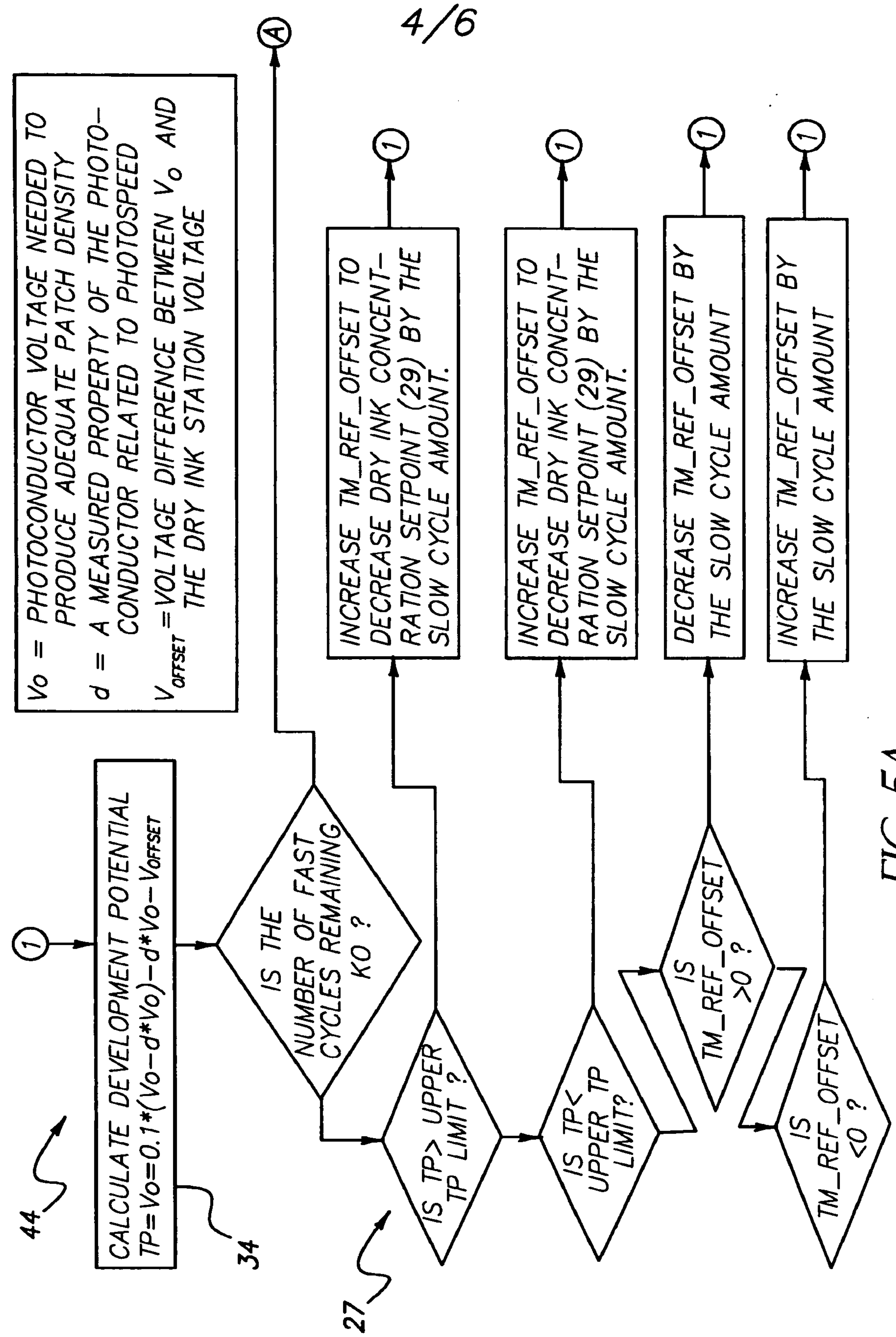

Vo = PHOTOCONDUCTOR VOLTAGE NEEDED TO PRODUCE ADEQUATE PATCH DENSITY
d = A MEASURED PROPERTY OF THE PHOTOCONDUCTOR RELATED TO PHOTOSPEED
VOFFSET = VOLTAGE DIFFERENCE BETWEEN Vo AND THE DRY INK STATION VOLTAGE
1
CALCULATE DEVELOPMENT POTENTIAL TP=Vo=0.1*(Vo−d*Vo)−d*Vo−VOFFSET
44
34
IS THE NUMBER OF FAST CYCLES REMAINING KO ?
A
27
IS TP> UPPER TP LIMIT ?
INCREASE TM_REF_OFFSET TO DECREASE DRY INK CONCENTRATION SETPOINT (29) BY THE SLOW CYCLE AMOUNT.
IS TP< UPPER TP LIMIT?
INCREASE TM_REF_OFFSET TO DECREASE DRY INK CONCENTRATION SETPOINT (29) BY THE SLOW CYCLE AMOUNT.
IS TM_REF_OFFSET >0 ?
DECREASE TM_REF_OFFSET BY THE SLOW CYCLE AMOUNT
IS TM_REF_OFFSET <0 ?
INCREASE TM_REF_OFFSET BY THE SLOW CYCLE AMOUNT

FIG. 5A

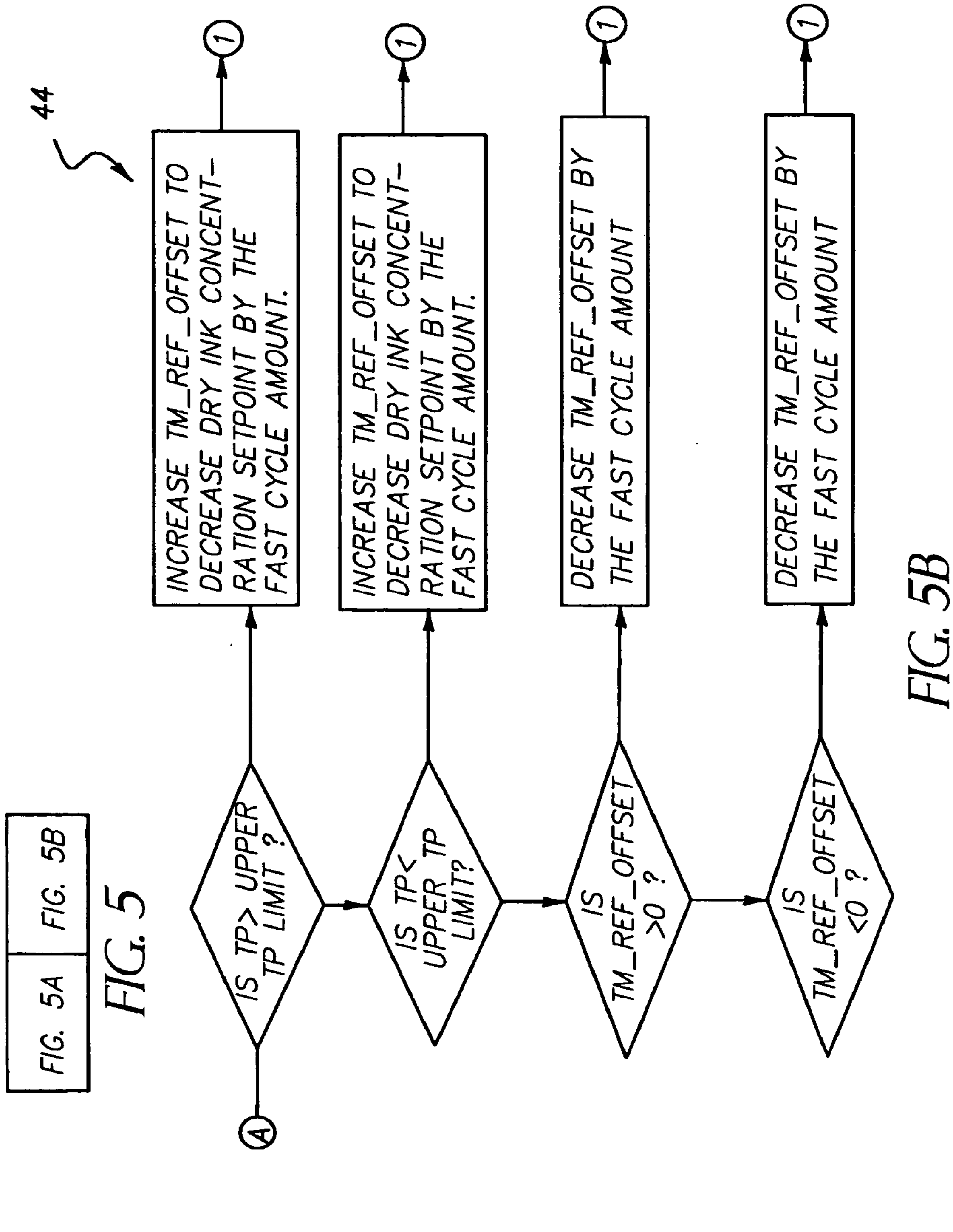


FIG. 5A
FIG. 5B
44
IS TP> UPPER TP LIMIT ?
INCREASE TM_REF_OFFSET TO DECREASE DRY INK CONCENT-RATION SETPOINT BY THE FAST CYCLE AMOUNT.
IS TP< UPPER TP LIMIT?
INCREASE TM_REF_OFFSET TO DECREASE DRY INK CONCENT-RATION SETPOINT BY THE FAST CYCLE AMOUNT.
IS TM_REF_OFFSET >0 ?
DECREASE TM_REF_OFFSET BY THE FAST CYCLE AMOUNT
IS TM_REF_OFFSET <0 ?
DECREASE TM_REF_OFFSET BY THE FAST CYCLE AMOUNT
A
1
1
1
1

FIG. 5

FIG. 5B

6/6

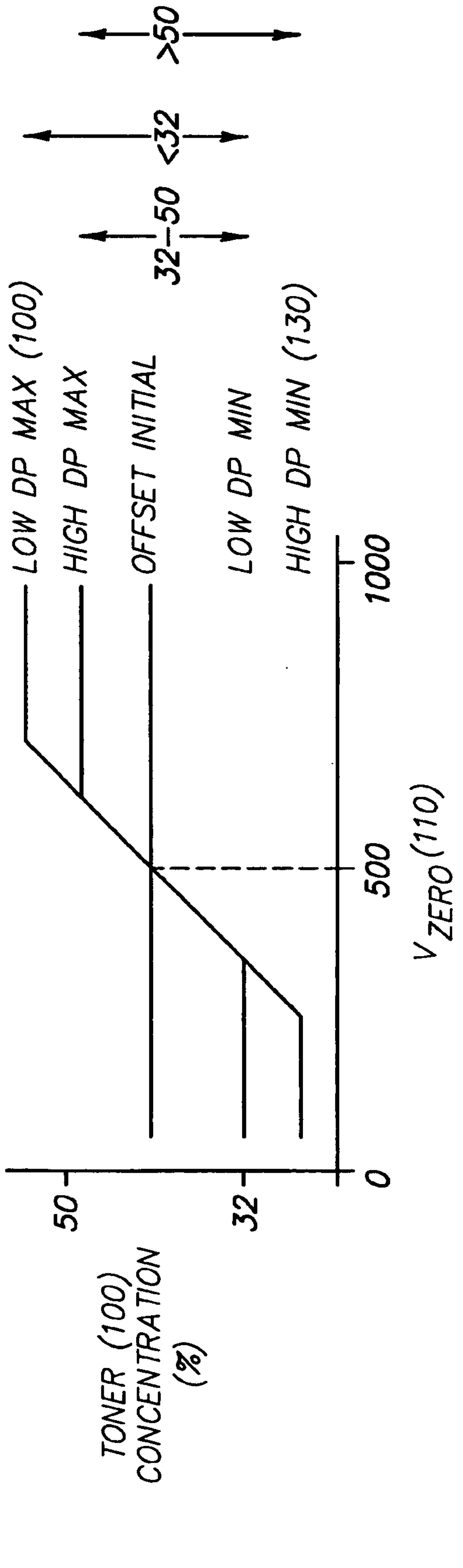

>50
<32
32–50
LOW DP MAX (100)
HIGH DP MAX
OFFSET INITIAL
LOW DP MIN
HIGH DP MIN (130)
TONER (100)
CONCENTRATION
(%)
50
32
0
500
1000
V_{ZERO} (110)

FIG. 6