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McVeigh

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[54] **COLOR STANDARD AND METHOD OF CALIBRATING A MULTI-COLOR ELECTROPHOTOGRAPHIC PRINTING MACHINE**

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[52] **U.S. Cl.** .... **355/4,** 95/1 R, 96/1.2, 355/17, 355/88

[51] **Int. Cl.** **G03g 15/00**

[58] **Field of Search** .... 355/4, 17, 88; 95/1 R; 96/1.2

[56] **References Cited**

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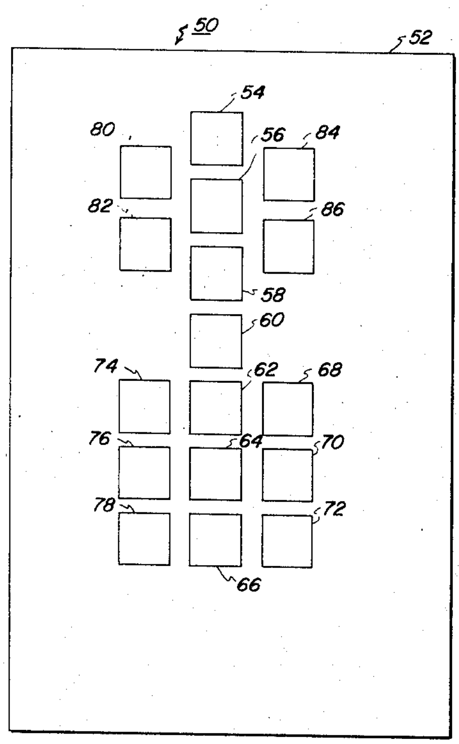
[57] **ABSTRACT**

A color standard and method of use therefore in which a multi-color electrophotographic machine is calibrated for controlling the color balance and image density of a copy being reproduced therein.

17 Claims, 3 Drawing Figures



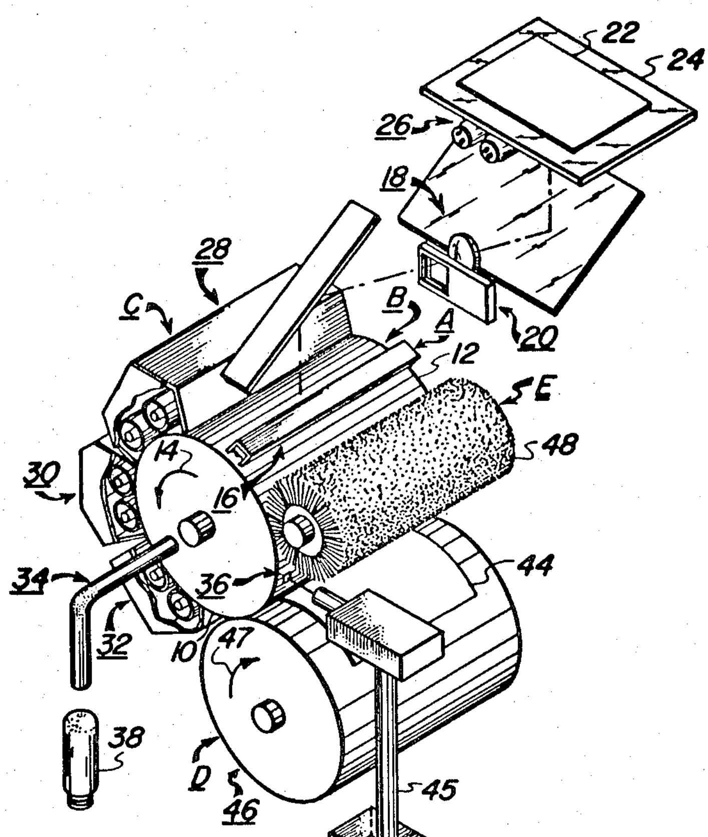


FIG. 1

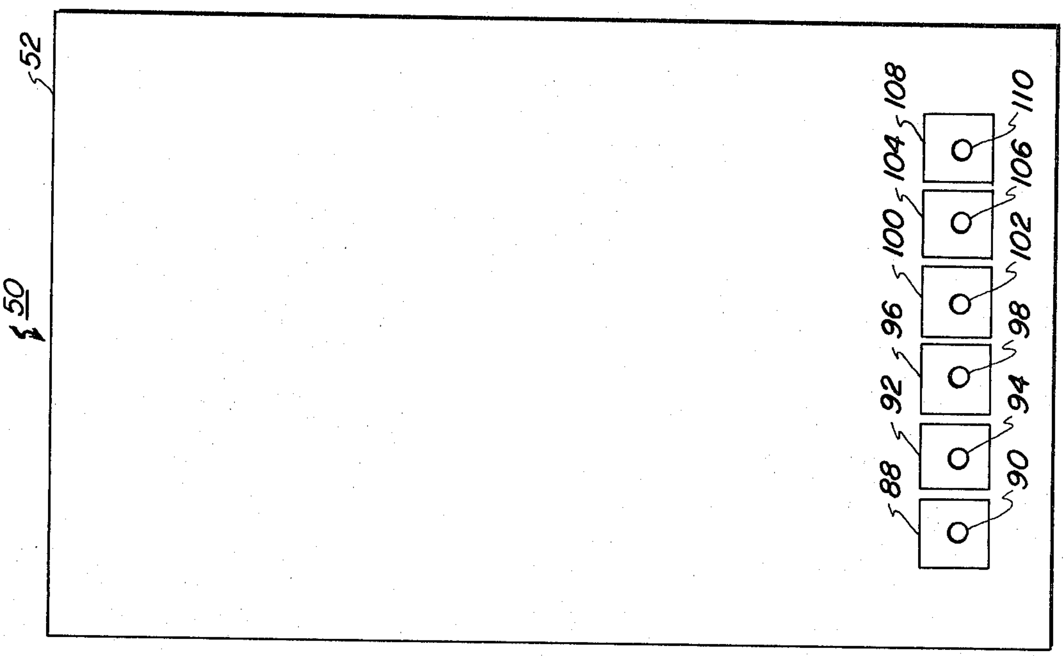

52
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FIG. 3

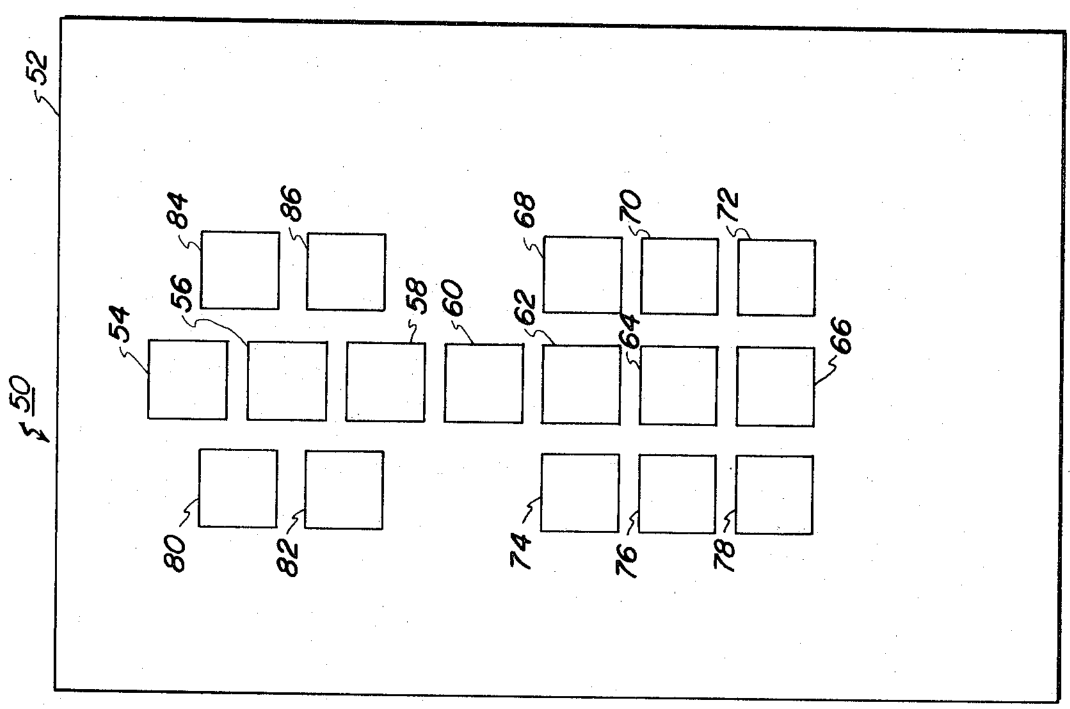
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FIG. 2

COLOR STANDARD AND METHOD OF CALIBRATING A MULTI-COLOR ELECTROPHOTOGRAPHIC PRINTING MACHINE

BACKGROUND OF THE INVENTION

This invention relates generally to a multi-color electrophotographic printing machine, and more particularly concerns a color standard and method of use therefore in which the multi-color electrophotographic printing machine is calibrated for controlling the color balance and density of copies being reproduced thereon.

In a multi-color electrophotographic printing machine, developability is defined as the ability of the developer mix used therein to form an image having a specified density and color balance. A developability control system adjusts the concentration of developer mix to produce images on a copy which have a suitable density and color balance. Developability is related to the concentration of toner particles in the developer mix. By this, it is meant that the percentage of toner particles relative to carrier granules in the developer mix is a major factor in defining the developability capability of the printing machine. Thus, the function of the developability control system is to regulate the toner particle concentration within the developer mix to aid in maintaining the appropriate image density and color balance of the copy being reproduced.

Generally, an electrophotographic printing machine, particularly a multi-color printing machine, utilizes a plurality of discretely colored toner particles. The density of toner particles relative to one another on the copy defines the color balance of the system. The density of toner particles on the copy is a function of the toner particle concentration in the developer mix. The developability control system has included therein appropriate circuitry arranged to provide a variable reference which represents the desired toner particle level within the respective developer mix. Hence, as the level of the reference for the respective toner particles within the developability control system is varied, the color balance within the electrophotographic printing machine changes. In order to obtain multi-color copies having the desired color balance and density, the printing machine must be calibrated in the field prior to the installation thereof.

Calibration of a multi-color printing machine requires adjustment of the development system, exposure system and developability regulating system to substantially optimize color copies being produced thereon. Heretofore, no simple procedure has been developed which facilitates the ready calibration of a multi-color printing machine. Moreover, any such calibration procedure should insure that the color balance and density of copies being reproduced on the printing machine are within the desired standards for the requisite period of operation.

Accordingly, it is the primary object of the present invention to improve the method of calibrating a multi-color electrophotographic printing machine.

SUMMARY OF THE INVENTION

Briefly stated, and in accordance with the present invention, there is provided a method of calibrating a multi-color electrophotographic printing machine for controlling the color balance and density thereof.

In the preferred method, the printing machine is placed in the calibration mode of operation for producing first color test copies. The printing machine is actuated to produce the first color test copies which are then compared to the color standard. Thereafter, the developability regulating mechanism of the printing machine is adjusted until successive first color test copies are intermediate a maximum and minimum density color samples of the color standard corresponding to the first color test copies.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the present invention will become apparent upon reading the following detailed description and upon reference to the drawings, in which:

FIG. **1** is a schematic perspective view of a multi-color electrophotographic printing machine having a developability regulating mechanism for controlling the color balance and density of copies being reproduced thereby;

FIG. **2** is a front elevational view of the color standard utilized for calibrating the FIG. **1** printing machine; and

FIG. **3** is a back elevational view of the FIG. **2** color standard.

While the present invention will be described in connection with the preferred embodiment and method of use therefore, it will be understood that it is not intended to limit the invention to that embodiment and method of use. On the contrary, it is intended to cover all alternatives, modifications and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

With continued reference to the drawings wherein like reference numerals have been used throughout to designate like elements, FIG. **1** schematically depicts an electrophotographic printing machine in which the present invention may be utilized for the calibration thereof. The electrophotographic printing machine illustrated schematically in FIG. **1** shows the various components utilized therein for producing multi-color copies from a colored original.

Electrophotographic printing machines employ a drum **10** mounted rotatably within the machine frame (not shown) and having a photoconductive surface **12** mounted on the exterior circumferential surface thereof. One type of suitable photoconductive material is disclosed in U.S. Pat. No. 3,655,377 issued to Sechak in 1972. A series of processing stations are disposed such that as drum **10** rotates in the direction of arrow **14**, it passes sequentially therethrough. Drum **10** is driven at a predetermined speed relative to the other machine operating mechanisms from a common drive motor (not shown). The various machine operations are coordinated with one another to produce the proper sequence of events at the appropriate processing stations.

Initially, drum **10** rotates so that photoconductive surface **12** moves through charging station A. Charging station A has positioned thereat a corona generating device, indicated generally at **16**. As shown in FIG. **1**, corona generating device **16** extends in a generally transverse direction across photoconductive surface **12**. This readily enables corona generating device **16** to charge photoconductive surface **12** to a relatively high substantially uniform potential. Preferably, corona generating device **16** is of a type described in U.S. Pat. No. 2,778,946 issued to Mayo in 1957.

Drum **10**, thereafter, is rotated to exposure station B where the charged photoconductive surface **12** is exposed to a color filtered light image of the original document. Exposure station B includes thereat a moving lens system, generally designated by the reference numeral **18**, and a color filter mechanism shown generally at **20**. A suitable moving lens system is disclosed in U.S. Pat. No. 3,062,108 issued to Mayo in 1962, and a suitable color filter mechanism is described in copending application Ser. No. 830,282 filed in 1969. Filter mechanism **20** includes a neutral density filter adapted to regulate the minimum discharge level of photoconductive surface **12**. In association with the neutral density filters are blue, red and green filters. These filters are utilized therein in order to form color separated light images of the original document. Each colored filter may have a corresponding neutral density filter associated therewith. As part of the calibration procedure for the multi-color electrophotographic printing machine, the appropriate neutral density filter, if required, is selected to correspond with its respective colored filter.

With continued reference to FIG. **1**, an original document **22**, such as a sheet of paper, book, or the like is placed face down upon transparent viewing platen **24**. Lamp assembly **26** and lens system **18** are moved in a timed relation with drum **10** to scan successive incremental areas of original document **22** disposed upon platen **24**. In this manner, a flowing light image of original document **22** is projected onto photoconductive surface **12**. Filter mechanism **20** is adapted to interpose selected color filters and their respective neutral density filters into the optical light path. The appropriate color filter and its associate neutral density filter operate on the light rays passing through lens **18** to record an electrostatic latent image on photoconductive surface **12** corresponding to a preselected region of the electromagnetic wave spectrum hereafter referred to as a single color electrostatic latent image. An exposure slit (not shown) is operatively associated with filter mechanism **20** and lens **18**. The exposure slit slot is used to control the length of time the flowing light image is projected onto photoconductive surface **12**. Since the rotation of drum **10** is substantially constant, increasing the width of the slit increases the amount of time light strikes any area on photoconductive surface **12**. Thus, the exposure slit acts in a similar manner as the aperture of lens **18** which may be changed to alter the amount of light passing therethrough. The exposure slit may be disposed beneath platen **24** or above drum **10** in the optical light path.

After exposure, drum **10** rotates the single color electrostatic latent image recorded on photoconductive surface **12** to development station C. Development station C includes thereat three individual developer units, generally designated by the reference numerals **28, 30** and **32**, respectively. A suitable development station employing a plurality of developer units is disclosed in copending application Ser. No. 255,259, filed in 1972. Preferably, the developer units are all of a type referred to generally as magnetic brush developer units. In a magnetic brush development system, a developer mix typically comprising magnetic iron carrier granules together with colored resin toner particles is supplied to an electrostatic latent image recorded on photoconductive surface **12**. In such an apparatus, the iron particles are held by a magnetic roller in a bristle-like formation resembling a brush with the toner particles adhering to the iron by electrostatic attraction. The bristles of iron particles are electrically conductive and contribute to the transfer therefrom of toner particles to the charged photoconductive surface. A magnetic roller of this type is generally electrically biased at some fixed potential above ground. The electrostatic latent image recorded on photoconductive surface **12** is developed by bringing the brush of developer mix into contact therewith. Each of the respective developer units contain discretely colored toner particles corresponding to the complement of the spectral region of the wavelength of light transmitted through filter mechanism **20**, e.g. a green filtered electrostatic latent image is rendered visible by depositing green absorbing magenta toner particles thereon, blue and red latent images are developed with yellow and cyan toner particles, respectively. Preferably, each developer unit, **28, 30** and **32**, is electrically biased to a potential of about 500 volts.

Additional toner particles may be added to their respective developer mix when developability is reduced deleteriously. The developability regulating systems, indicated generally at **34**, includes a transparent electrode **36** mounted on photoconductive surface **12** of drum **10**. A light source **38** cooperates with fiber optic light pipe **40** to transmit light rays through transparent electrode **36**. During development, transparent electrode **36** is biased electrically to attract toner particles thereto. The toner particles are deposited on transparent electrode **36** during development and the intensity of the light rays passing therethrough is indicative of the density thereof. A photosensor **42**, located in oven **43**, is in a light receiving relation with light rays transmitted through transparent electrode **36** via fiber optic light pipe **45** and produces an electrical output signal corresponding to the intensity of rays passing therethrough. Suitable analog reference circuitry compares the electrical output signal from photosensor **42** with an adjustable reference to generate a logic control signal for dispensing selected toner particles into the corresponding developer unit. The logic elements, preferably, include a suitable discriminator circuit for comparing the reference with the electrical output signal from photosensor **42**. The discriminator circuit may utilize a silicone control switch which turns on and effectively locks in after an electrical output signal has been obtained having a magnitude greater than the reference (i.e. set point). The signal from the discriminator circuit changes the state of a flip-flop to generate an output signal therefrom. The output signal from the flip-flop, in conjunction with an output signal from the appropriate developer unit actuates an AND gate. The AND gate transmits a control signal to the toner dispenser housing the toner particles for the developer unit generating the signal output to the AND gate. The control signal also resets the flip-flop. The type of logic circuit heretofore disclosed is on-off. However, in the alternative, it is possible to utilize portional circuitry which varies the quantity of toner particles dispensed to the respective developer units as a function of the magnitude of the control signal. This may be achieved by a suitable integrated circuit module arranged to produce a stepped proportional dispensing rate. Duplicate logic elements are utilized for each developer unit, i.e. yellow developer unit, cyan developer unit and magenta developer unit. Hence, there are three separate independent logic channels, each channel being associated with its respective developer unit. The density of toner particles deposited on photoconductive surface **12** is a function of the concentration of toner particles within the developer mix. The concentration of toner particles is, in turn, a function of the magnitude of the reference in the developability regulating mechanism. Thus, by adjusting the respective references, image density as well as color balance is regulated. The foregoing is described in greater detail in copending application Ser. No. 213,056, filed in 1971.

Drum **10** is next rotated to transfer station D where the toner powder image adhering electrostatically to photoconductive surface **12** is transferred to a sheet of final support material **44.** Final support material **44** may be, amongst others, plain paper or a thermoplastic sheet. A transfer roll, shown generally at **46,** recirculates support material **44** and is biased electrically to a potential of sufficient magnitude and polarity to attract electrostatically toner particles from the latent image recorded on photoconductive surface **12** to support material **44.** A suitably electrically biased transfer roll is described in U.S. Pat. No. 3,612,677 issued to Langdon et al. in **1971.** Transfer roll **46** rotates in the direction of arrow **47** in synchronism with drum **10,** i.e. in this case at substantially the same angular velocity. Inasmuch as support material **44** is secured releasably thereon for movement in a recirculating path therewith, successive toner powder images may be transferred thereto in superimposed registration with one another.

After the toner powder images have been transferred to support material **44,** support material **44** is separated from bias transfer roll **46** and advanced to a suitable fuser (not shown) which coalesces the transferred powder image thereto. One type of suitable fuser is described in U.S. Pat. No. 3,498,592 issued to Moser et al. in 1970. After the fusing process, support material **44** is advanced by a plurality of endless belt conveyors (not shown) to a catch tray (not shown) for subsequent removal therefrom by the machine operator.

Although a preponderance of toner particles are transferred to support material **44,** invariably some residual toner particles remain on photoconductive surface **12** after the transfer of the toner powder image to support material **44.** These residual toner particles are removed from photoconductive surface **12** as it moves through cleaning station E. Here the residual toner particles are first brought under the influence of a cleaning corona generating device (not shown) adapted to neutralize the electrostatic charge remaining on the toner particles. The neutralized toner particles are then mechanically cleaned from photoconductive surface **12** by a rotatably mounted fibrous brush **48.** A suitable brush cleaning device is described in U.S. Pat. No. 3,590,412 issued to Gerbasi in **1971.** Rotatably mounted brush **48** is positioned at cleaning station E and maintained in contact with photoconductive surface **12.** In this manner, neutralized residual toner particles remaining on photoconductive surface **12** after each transfer operation are readily removed therefrom.

It is believed that the foregoing description is sufficient for purposes of the present application to illustrate the general operation of a multi-color electrophotographic printing machine adapted to be calibrated by the color standard of the present invention.

Referring now to specific subject matter of the present invention, FIGS. **2** and **3** depict the front and back elevational views of the color standard of the present invention. As shown in FIG. **2,** color standard **50** includes a generally planar support member **52.** Color standard **50** has disposed upon support member **52** a plurality of color samples of the primary input colors adapted to be reproduced within a specified toner particle density and made from spectrally photometrically calibrated inks. The ink colors are selected so as to achieve satisfactory copies from the printing machine of FIG. **1.** Preferably, color sample **54** is black, color sample **56** is cyan, color sample **58** is magenta, and color sample **60** is yellow. The foregoing color samples have a predetermined hue, value and chroma so as to be spectrally photometrically compatable with the sensitometric response of the printing machine depicted in FIG. **1.** Color standard **50** also includes a matrix of color samples which are adapted to be reproduced in full color. The color samples are selected such that when the printing machine has the proper color balance, color samples **74, 76** and **78** reproduce blank on a multi-color copy. In addition, color samples **62, 64** and **66** are reproduced as pure colors when the printing machine has the proper color balance. Finally, color samples **68, 70** and **72** contain unwanted or contaminated colors therein. For example, red is contaminated by cyan being produced in the red color sample. Hence, if pure colors are reproduced when color samples **68, 70** and **72** are being copied, i.e. the output colors of color samples **68, 70** and **72** in the copy are comparable to the colors of color samples **62, 64** and **66,** this indicates that the developer bias in the development system should be decreased. Similarly, if development occurs in the copy of any of the color samples **74, 76** and **78,** this indicates that the developer bias of the development system is too low and should be raised. Preferably, color samples **74, 76** and **78** are light blue, light pink and light yellow, while color samples **62, 64** and **66** are pure red, pure green, and pure blue, respectively. Finally, color samples **68, 70** and **72** are low chroma red, green and blue, respectively, i.e. a red, green and blue having a high unwanted absorption therein.

With continued reference to FIG. **2,** exposure color sample **80** is adapted to indicate an over-exposed condition, while exposure color sample **82** is adapted to indicate an underexposed condition for a red filtered copy, i.e. cyan development. For example, if in the copy, no development occurs in exposure color sample **80** an over-exposed condition exists, while if light development occurs in exposure color sample **82** an underexposed condition exists. In a similar manner, exposure color sample **84** is adapted to indicate an over-exposed condition for blue and green filtered copies or magenta and yellow development, while exposure color sample **86** is adapted to indicate an under-exposed condition therefore. Thus, if, in the copy, no development occurs in exposure color sample **84** there exists an over-exposed condition, while, if light development occurs in exposure color sample **86** there exists an under-exposed condition. Preferably, exposure color samples **80** and **84** are a darker gray, while exposure color samples **82** and **86** are lighter gray. All gray samples are spectrophotometrically defined for the FIG. 1 printing machine.

Referring now to FIG. 3, there is shown a back elevational view of color standard 50. As shown therein a plurality of limit color samples are disposed on support member 52. Each limit color sample has an aperture therein to permit ready comparison with the reproduction of any single color image produced on a copy. Limit color sample 88 is adapted to indicate the maximum acceptable density yellow image reproduction on a copy, and includes an aperture or hole 90 therein for facilitating a comparison therewith. Similarly, limit color sample 92 is adapted to indicate the minimum acceptable image density for yellow, and also includes a hole 94 therein for comparing with the copy thereof. Limit color sample 96 is adapted to indicate the maximum acceptable magenta density of a copy, and also includes a hole 98 therein for facilitating a comparison with the copy. In association therewith, limit color sample 100 indicates the minimum acceptable magenta density of a copy, and also includes a hole 102 therein for readily enabling the copy to be compared therewith. Limit color sample 104 is adapted to indicate the maximum cyan density for a copy and also includes a hole 106 therein for facilitating a comparison with the copy. Finally, limit color sample 108 is associated with limit color sample 104 to indicate the minimum acceptable cyan density of a copy, and also includes a hole 110 therein for readily enabling the copy to be compared therewith. Thus, color standard 50 may be disposed upon platen 24 (FIG. 1) and utilized as original 22 to have copies reproduced therefrom. In this way, single color copies and multi-color copies may be compared with color standard 50 to insure that the density of toner particles being reproduced thereon are of a satisfactory degree. Moreover, the exposure characteristics of the printing machine may also be checked. Should the printing machine not be producing copies having the requisite color balance and density, the machine is placed in a calibration mode and suitably adjusted with the color standard. Utilization of color standard 50 to calibrate the printing machine of FIG. 1 insures that multi-color copies produced therefrom have uniform high quality.

While the present invention has been described in connection with cyan, magenta and yellow limit color samples, one skilled in the art will appreciate that the invention is not necessarily so limited. For example, the printing machine of FIG. 1 may utilize, in lieu of cyan, magenta and yellow toner particles, black toner particles to form a single color black copy, as well as red and cyan toner particles to form partial color copies. In the foregoing arrangement red, cyan and black maximum and minimum limit color samples are provided for evaluating the respective toner particle density on the copy.

In calibrating the multi-color electrophotographic printing machine of FIG. 1 with the color standard depicted in the FIGS. 2 and 3, a three-part procedure is utilized. Prior thereto, however, the printing machine is placed in the calibration mode. Calibration of the printing machine comprises adjusting the developability regulating mechanism to achieve copies having the requisite density, determining the neutral density filters necessary to obtain the requisite exposure with all three color filters, determining the F/stop and the exposure slit to be used in the imaging system during operation, and final color balance. The foregoing is required in order to compensate for the different sensitives of photoconductive surfaces 12, and the varying spectral irradiance between lamps 26. Finally, the electrical bias levels of developer units 28, 30 and 32, respectively, are adjusted to provide optimum multi-color copy quality. Lens system 18 has operating therewith an exposure slit associated with lamps 26 in order to provide incremental width exposure of original document 22. The exposure slit is configured in the shape of a butterfly to correct for the $\cos^4$ light attenuation effect through lens 18 and thereby provide a substantially uniform illumination intensity across the width of photoconductive surface 12. During the calibration mode, a specific set of exposure slits are utilized therein. Preferably, the set-up exposure slit has a maximum width at the end regions thereof of about 0.341 inches, and a minimum width at the center thereof of about 0.271 inches.

The following procedure may be utilized to place the multi-color printing machine in the calibration mode. The developability regulating mechanism 34 is adjusted by setting the electrical bias level of transparent electrode 36 at a voltage level of about 200 volts DC above the developer unit electrical bias. Thereafter, the electrical bias of transfer roll 46 is set at about 2,000 volts DC. The electrical bias of developer units 28, 30 and 32 are adjusted. Preferably, the developer electrical bias for the cyan developer unit is set at about 470 volts DC, the electrical bias for the magenta developer unit is set at about 500 volts DC, and the electrical bias for the yellow developer unit is set at about 550 volts DC. Lens 20 is set an an F/stop of about 4.5. Each of the toner dispensers housing the toner particles for the respective developer units 28, 30 and 32 are removed from the machine, and all neutral density filters are removed from filter pack 20. The multi-color electrophotographic printing machine is now ready to be calibrated.

Initially, the developability regulating mechanism is adjusted. The calibration procedure for the developability regulating mechanism requires the adjustment of the reference levels for cyan, magenta and yellow, preferably, in that sequence. Initially, a single color cyan copy of the front side (FIG. 2) of color standard 50 is reproduced. For example, color sample 54 is compared with high and low limit color samples 104 and 108, respectively, to determine whether or not the density of the copy of color sample 54 is satisfactory. If the copy density of color sample 54 is too low, the cyan toner cartridge is inserted into the printing machine and the developability regulating mechanism is actuated so as to increase the concentration of cyan toner particles within the developer mix. The preceding procedure is repeated until the density of the copy of color sample 54 is satisfactory, i.e. it lies intermediate color samples 104 and 108, respectively. If the copy density is too high, the cyan reference level of the developability regulating system is set to prevent cyan toner particles from being added to the developer mix. Thereafter, a plurality of copies are reproduced until the copy of color sample 54 has a density which lies between limit color samples 104 and 108. Brush 48 is, thereafter, removed from the printing machine to prevent the cleaning of transparent electrode 36. The printing machine of FIG. 1 is then actuated for at least one cycle, and the reference levels of the developability regulating system adjusted such that toner particle dispensing is just initiated. Alternately, the light rays passing through transparent electrode **36** may be attenuated by a neutral density filter or aperture simulating the appropriate amount of toner particles thereon. Brush **48** is replaced and developability regulating mechanism **34** is monitored so as to insure that as a plurality of copies are being made, cyan toner particles are periodically dispensed to the developer mix. Developability regulating system **34** is checked to determine if toner particles are being dispensed into the developer mix at least once during the formation of the initial three copies. After a plurality of copies have been made, the copies from the color standard are compared with the appropriate limit color samples **88, 92, 96, 100** and **104** and **108** on the back (FIG. **3**) thereof. For example, the cyan copies must have a density which lies between the high density limit color sample **104** and the low density limit color sample **108.** If the density of the cyan copy is not within the limits of color sample **104** and color sample **108,** the reference on the developability regulating mechanism is suitably adjusted. Thereafter, additional copies are made and the foregoing procedure repeated. Finally, after a copy is reproduced which has a toner image thereon falling within the density range of color samples **104** and **108,** a plurality of copies are made until at least three consecutive copies are formed wherein no toner particles are dispensed to the developer mix. The copy immediately before the three copies and the three copies immediately following the last dispense signal are compared with the high and low density limit color samples **104** and **108** to insure that they are within specification. If the foregoing copies are within specification, the developability regulating mechanism is calibrated. However, if the copies are not within specification, a developer unit problem is identified, and the appropriate repair procedure indicated. This calibration procedure is repeated for magenta and yellow toner particles.

Next, the exposure balance of the system is calibrated. This is achieved by setting lens **18**, preferably to an F **5.6** stop and replacing the set-up exposure slit preferably with a number **4** exposure slit. Table **1** presents a tabulation of the preferred dimensions for various exposure slits.

TABLE 1

Exposure Slit No.	Maximum Width Inches	Minimum Width Inches
2	0.682	0.542
4	0.751	0.597
6	0.829	0.659
8	0.913	0.726
10	1.006	0.800

In addition, the electrical bias for the cyan developer unit is set at about 370 volts DC, the electrical bias for the magenta developer unit being set at about 450 volts DC, and the electrical bias for the yellow developer unit being set at about 420 volts. DC. Thereafter, single color copies of cyan, magenta and yellow are made in which color standard **50** is used as an original document in the printing machine of FIG. **1.** These color copies are compared to color standard **50** in order to ascertain whether or not the system exposure criteria are being satisfied by the printing machine. Color samples **80** and **82** are utilized for cyan development and color samples **84** and **86** are utilized for yellow and magenta development. The exposure criteria is met when copies of color samples **80** and **84** have a very light density toner powder image thereon and copies of color samples **82** and **86** remain completely devoid of toner particles. Contrawise, if no development occurs in color samples **80** or **84,** an over-exposed condition exists. When an over-exposed condition exists, the printing machine exposure is decreased until the exposure criteria is met. The slit number and F/stop is recorded on the copy that meets the exposure criteria. This slit is termed the separation slit. Each succeeding F/stop and slit is adapted to reduce exposure and raise image potential. Exposure is continually reduced until development is within the standards prescribed by color samples **80** and **84.** If, however, light development occurs in the no development color samples **82** and **86,** an under-exposed condition exists. For each copy that indicates an under-exposed condition a plurality of copies are run wherein exposure is increased between each copy. Each succeeding set of F/stops and slits increases image exposure and reduces image potential. Image exposure is continually increased until correct development is indicated, as evidenced by no development color samples **82** and **86.** The slit number and F/stop on the copy that meets the exposure criteria is noted once again, this slit is termed the separation slit. After determining the F/stop and separation slit numbers that satisfy the exposure criteria for each of the colors, the condition of the F/stop and slit number resulting in the largest exposure is selected. This slit is termed the run slit. For example, the F/stop for cyan is 4.5 and the separation slit is slit number **4,** the F/stop number for magenta is 4.5 and the separation slit is slit number **8,** and the F/stop number for yellow is **6.3** and the separation slit is slit number **2.** The condition representing the largest amount of light F/4.5 slit number **8,** the cyan example, indicates the F/stop and run slit. The run slit is one that will be left on the machine in the operating mode. The F/stop associated with the run slit is the proper lens setting for the printing machine. This is a combination that provides the maximum allowable exposure energy. Having selected the appropriate F/stop and slit, the associate neutral density filters for each of the colored filters, i.e. red, blue and green, must be chosen to balance the exposure for the remaining color separations which do not require the same amount of exposure energy. The values of the neutral density filters are determined by calculating the slit difference from the following formula:

Slit Difference = (Run Slit Number + Correction factor) − Separation Slit.

The correction factor may be determined from Table **2.**

TABLE 2

Run Slit At	Separation Slit At	Correction Factor
F/4.5	F/4.5	0
F/4.5	F/5.6	9
F/4.5	F/6.3	14
F/4.5	F/8	20
F/4.5	F/11	33
F/5.6	F/5.6	0
F/5.6	F/6.3	5
F/5.6	F/8	14
F/5.6	F/11	24
F/6.3	F/8	9
F/6.3	F/11	19
F/8	F/8	0
F/8	F/11	10
F/11	F/11	0

The correction factor is required due to an overlap in exposure for some combination of F/stop and slit numbers. The correction factors of Table 2 may be evaluated from the overlap of available exposure energy for different combinations of F/stop and slit numbers. Table 3 only presents the combination of slit numbers with F/stops **4.5**, **5.6** and **6.3**. The correction factors for F/stops of **8** and **11**, as shown in Table 2, may be calculated in a similar fashion. An F/stop of **4.5** with the largest slit, i.e. slit number **10**, is treated as furnishing the maximum available energy, i.e. 100 percent.

TABLE 3

Percent of Available Exposure Energy	Slit No. for F/4.5	Slit No. for F/4.5	Slit No. for F/6.3
100.0	10	—	—
95.4	9	—	—
90.6	8	—	—
86.3	7	—	—
82.1	6	—	—
78.1	5	—	—
74.4	4	—	—
70.7	3	—	—
67.4	2	—	—
64.1	1	10	—
61.5	—	9	—
58.6	—	8	—
55.7	—	7	—
53.1	—	6	—
50.4	—	5	10
48.1	—	4	9
45.7	—	3	8
43.6	—	2	7
41.4	—	1	6
39.1	—	—	5
37.2	—	—	4
35.4	—	—	3
33.7	—	—	2
32.1	—	—	1

Referring now to Table **3**, it is shown therein that the overlap in exposure between F/stop **4.5** and F/stop **5.6** occurs at 64.1 percent of available exposure energy. Slit number **1** and F/stop **4.5** provide 64.1 percent of the available exposure energy, as does slit number **10** and F/stop **5.6**. Thus, the correction factor for a run slit number at an F/stop of 4.5 and a separation slit number at an F/stop of **5.6** is 9, i.e. 10–1. Similarly, the overlap between F/stop **5.6** and F/stop **6.3** occurs at 50.4 percent of the available exposure energy and the correction factor is **5**, i.e. 10–5. The correction factor from an F/stop of **4.5** to an F/stop of **6.3** is determined by summing the correction factor of F/**4.5** to F/**5.6** with the correction factor of F/**5.6** to F/**6.3**, i.e. 9+5, to obtain a correction factor of **14** as indicated in Table **2.** In this manner, the various correction factors of Table **2** may be determined for utilization in the preceeding formula for determining the slit difference. Having determined the slit difference, the neutral density filter may be determined from Table 4. The neutral density filters of Table 4 are determined from the transformation of percent transmission to density. The values are rounded to the nearest 0.05 neutral density filter so as to be consistent with the required sensitivity and to facilitate manufacture.

TABLE 4

Slit Difference	Neutral Density Filter
0	None
1	None
2	0.05
3	0.10
4	0.10
5	0.10
6	0.15
7	0.15
8	0.15
9	0.20
10	0.20
11	0.25
12	0.25
13	0.25
14	0.30
15	0.30
16	0.35
17	0.35
18	0.40
19	0.40
20	0.40

For example, if the run slit is slit number **2**, at an F/stop of 4.5 and the separation slit for magenta is slit number **4** at an F/stop of 6.3, the correction factor from Table 2 will be **14** and the slit difference will be **12**. The required neutral density filter may be determined from Table 4. For a slit difference of **12**, an 0.25 neutral density filter is required. The appropriate neutral density filters are inserted in the machine in filter mechanism **20.** Lens **18** is set to the F/stop heretofore determined and the appropriate run slit is also inserted in the machine. Thereafter, the developer unit electrical bias for cyan is adjusted to 410 volts DC, for magenta to 450 volts DC, and for yellow to 450 volts DC for final calibration.

The printing machine is, then, finally calibrated for optimum color balance. This is achieved by adjusting the electrical biases within each of the developer units **28, 30** and **32**, respectively. A plurality of multi-color copies are produced with color standard **50** utilized as original document **22** in the printing machine of FIG. **1.** If development occurs in color samples **74, 76** and **78** the appropriate developer bias is raised in increments of 10 volts and additional copies run to verify that no development occurs in color samples **74, 76** and **78**, respectively. If the color of the copies from color samples **68, 70** and **72** are as pure (not contaminated), as the color in color samples **62, 64** and **66**, the appropriate developer bias is decreased in increments of 20 volts until the image is acceptable. Once the copies of color samples **68, 70** and **72** and **74, 76** and **78**, respectively, are satisfactory, the multi-color electrophotographic printing machine is calibrated. However, if the foregoing criteria cannot be achieved by adjusting the developer bias of the respective developer units, the developability regulating system or exposure system must be readjusted in accordance with the procedure hereinbefore described.

It will be evident to one skilled in the art that a printing machine utilizing black, red and cyan toner particles will require an array of color samples including light blue, pure red, and contaminated red as one set thereof, while light red, pure blue and contaminated blue is the second set thereof.

In recapitulation, it is apparent that the color standard of the present invention may be utilized in a multicolor electrophotographic printing machine to provide appropriate calibration therefore. In use, the color standard permits the calibration of the developability regulating mechanism, the selection of the appropriate lens F/stop number as well as the appropriate exposure slit to be utilized in conjunction therewith in the image exposure system. Moreover, the color standard permits the electrical bias of the development system to be adjusted to the proper levels so as to optimize copies being reproduced in the printing machine.

Thus, it is apparent that there has been provided in accordance with the present invention, a color standard and method of use therefore that fully satisfies the objects, aims and advantages set forth above. While the invention has been described in conjunction with specific embodiments and methods of use, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications and variations as fall within the spirit and broad scope of the appended claims.

What is claimed is:

1. A method of calibrating a multi-color electrophotographic printing machine of the type having a developability regulating mechanism arranged to control the color balance and density of a copy being reproduced thereby with a color standard including the steps of:

setting the printing machine in the color calibration mode of operation for producing a first color test copy;

actuating the printing machine to produce a first color test copy;

comparing the first color test copy with the color standard; and

adjusting the developability regulating mechanism until the density of the first color test copy is intermediate the maximum and minimum density ranges of the color standard.

2. A method as recited in claim 1, wherein said step of setting the printing machine in the calibration mode includes the steps of:

inserting a toner dispenser housing toner particles of a color corresponding to the first color test copy being reproduced into the development system of the printing machine;

determining the number of copies required to actuate the developability regulating mechanism to energize the toner dispenser and increase the concentration of toner particles within the developer mix;

placing the color standard in the printing machine as the original document to be reproduced when the toner dispenser is energized prior to the formation of the predetermined number of test copies; and

forming a first color test copy without an original document in the printing machine when the toner dispenser is not energized prior to the formation of the predetermined number of test copies.

3. A method as recited in claim 2, further including the steps of:

printing a plurality of first color test copies when the color standard is disposed in the printing machine until a predetermined number of first color test copies are produced without the toner dispenser being energized by the developability regulating apparatus; and

comparing the first color test copy immediately prior to the toner dispenser being energized, and the first color copy immediately following the printing of the predetermined number of first color test copies with the color standard to determine if the first color test copy prior to toner dispensing and the first color test copy subsequent to the printing of the predetermined number of first color test copies are intermediate the maximum and minimum density ranges of the color standard.

4. A method as recited in claim 1, further including the steps of:

setting the printing machine in the color calibration mode of operation for producing a second color test copy;

actuating the printing machine to produce a second color test copy;

comparing the second color test copy with the color standard; and

adjusting the developability regulating mechanism until the density of the second color test copy is intermediate the maximum and minimum density ranges of the color standard.

5. A method as recited in claim 4, further including the steps of:

setting the printing machine in the color calibration mode of operation for producing a third color test copy;

actuating the printing machine to produce the third color test copy;

comparing the third color test copy with the color standard; and

adjusting the developability regulating mechanism until the density of the third color test copy is intermediate the maximum and minimum density range of the color standard.

6. A method as recited in claim 1, further including the steps of:

setting the printing machine in the exposure calibration mode of operation after said step of adjusting the developability regulating mechanism;

actuating the printing machine to produce a plurality of first color test copies with the color standard disposed therein as the original document;

comparing each first color test copy with the color standard;

adjusting the exposure system of the printing machine until each first color test copy reproduced therein is of a predetermined exposure condition; and

determining the neutral density filter to be utilized in the exposure system of the printing machine in the normal operating mode thereof.

7. A method as recited in claim 1, further including the steps of:

actuating the printing machine to produce a multi-color test copy;

comparing the multi-color test copy with the color standard; and

adjusting the electrical bias of each developer unit of the development system in the printing machine until the multi-color test copy is reproduced within the specified density ranges of the color standard.

8. A color standard for calibrating a multi-color electrophotographic printing machine, including:

a generally planar support member;

a plurality of color samples disposed on said support member, each of said color samples being of a predetermined hue, value and chroma so as to be substantially optimum for reproduction as a test copy on the printing machine; and

a plurality of pairs of limit color samples disposed on said support member, each of said pair of limit color samples corresponding in hue, value and chroma to one color being reproduced by the printing machine, one of said limit color samples being of a maximum acceptable density and the other of said limit color samples being of a minimum acceptable density to define the permissible density range for each of said colors being reproduced by the multi-color electrophotographic printing machine.

9. A color standard as recited in claim **8,** wherein said support member includes a plurality of apertures therein, each of said apertures passing through one of said limit color samples permitting the color copy corresponding thereto to be disposed therebeneath so as to be visible through the aperture for comparison therewith to ascertain whether the color is between the maximum and minimum acceptable density range of said limit color samples.

10. A color standard as recited in claim **9,** wherein said plurality of limit color samples include:

a high density cyan color sample and a low density cyan color sample;

a high density magenta color sample and a low density magenta color sample; and

a high density yellow color sample and a low density yellow color sample.

11. A color standard as recited in claim **9,** wherein said plurality of limit color samples include:

a high density red color sample and a low density red color sample;

a high density cyan color sample and a low density cyan color sample; and

a high density black color sample and a low density black color sample.

12. A color standard as recited in claim **8** for a multicolor electrophotographic printing machine having a development system with a controllable developer bias voltage arranged to adjust copy image density, wherein said plurality of color samples include an array of developer color samples disposed on said support member, said array of developer color samples comprising a first set of developer bias color samples adapted to be reproduced only when the electrical bias of the development system is less than the optimum value, a second set of developer bias color samples corresponding to the optimum electrical bias of the development system, and a third set of developer bias color samples adapted to indicate when the electrical bias of the development system is greater than the optimum value.

13. A color standard as recited in claim **12,** wherein:

said first set of developer bias color samples include a light blue color sample, a light pink color sample, and a light yellow color sample;

said second set of developer bias color samples include a substantially pure red color sample, a substantially pure green color sample, and a substantially pure blue color sample; and

said third set of developer bias color samples include a contaminated red color sample, a contaminated green color sample, and a contaminated blue color sample.

14. A color standard as recited in claim **12,** wherein:

said first set of developer bias color samples include a light red color sample and a light blue color sample;

said second set of developer bias color samples include a substantially pure red color sample and a substantially pure blue color sample; and

said third set of developer bias color samples include a contaminated red color sample and a contaminated blue color sample.

15. A color standard as recited in claim **8,** wherein said plurality of color samples include a plurality of pairs of exposure color samples disposed on said support member, one of said exposure color samples of each of said pairs of exposure samples being arranged to indicate an underexposed condition for the printing machine, and the other of said exposure color samples of each of said pairs of color samples being arranged to indicate an overexposed condition for the printing machine.

16. A color standard as recited in claim **15,** wherein said pairs of exposure color samples include a first pair of exposure samples having one exposure color sample arranged to indicate an underexposed condition for the development of a cyan image in the printing machine, and the other exposure color sample arranged to indicate an overexposure condition for the development of the cyan image in the printing machine.

17. A color standard as recited in claim **16,** wherein said pairs of exposure color samples include a second pair of exposure color samples having one exposure color sample arranged to indicate an underexposed condition for the development of a yellow and magenta image in the printing machine, and the other exposure color sample arranged to indicate an overexposed condition for the development of a yellow and magenta image in the printing machine.

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