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Manring

[11] **3,756,725**

[45] **Sept. 4, 1973**

[54] **MEASUREMENT AND CONTROL OF INK DENSITY**

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[52] **U.S. Cl.** **356/195,** 356/211, 356/212

[51] **Int. Cl.** **G01n 21/48**

[58] **Field of Search** .... 356/175, 195, 202, 356/203, 206, 212; 250/219 FR

[56] **References Cited**

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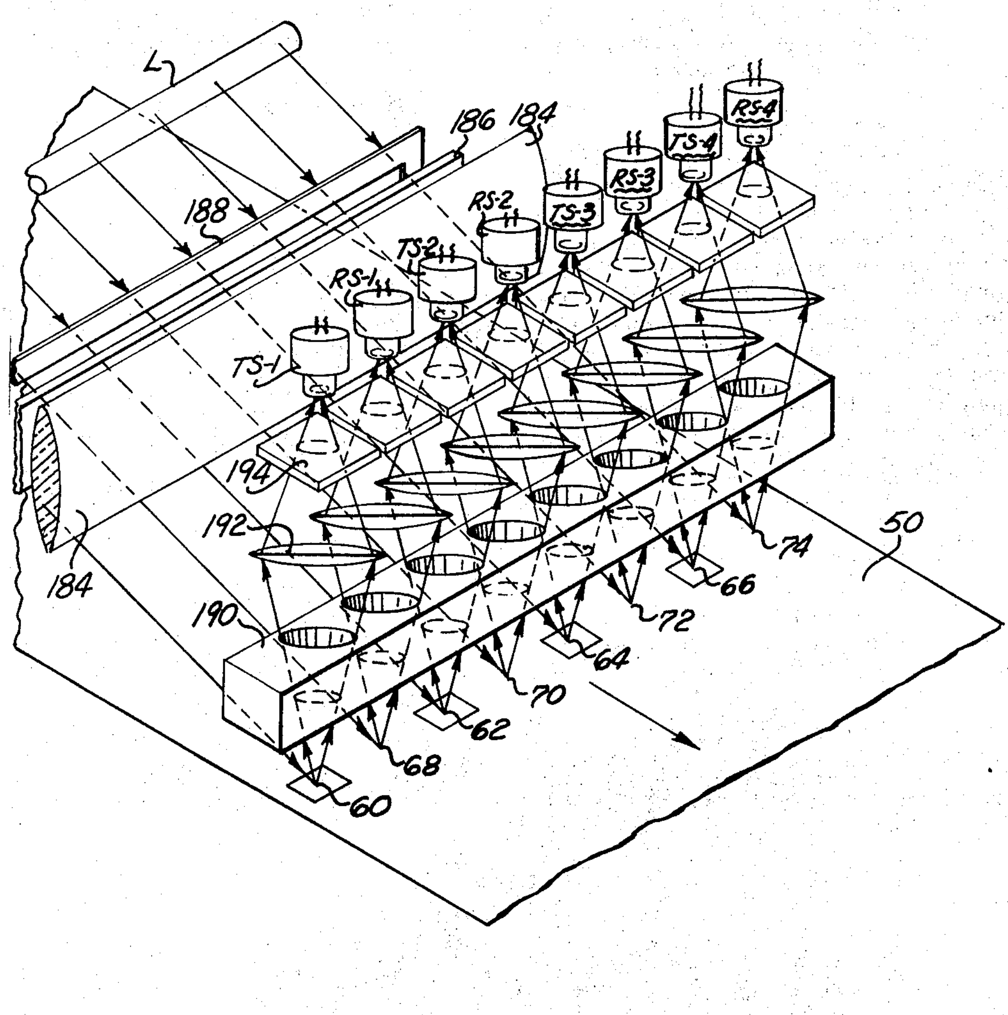
[57] **ABSTRACT**

Apparatus and method are provided for use in determining the density of color reproductions in printing with ink on moving sheet material, such as sheet members or elongated webs, in a printing press, such as a sheet fed or a web fed press. Light is transmitted to the sheet material so as to simultaneously impinge upon an inked test patch surface area and an adjacent reference surface area. Light reflected from these areas along a particular angle is sensed and electrical signals are obtained and which are utilized to provide output indications of ink density of the test patch surface area.

22 Claims, 12 Drawing Figures



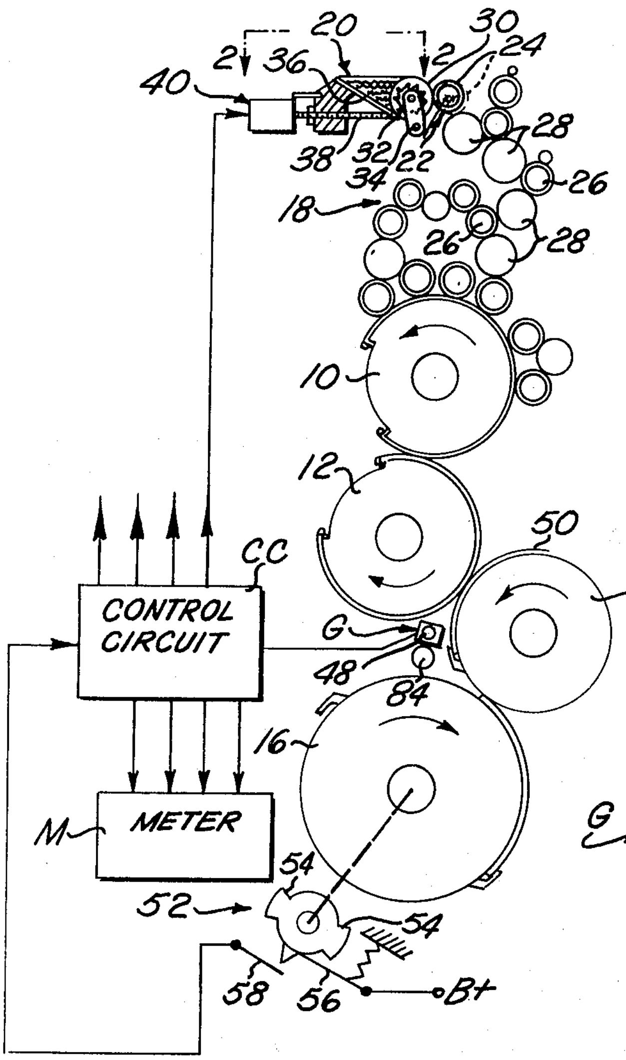


FIG. 1

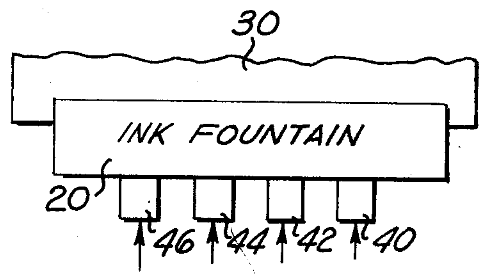


FIG. 2

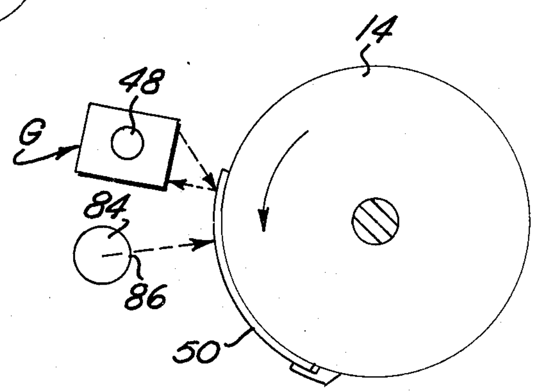


FIG. 4

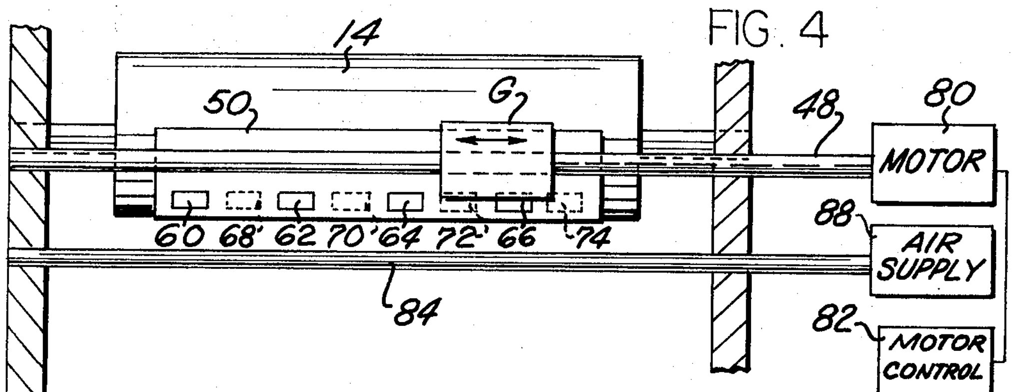


FIG. 3

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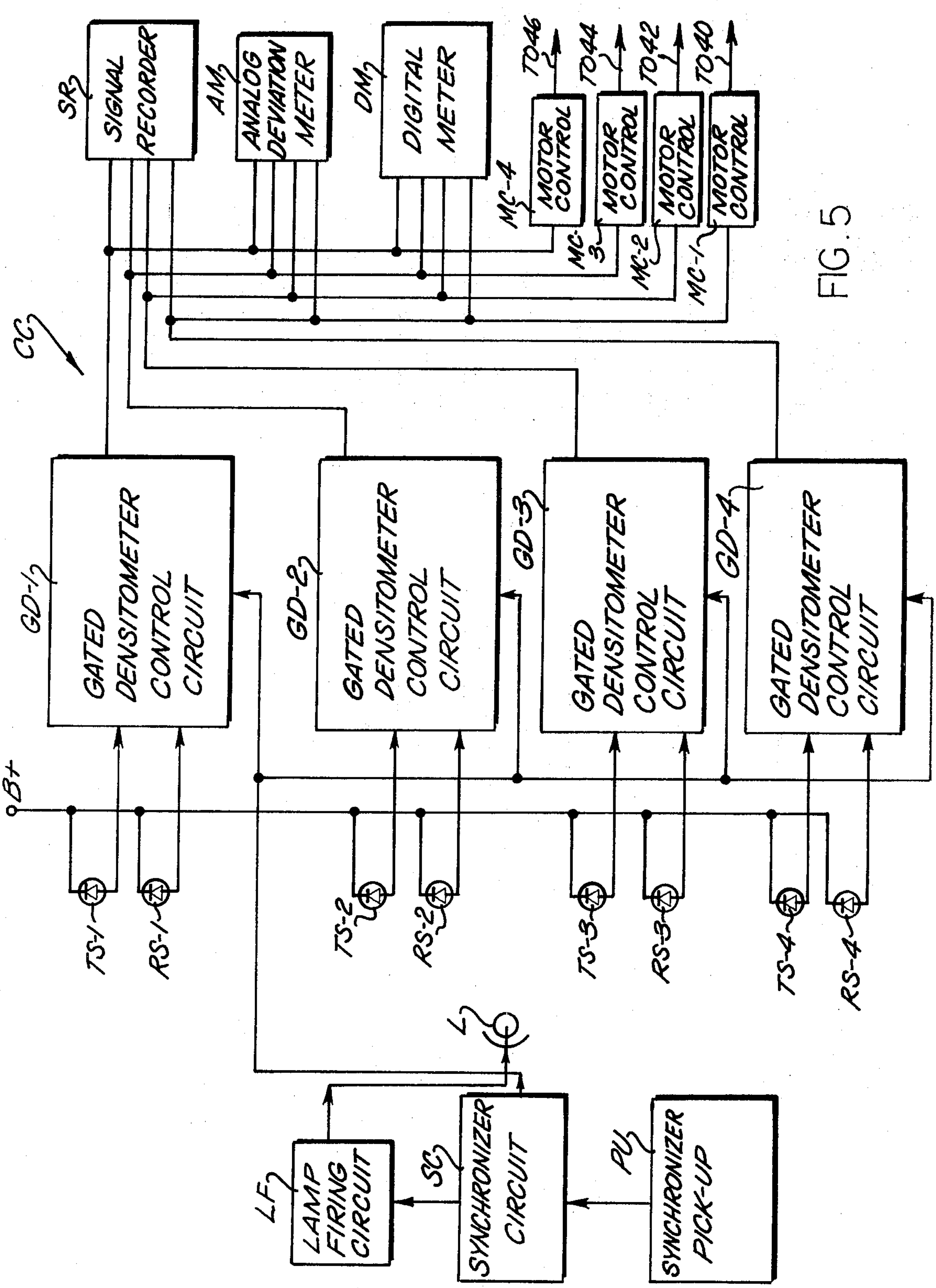

FIG. 5

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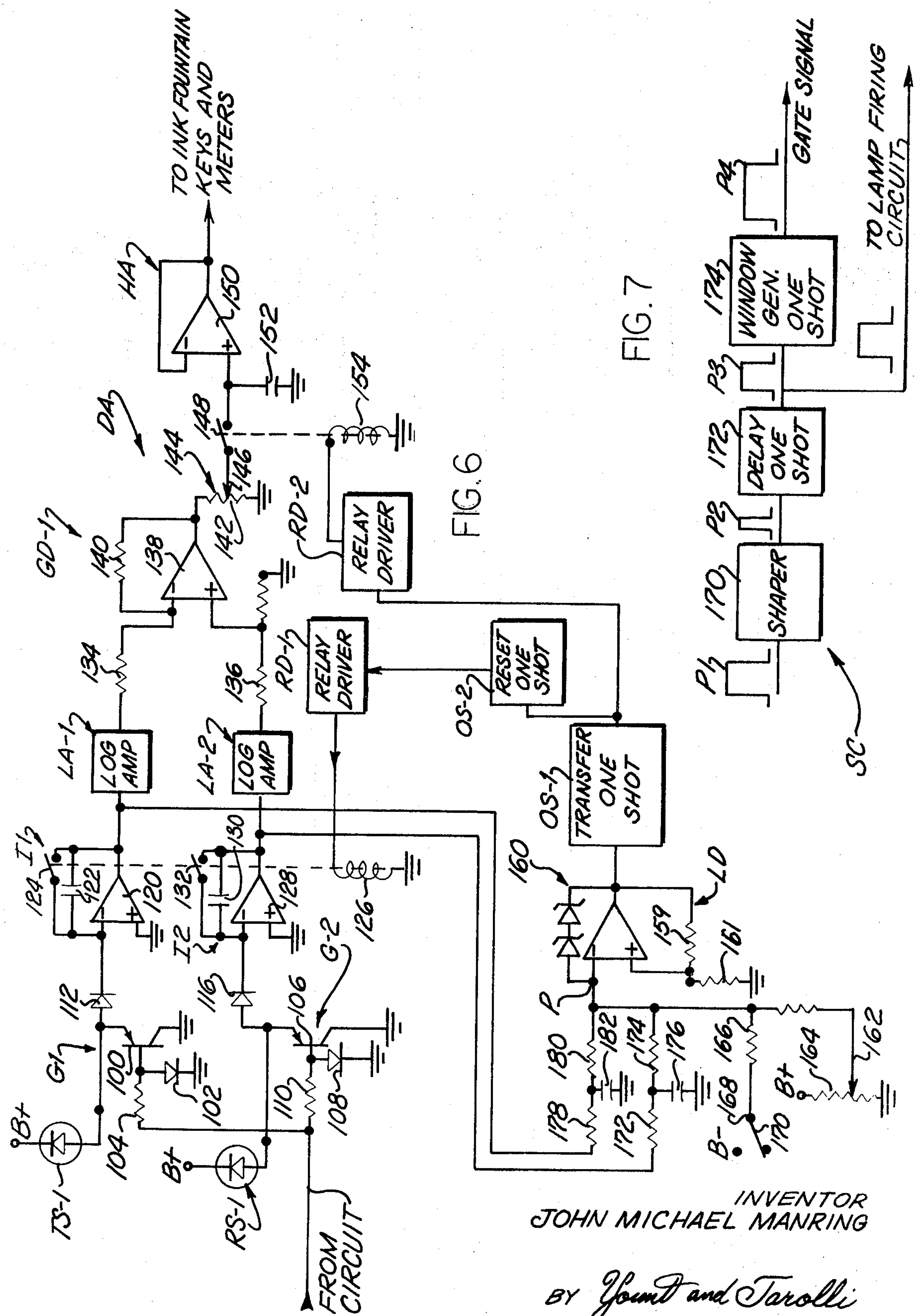

FIG. 6

FIG. 7

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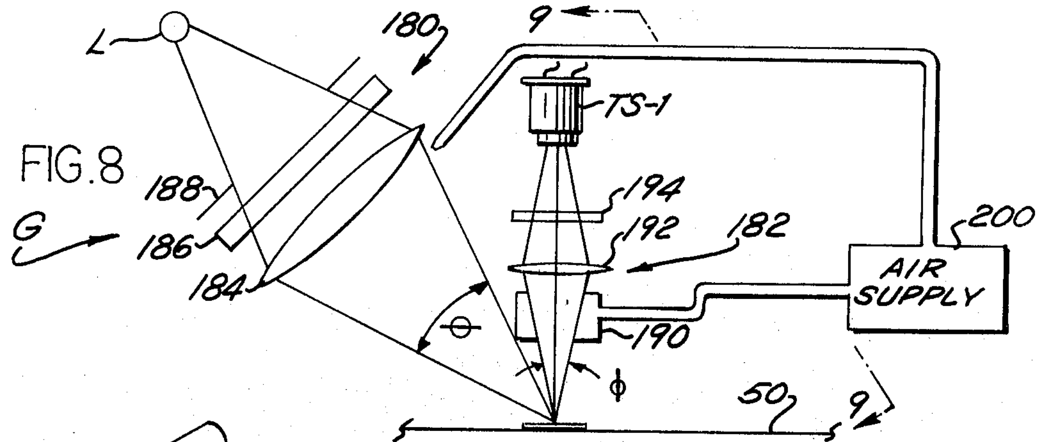

FIG. 8

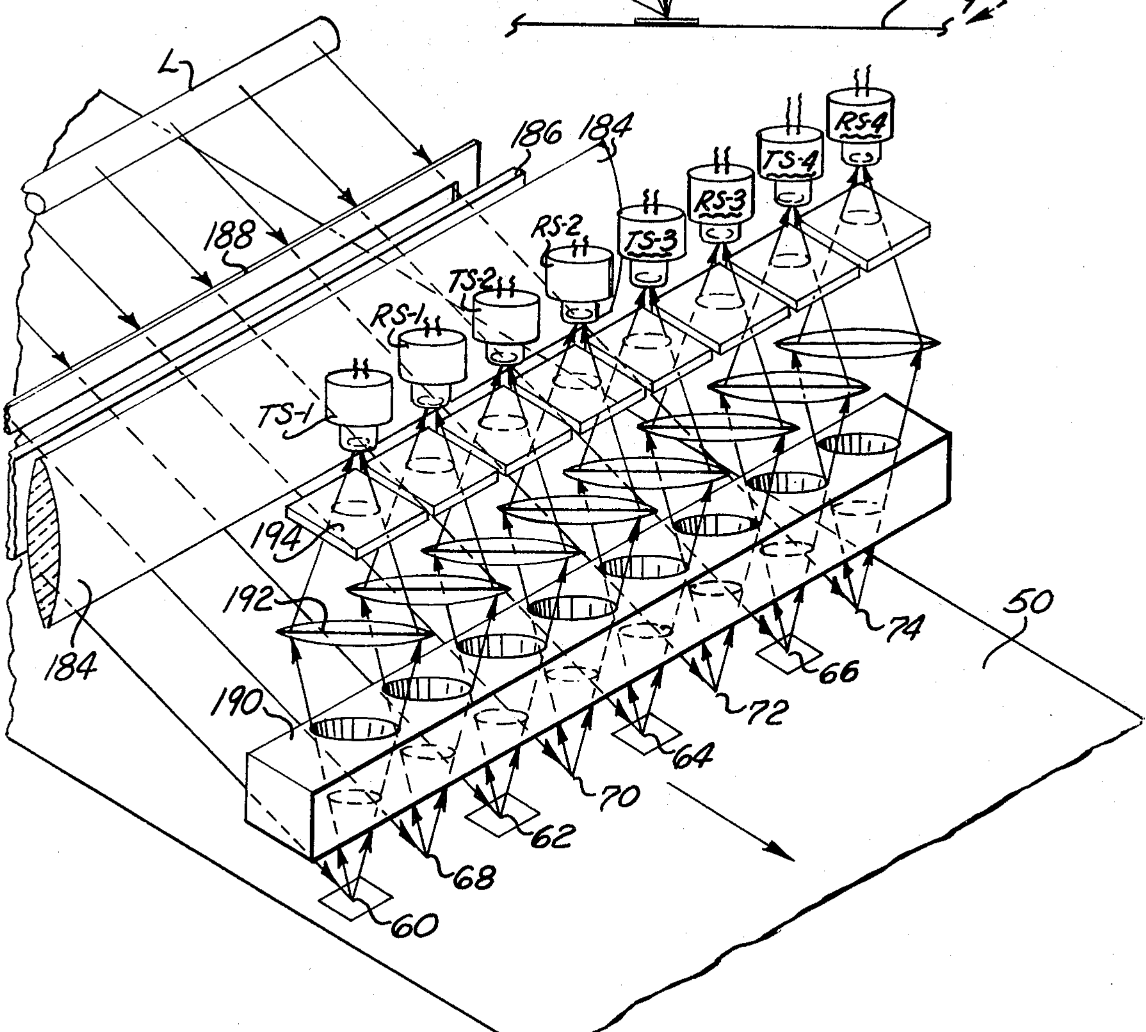

FIG. 9

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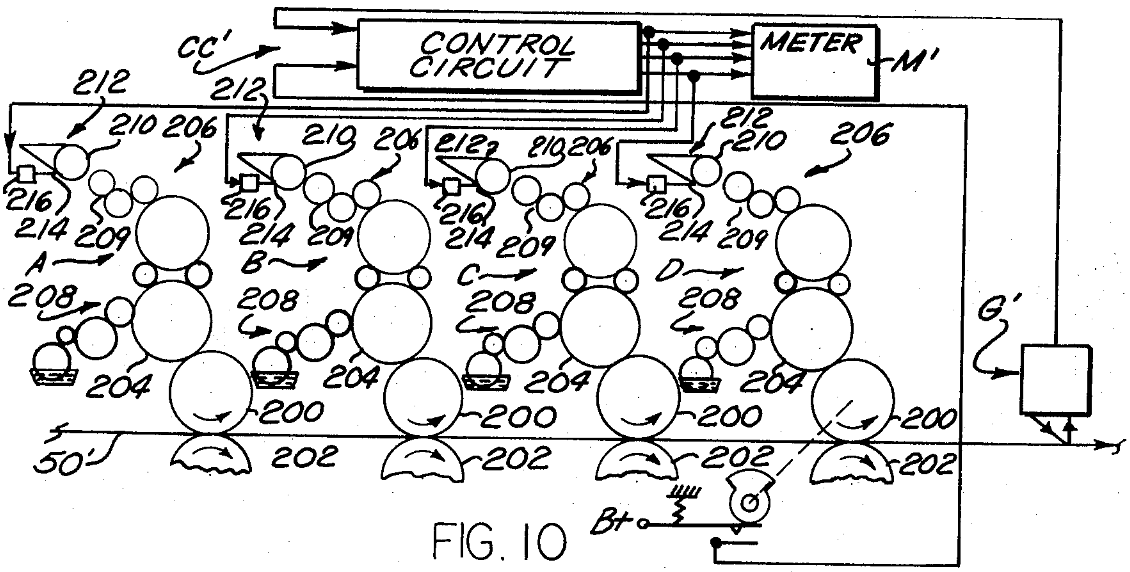

FIG. 10

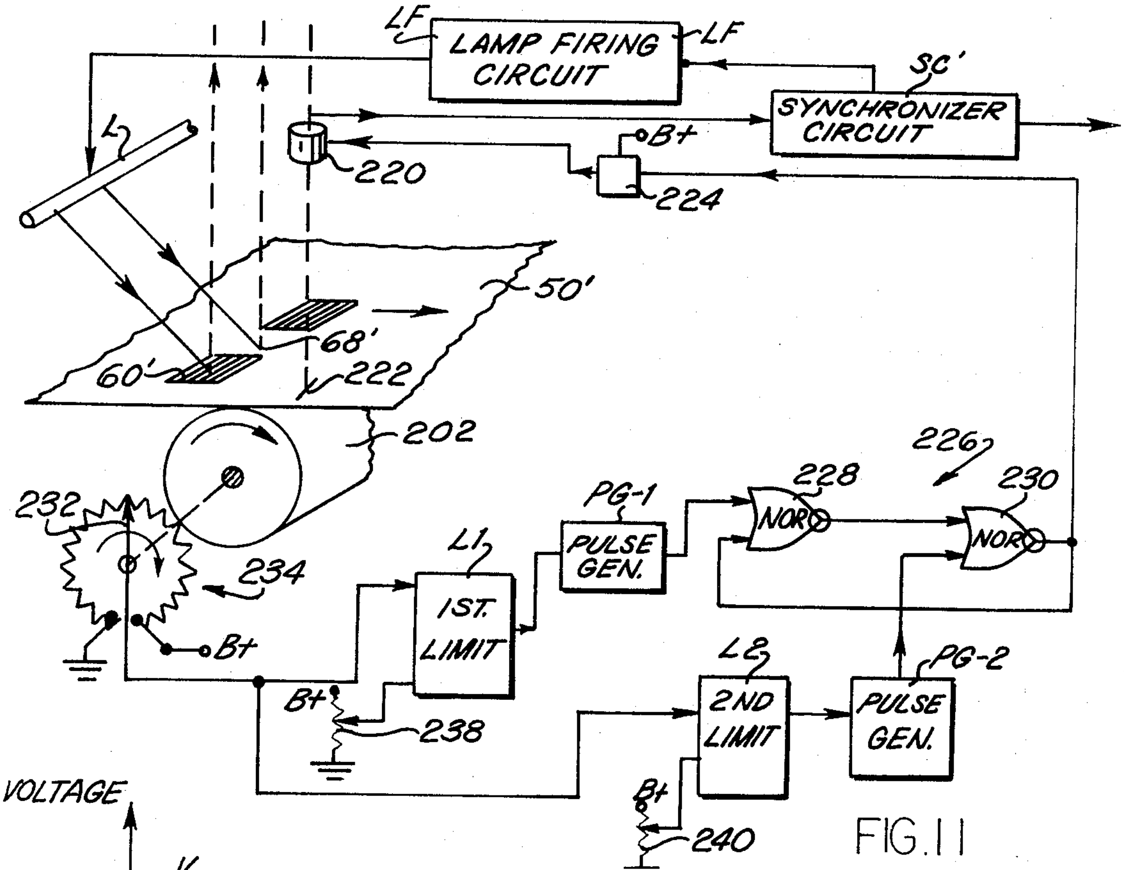

FIG. 11

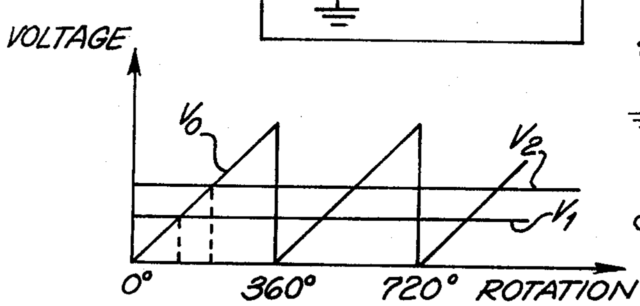

FIG. 12

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MEASUREMENT AND CONTROL OF INK DENSITY

This invention relates to the art of measuring and, more particularly, to obtaining indications as to the ink density of printed reproductions on sheet material.

The invention is particularly applicable in conjunction with obtaining indications as to the density of color reproductions printed with ink on sheet material, although the invention is not limited thereto, and may be used, for example, in various applications requiring accurate indications as to the density of ink on printed material.

In the printing industry determination of press color quality is normally obtained from visual observations of a pressman. But, the eye has a poor memory and is influenced by emotions, ambient lighting and fatigue. Consequently, if two samples of printed material are visually examined in different rooms or at different points in time, the eye of the same person making the judgment will, in all probability, make an erroneous evaluation as to color density. It is well known, for example, that in pressrooms where color density of colored reproductions is visually judged, the quality of color reproduction differs between day and evening shifts.

For effective quality control of color reproduction, the amount of each process ink printed on sheet material must be measured and accurately controlled. Where quality control through non-visual means is available, it is typical for a pressman to remove individual sheets or signatures from the printing units and ink density readings are obtained at a work bench with the use of a densitometer. This is a cumbersome, time-consuming process in that there is considerable delay in obtaining measurements. As there is a tremendous demand on the printing industry for higher production rates, faster make-ready and lower costs, it is desirable that the density of colored ink reproductions be determined with on-press monitoring equipment. The U.S. patent to J. F. Crosfield U.S. Pat. No. 2,968,988 discloses the use of a densitometer for on-press operation to provide pressmen with indications as to the density of ink printed on sheet material. In the Crosfield system a comparison is made of light reflected from a test patch against light reflected from white paper as a white reference and light reflected from the back of a shutter as a dark reference. However, the measurements are made at different points in time and, hence, variations in the light intensity of the light source or ambient light changes during the measuring intervals will degrade the significance of the measurements. Crosfield's system employs an incandescent lamp which is constantly energized and light is passed to the test patches at intervals determined by a rotating shutter and, hence, the spectral distribution of the light is relatively inadequate for obtaining accurate measurements of ink density for high quality color reproduction.

The present invention is directed to improved apparatus and method for providing indications of ink density of printed material to satisfy the foregoing needs and overcome many of the problems noted above in using presently available densitometers.

In the present invention light is transmitted to the sheet material so as to simultaneously impinge on at least one test patch surface area which is printed with colored ink and a reference surface area. A pair of light

sensors serve to receive light reflected from the two surface areas and provide output signals respectively representative of the amount of light received by the sensors. Control circuitry serves to provide an output indication as to the ink density of the test surface area in dependence upon the signals provided by the two sensors.

Further in accordance with the present invention, the light source is periodically energized in synchronism with movement of the sheet material.

Still further in accordance with the present invention, the control circuitry for responding to signals from the sensors is activated in synchronism with the energization of the light source so as to provide output indications of ink density which are not affected by conditions existing during periods when the light source is not energized.

Still further in accordance with the present invention the amount of ink applied to the sheet material in a printing press for color reproduction is controlled in accordance with the ink density indications obtained from the control circuitry.

Still further in accordance with the present invention, the test and reference surface areas may be provided on the trailing edge of sheets in a sheet-fed printing press and means are provided for ensuring that the trailing edge of the sheet is held against a rotatable member, such as an impression cylinder, while the light source and sensors are held in close proximity thereto to obtain indications as to the ink density of the test area.

The primary object of the present invention is to advance the quality of color reproductions in the printing industry.

A still further object of the present invention is to provide improved color reproduction in both sheet-fed and web-fed printing presses with the use of an on-press densitometer for providing indications as to the density of ink employed in making the color reproductions.

A still further object of the present invention is to provide means for automatically adjusting the amount of ink applied to sheet material in a printing press in accordance with indications as to the ink density of color reproductions.

A still further object of the present invention is to provide apparatus capable of on-press operation for providing indications as to absolute ink density of color reproductions.

The foregoing and other objects and advantages of the invention will be more readily appreciated from the following description of the preferred embodiments of the invention, taken in conjunction with the accompanying drawings which are a part hereof and wherein:

FIG. 1 is a schematic illustration of one application of the invention to a web-fed printing press;

FIG. 2 is a schematic illustration of an ink fountain, taken generally along lines 2—2 looking in the direction of the arrows in FIG. 1;

FIG. 3 is a schematic illustration of a portion of the sheet-fed press shown in FIG. 1 and illustrating the manner in which the gauging apparatus of the present invention may be mounted;

FIG. 4 is an enlarged schematic illustration of the gauging apparatus and air bar of FIG. 3;

FIG. 5 is a block-diagram illustration of the control circuitry employed by the present invention;

FIG. 6 is a combined schematic-block diagram illustration of one of the gated densitometer control circuits illustrated in FIG. 5;

FIG. 7 is a more detailed, block -diagram illustration of the synchronizer circuit shown in FIG. 5;

FIG. 8 is a detailed schematic illustration of the light source and sensor portions of the gauging apparatus employed by the present invention;

FIG. 9 is a perspective schematic illustration showing the manner in which the present invention is employed to obtain indications of ink density of color reproductions on printed material;

FIG. 10 is a schematic illustration of another application of the invention to a web-fed four-unit color printing press;

FIG. 11 is a schematic illustration of an alternative form of synchronizer pickup arrangement; and

FIG. 12 is a graphic illustration of voltage versus rotation illustrating the function of the synchronizer pickup shown in FIG. 11.

Referring now to the drawings, wherein the showings are for purposes of illustrating the preferred embodiments of the invention only and not for limiting same, FIGS. 1, 2, 3 and 4 illustrate the invention in conjunction with a conventional sheet-fed lithographic press which includes a plate cylinder 10, a blanket cylinder 12, an impression cylinder 14, and a delivery cylinder 16. The plate cylinder is inked by a conventional inker 18 comprising an ink fountain 20, an adjustable ducting mechanism 22 including a duct roll 24, and a plurality of ink transfer and vibrating rolls 26 and 28 located between the ducting mechanism 22 and the plate cylinder 10.

The ink fountain 20 includes a fountain roll 30 which rotates in the ink fountain to form an ink film thereon. The duct roll 24 is reciprocated between a position in engagement with the fountain roll and a position in engagement with one of the vibrating rolls 28. During the portion of the cycle that the duct roll 22 is in engagement with the fountain roll 30, the latter is rotated an angular amount determined by the setting of an adjustable mask 32 of a pawl and ratchet drive 34 for the fountain roll. The extent of rotation of the fountain roll while in engagement with the duct roll determines, for a given film thickness on the fountain roll, the amount of ink transferred from the fountain roll to the duct roll and, in turn, the amount of ink transferred to the plate cylinder.

The ink fountain 20, in addition to fountain roll 30, includes a fountain blade 36 which extends for substantially the length of the fountain roll. The blade is resilient and is urged into engagement toward fountain roll 30 by means of a plurality of ink keys in the form of screws, such as screw 38, shown in FIG. 1, by reversible motors 40, 42, 44 and 46 so as to control the flow of ink at various sections across the length of fountain roll 30. For a more complete description of inker 18 and ink fountain 30, reference is made to the United States Patent to R.K. Norton, U.S. Pat. No. 3,185,088, assigned to the assignee of the present invention.

In accordance with the present invention, gauging apparatus G is adjustably positioned on a support bar 48 so as to monitor sheet member 50 carried by the impression cylinder 14. As will be described in detail hereinafter, the gauging apparatus G includes a light source for transmitting light to sheet 50 to simultaneously impinge on at least one printed test patch surface area and on an adjacent reference surface area, together with a pair of sensors for receiving light reflected from the two surface areas and providing output signals indicative of amount of light received. These signals are applied to a control circuit CC which determines the density of the ink on the test patch surface area and provides output signals to a suitable meter M to provide the pressman with indications as to the quality of ink reproduction. Also, the control circuit CC provides signals for application to motors 40, 42, 44 and 46 to control the positioning of fountain blade 30 in dependence upon the measured ink density. The operation of control circuit CC and gauging apparatus G is synchronized with the movement of sheet member 50, as with a cam 52 provided with a pair of diametrically opposed lobes 54, each for camming against a movable switch member 56 to electrically contact a stationary contact 58 so that an electrical signal, such as that taken from a B+ voltage supply source, may be applied to control circuit CC.

Reference is now made to FIGS. 3 and 4 which are schematic illustrations of the impression cylinder 14 carrying sheet 50 past gauging apparatus G. As shown in FIG. 3, transversely arranged colored ink patches 60, 62, 64 and 66 are provided on the trailing edge of sheet 50. Immediately adjacent each test patch are respectively associated reference surface areas 68, 70, 72 and 74. These surface areas are uninked areas on sheet 50, although they may be printed to provide a reference level of ink density if desired. The test or reference areas are each of small size, such as 0.375 inches by 0.500 inches. Gauging apparatus G is slidably secured to support bar 76 for transverse movement along the bar to monitor ink density at each of the four locations provided with adjacent inked, test and reference surface areas under the control of a conventional drive shaft 48 extending from a reversible motor 80 having its direction of rotation controlled by a motor control circuit 82.

If the test patches to be monitored by gauging apparatus G are located on the trailing edge of a sheet member, as is shown in FIG. 3, then it is desirable to provide means for maintaining sheet 50 against the cylindrical surface of cylinder 14. This function is obtained with air bar 84 extending parallel to the axis of rotation of the cylinder 14 and spaced from the cylinder approximately as shown in FIGS. 3 and 4. The air bar is provided with a plurality of apertures, such as aperture 86, shown in FIG. 4, which serve to direct air under pressure received from an air supply 88 toward sheet member 50 so as to hold the trailing edge thereof against the cylindrical surface of cylinder 14.

GATED DENSITOMETER CIRCUITRY

In accordance with the present invention, control circuit CC serves to provide indications as to the density of color reproduction in printing with ink with at least one color on sheet material while the material is moving in a printing press. The application of the invention described thus far has been given with respect to four pairs of test patch-reference surface area combinations and, hence, the control circuit CC illustrated in FIG. 5 employs four gated densitometer control circuits GD–1, GD–2, GD–3 and GD–4. Each control circuit is connected to one sensor for receiving therefrom signals indicative of light reflected from the printed test patch surface area and another sensor for receiving therefrom signals indicative of light reflected from the adjacent reference surface area. Thus, as shown in FIG. 5, the control circuit GD–1 is connected to a test sensor TS–1 and a reference sensor RS–1. The sensors preferably take the form of photodiodes, although other light sensors may be employed. As in the case of the sensor TS–1, each sensor has its cathode connected to a B+ voltage supply source and its anode connected to the associated control circuit. In similar fashion, circuit GD–2 is connected to test sensor TS–2 and reference sensor RS–2. Similarly, test sensor TS–3 and reference sensor RS–3 are connected to circuit GD–3. Lastly, test sensor TS–4 and reference sensor RS–4 are connected to circuit GD–4.

Control circuit CC also includes a synchronizer pickup assembly PU which serves to provide signals for synchronizing the operation of the control circuit with the movement of the sheet material being monitored. Each time the synchronizer pick-up PU develops an output signal, the signal is applied to a synchronizer circuit SC which serves to energize a lamp firing circuit LF for, in turn, energizing lamp L. In addition, each of the control circuits GD–1 through GD–4 are gated into an active operable condition in synchronism with the energization of lamp L. The output signals taken from the control circuit GD–1 through GD–4 are applied to a conventional four-channel signal recorder SR as well as to an analog deviation meter AM and a digital meter DM. The signal recorder SR may be of conventional design and serves to provide a permanent record of the density measurements made for each channel. Similarly, the analog deviation meter AM may be of a conventional design and serves the purpose of providing a visual indication for each channel as to deviations from a desired density level. Also, the digital meter DM provides, for each channel, a visual digital presentation as to the ink density of the test patch surface area.

Reference is now made to FIG. 6 which provides a detailed illustration of gated densitometer control circuit GD–1, it being understood that circuits GD–2, GD–3 and GD–4 are constructed in the same fashion. As shown in FIG. 6, circuit GD–1 is connected to test sensor TS–1, as well as to reference sensor RS–1. Whereas various light-sensitive sensors may be used, it is preferred that the sensors serve to filter out wave lengths beyond the visible red region (0.7 microns). Each sensor is preferably an essentially constant current photodevice and exhibits good spectral characteristics. One diode that has been tested and found satisfactory for this purpose is one provided by United Detector Technology Corporation, Model No. UDT 385 and known as a PIN photodiode.

Test sensor TS–1 is connected to the inverting input of an integrator circuit I1 and reference surface RS–1 is connected to the inverting input of an integrator circuit I2. However, during operation, as will be described in detail hereinafter, a pair of gates G1 and G2 serve to activate circuit GD–1 only when gating signals are received from synchronizer circuit SC. Thus, gate G–1 includes a PNP transistor 100 having its emitter connected to sensor TS–1, its collector connected to ground, and its base connected through a diode 102, poled as shown, to ground so that the transistor is normally forward biased. The base of transistor 100 is also connected through a resistor 104 to a synchronizer circuit SC so that upon receipt of a positive signal therefrom, the transistor is reversed biased to permit electrical signals from sensor TS–1 to be applied to the inverting input of integrator circuit I1. Similarly, gate G–2 includes a PNP transistor 106 having its emitter connected to sensor RS–1, its collector connected to ground, and its base connected through a path including a diode 108, poled as shown, to ground and another path including a resistor 110 to the synchronizer circuit SC. Gate G–1 is connected to the inverting input of integrating circuit I1 through a diode 112, poled as shown. Similarly, diode 116 connects gate G–2 with the inverting input circuit of integrator I2.

Integrator circuit I1 includes a conventional operational amplifier 120 having its non-inverting input connected to ground and an integrating capacitor 122 connected between the output circuit and the inverting input circuit. The capacitor may be reset with the use of normally open reed relay contacts 124 actuated to a closed condition for discharging the capacitor upon energization of a relay coil 126. Similarly, integrator circuit I2 includes an operational amplifier 128 having an integrating capacitor 130 and normally open reed relay contacts 132 connected in shunt across capacitor 130 and also operated by relay coil 126.

The output circuits of integrator circuits I1 and I2 are respectively connected to conventional log amplifiers LA–1 and LA–2 having their outputs, in turn, respectively connected through resistors 134 and 136 to input circuits of a differential amplifier DA. This amplifier is comprised of a conventional operational amplifier 138 having a feedback resistor 140 connected between its output circuit and its inverting input circuit. The output circuit of amplifier DA is connected through the resistance portion 142 of a potentiometer 144 to ground. The wiper arm 146 of the potentiometer is connected through a normally open relay contact 148 to a holding amplifier HA. The holding amplifier HA includes a voltage follower operational amplifier 150 having its output connected to the inverting input circuit and a capacitor 152 connected between ground and the junction of relay contacts 148 and the non-inverting input of operational amplifier 150. Relay contacts 148 are operated to a closed position upon energization of an associated relay coil 154.

The output circuits of integrators I1 and I2 are also connected to a level detector LD which serves to monitor the integrator output signals and trigger the holding amplifier HA only when the integrator signals exceed a preset level. This ensures that there will always be adequate light to make a valid measurement and compensates for variations in paper brightness during absolute density measurements. The level detector LD incorporates an operational amplifier 160 having its output circuit connected to its inverting input circuit, as well as to its non-inverting input circuit through resistor 159, which is also connected through resistor 161 to ground.

The inverting input circuit of amplifier 160 has a summing point P which is connected to the wiper arm 162 of a potentiometer 164, having its resistance portion connected between ground and a B+ voltage supply source. The positioning of this wiper arm serves to provide the reset level against which the level detector compares signals received from integrator circuits I1 and I2. Summing point P is also connected through a resistor 166 to a reset switch 168 having a movable arm 170 normally connected to ground but operable to be connected to a B– voltage supply source for purposes of obtaining manual reset. The summing point P is also connected to the output circuit of integrator circuit I1 through resistors **172** and **174** having their junction connected through a capacitor **176** to ground. Similarly, summing point P is connected to the output circuit of integrator circuit I2 through resistors **178** and **180** having their junction connected through a capacitor **182** to ground. When the output signals from the integrator circuits I1 and I2 exceed the preset level, as determined by the setting of wiper arm **162** of potentiometer **164**, the level detector provides an output signal which is received by a transfer one shot circuit OS–1, which may be a conventional monostable oscillator, and which provides an output signal pulse having a predetermined magnitude and duration. The signal is applied to a conventional relay driver circuit RD–2 for energizing relay coil **154** to close relay contacts **148.** During the period that relay coil **154** is energized, the potential existing at wiper arm **146** is applied to capacitor **152** so that the output potential of amplifier **150** is proportional to that of the differential amplifier DA during this sampling period. Also, the output circuit of transfer one-shot OS–1 is applied to a reset one-shot OS–2, constructed in the same fashion, and which provides a time delayed pulse relative to that from circuit OS–1 of a predetermined magnitude and duration for energizing relay driver RD–1. Relay driver RD–1, in turn, energizes coil **126** to close relay contacts **124** and **132** to discharge capacitors **122** and **130.**

The synchronizer circuit SC is shown in greater detail in FIG. 7 and includes a wave shaper circuit **170** for receiving pulses from the synchronizer pickup PU which, as shown in FIG. **1**, may take the form of a cam-operated switch which is operated in synchronism with the movement of the sheet members. Depending on the diameter of the transfer cylinder, two or more circumferentially spaced sheet members may be carried at one time and, consequently, one pulse per cycle should be provided for each sheet member. For purposes of illustration, transfer cylinder **16** carries two sheet members during each cycle of rotation and, hence, cam **52** includes two lobes **54** for activating switch **56, 58** twice per cycle of rotation. Each synchronizer pickup pulse is applied to the wave shaper circuit **170** in the synchronizer circuit SC and this shaper circuit converts the pulse, such as pulse P1, into a pulse P2 of a predetermined size and duration. The output of shaper circuit **170** is then applied to a delay one-shot monostable oscillator circuit **172** which serves to produce a time delayed signal pulse P3 having a specific amplitude and time duration. This signal is then applied to the lamp firing circuit LF (see FIG. **5**) for energizing lamp L. The signal is also applied to a second one-shot monostable oscillator circuit **174** that serves as a window generator for producing an output signal pulse P4 having a specific magnitude and time duration and the signal is used as the gating signal for gating gates G–1 and G–2 (see FIG. **6**) into conduction to activate the associated densitometer control circuit.

DENSITOMETER GAUGING APPARATUS

The densitometer gauging apparatus G is schematically illustrated in FIGS. **8** and **9** and comprises a lamp L, a filter lens arrangement **180**, a plurality of photodiodes, such as test sensor TS–1, and a collimator lens arrangement **182**. Lamp L, as best shown in FIG. **9**, extends so as to be transversely aligned relative to sheet member **50** and, when energized, serves to provide a source of illumination for a plurality of inked test patch surface areas **60, 62, 64** and **66**, as well as illumination of the adjacent reference surface areas **68, 70, 72** and **74.** Preferably, lamp L takes the form of a Xenon linear quartz flash tube. Other light sources providing similar spectral balance may be employed. Lamp L should have an arc length sufficient to illuminate several test patches and their adjacent reference surface areas and, for example, may have an arc length on the order of 9 inches and operate from a voltage source on the order of 2,000 volts. It has been determined that with a 10 microfarad discharge capacitor in the firing circuit LF, the energy per flash is on the order of 20 joules. Preferably, lamp L is operated in a self-extinguishing mode and is triggered into conduction by an ignition transformer driven by a conventional capacitor discharge circuit including a silicon-controlled rectifier, used as a shorting switch, and which is triggered into conduction by the synchronizing pulse P3 taken from the synchronizing circuit SC. An appropriate synchronizing pulse for this purpose has been found to be a pulse having a magnitude in the order of 15 volts with a time duration of 8 microseconds. With these parameters, it has been found from tests that the shape of the light pulse obtained from lamp L is roughly that of an exponential decay pulse with a rise time to peak value of about 5 microseconds and a characteristic decay time constant in the vicinity of 15 microseconds to 25 microseconds, depending on the size of the discharge capacitor and the particular flash tube employed by lamp L.

The filter lens arrangement **180** for lamp L includes a convex cylindrical lens **184** which has a length substantially that of lamp L, such as in the order of 9 inches, and is provided with an aperture of approximately 2.25 inches and a focal length of 43 mm. The image of the flash from lamp L is focused on sheet member **50** with no magnification. Between lamp L and lens **184** there is provided an elongated glass filter **186** having a length substantially that of lamp L. Filter **186** is used to enhance the blue light obtained from lamp L and to suppress infra-red light. Located between filter **186** and lamp L is an aperture plate **188** used to suppress stray light. As is conventional with densitometers, the image of the flash is focused onto sheet member **50** with an incident angle of 45° and sensor TS–1 serves to receive light reflected from the sheet member at 90°. To minimize gloss reading effects, the included focus angle θ is preferably not greater than 34° and the included detector angle ϕ is on the order of 16°.

The collimator lens assembly includes a collimator **190** which extends the length of the surface areas **60** through **74** (see FIG. **9**). This collimator is essentially a snout containing threaded tubes, each aligned with one of the optical diodes. Interposed between each sensor and associated tube there is provided a condensing lens **192** which serves to collect and focus light received from the paper to the sensitive surface of the photodiode. The focus area on the paper is approximately one-fourth inch in diameter. Interposed between lens **192** and the associated photodiode, there is provided a Wratten filter **194.** Of course, the particular Wratten filter employed is dependent on the color of the ink test patch being monitored. For example, Wratten filter Nos. **47, 58** and **25** provide broad, slightly overlapping bands in the blue, green and red wave length regions, respectively. The filters are used as complementary filters in the measurement of density for the basic process of color inks, yellow, magneta and cyan. A neutral density filter (Wratten No. 96) or visual filter (Wratten No. 106) may be used in the measurement of black ink density. These filters have been generally accepted by the industry for use in density measurements and, for example, may be obtained from Kodak Corporation.

To facilitate in maintaining clean optical viewing and illuminating surfaces, it is desirable to introduce air (positive pressure) over the surface of viewing lens **192** and to divert blanket wash from the lens **184**. Consequently, a suitable air supply **200**, as schematically illustrated in FIG. **8**, is provided along with suitable tubing to direct air across the surfaces of lenses **184** and **192**, as well as to direct air through the collimator tubes to protect the lenses and tubes from offset powder sifting in and settling therein.

OPERATION

During the operation of control circuit CC each gated densitometer control circuit GD–1 through GD–4 is activated upon receipt of a gating signal from synchronizer circuit SC. Each time cam **52** actuates movable switch arm **56** to engage stationary switch arm **58** 7) signal such as pulse P1 (see FIG. &) is applied to pulse shaper **170** in the synchronizer circuit SC. The delay one-shot circuit **172**, in turn, applies a trigger signal pulse P3 to the lamp firing circuit LF to energize the Xeon lamp L for a predetermined time duration. The short duration of the flash from lamp L serves to "freeze" the motion of the test areas and to provide high light intensity with good spectral distribution. The window generator **174** applies a gating signal to activate each control circuit GD–1 through GD–4.

Reference is now made to control circuit GD–1 shown in FIG. **6**, it being understood that circuits GD–2 through GD–4 are constructed to function in the same manner. Transistors **100** and **106** are biased into conduction by the gating signal from synchronizer circuit SC for a predetermined period of time.

Sensors TS–1 and RS–1 receive light reflected from inked test patch surface area **60** and its immediately adjacent reference surface area **68** respectively (see FIG. 9). The amount of current from each sensor TS–1 and RS–1 is proportional to the instantaneous value of the light reflected from the associated surface area and, since gates G–1 and G–2 are conductive, the currents are applied to integrator circuits I1 and I2. The output current from the sensors is integrated by respective integrator circuits I1 and I2 over an arbitrary period of time (one or more flashes of lamp L). Thus, the output voltage VT from the test sensor integrator circuit I1 and the output voltage VR from the reference sensor integrator circuit I2 are respectively proportioned in magnitude to the total light reflected from areas **60** and **68** during the measuring interval.

The generally accepted definition of ink density is given by the expression:

Density = $\log_{10}$ (light reflected from uninked paper)/(light reflected from inked paper)

= $\log_{10}$ (light reflected from uninked paper)− $\log_{10}$ (light reflected from inked paper)

= $\log_{10}(V_R) - \log_{10}(V_T)$

Consequently to obtain an output signal representative of density in accordance with the above expression the output signals of integrators I1 and I2 are applied through log amplifiers LA–1, LA–2 to respectively provide voltages proportional to the $\log_{10}$ of the signals from integrators I1 and I2. The output voltages from log amplifiers LA–1 and LA–2 are applied to differential amplifier circuit DA which provides an output voltage proportional to the difference voltage of these output voltages. This difference voltage is proportional to the reflection density.

The output voltage of differential amplifier DA is proportional to the absolute ink density of the colored ink patch **60** when the adjacent reference surface area **68** is uninked. This is preferably the measurement to be made in practicing the invention. However, it is to be appreciated that a relative density measurement may be obtained if surface area **68** is a reference inked area. In such case the output voltage from differential amplifier DA will have a value proportional to the relative density of the inked test patch **60** to that of the reference surface area **68**.

The synchronizer pick-up assembly PU and the synchronizer circuit SC serve to ensure that lamp L is triggered into conduction and that gates G1, G2 are biased into conduction just at the point in time when the test patches and their adjacent reference surface areas are passing the sensor assembly. This synchronization should be such that once lamp L is energized the light therefrom will impinge upon the transversely aligned test patch surface areas and reference surface areas being monitored at a point in time when the corresponding sensors are aligned at an angle of 90° to the monitored areas. Synchronization is obtained by, for example, adjusting cam **52** so that it actuates movable arm **56** into engagement with stationary arm **58** so that the gating signal derived from synchronizing circuit SC forward biases gates G1 and G2 and that lamp L is energized at the point in time when the lamp and sensors are aligned with the transversely arranged test and reference surface areas.

The level detector LD senses the total reflected light from both the test patch surface area **60** and the immediately adjoining reference surface area **68** by summing the integrated voltages from the integrators and providing an output signal to the transfer one-shot circuit OS–1 when the summed voltage exceeds a preset level, as adjusted by potentiometer **164**. Depending on the setting of potentiometer **164** several flashes of lamp L may take place before an output signal is applied to the transfer one-shot circuit OS–1. This ensures that there is always sufficient light to make a valid measurement. Thus, if the absolute level of the light changes because of changes in paper brightness or because of a comparative measurement being made between two inked patches, both of whose densities are high, then the level detector will not trigger until there have been enough flashes of light L to bring the integrated light level to the trigger point. The light level detector and one-shot circuit OS–1 are designed so that the output signal from circuit OS–1 occurs during the dead interval between flashes of light from lamp L. The output signal taken from the one-shot circuit OS–1 is to be considered as a transfer signal in that it energizes the relay driver RD–2 to thereby momentarily energize relay coil **54** to close relay contacts **148**. Thus the output voltage taken from wiper arm **146** is applied to the hold amplifier HA, which, in turn, provides an output signal proportional to that obtained from wiper arm **146**. The output signal from the transfer one-shot circuit OS–1 is also applied to reset one-shot circuit OS–2 which provides a still further delayed signal to energize relay drive RD–1 to momentarily energize relay **126.** Relay coil **126** is energized for a period sufficiently long that relay contact **144** and **132** are closed to discharge integrating capacitors **122** and **130,** respectively, prior to commencing another measuring cycle of operation.

The output signals taken from the hold amplifier HA in each of the gated densitometers GD–1 through GD–4 are applied to signal recorder SR, an analog deviation meter AM, a digital meter DM as well as to suitable motor circuits MC–1, MC–2, MC–3 and MC–4 for controlling respective reversible motors **40, 42, 44, 46** for, in turn, controlling the amount of ink applied to the sheet material in accordance with the density measurements.

MODIFICATIONS

Referring now to FIG. **10** there is illustrated another application of the invention in conjunction with a conventional web fed lithographic press which includes four press units, A, B, C and D. The units are identical and each includes a pair of blanket cylinders **200** and **202** for printing on opposite sides of a web **50'**. Blanket cylinder **200** cooperates with a conventional plate cylinder **204** to which ink is applied in a known manner by an ink assembly **206** and to which moisture is applied by a conventional dampener assembly **208.** Of course, an inker assembly and dampener assembly cooperate with a plate cylinder (not shown) which engages blanket cylinder **202.** The inker assembly **206** includes a plurality of rollers forming a conventional ink train **209** which receives ink from the ink fountain roll **210** located in the ink fountain **212.** As in the case of the embodiment of the invention described relative to FIG. **1** the amount of ink applied to the ink train and, hence, to the plate cylinder **204** is controlled by fountain keys shown schematically as **T214** in FIG. **10.**

In accordance with the present invention, a gauging apparatus G', constructed in the same fashion as gauging apparatus G described hereinbefore, is mounted so as to monitor ink test surface areas and reference surface areas extending transversely across web **50'**. The output signal from the gauging apparatus is applied to a control circuit CC', which is constructed in the same fashion as control circuit CC described in detail hereinbefore with reference to FIG. **5.** It is contemplated that each of the printing units A, B, C, and D print different ink test patches on web **50'** such as for example with reference to FIG. **9** unit A may print test patch **60,** unit B may print test patch **62,** unit C may print test patch **64** and unit D may print test patch **66.** The output signals obtained from the control circuit CC', as in the embodiment described hereinbefore with reference to FIG. **1,** are applied to a suitable meter M' for providing an operator with visual indications as to the density of the ink applied by each of the four press units. In addition, the output signals from control circuit CC' are used to control the amount of ink applied by the ink train in each press unit, as by energization of a reversible motor **216** for controlling fountain key **214.**

Reference is now made to FIG. **11** which illustrates a modification which may be employed as a substitute for the synchronizer pick-up apparatus PU described hereinbefore with reference to FIG. **5.** The modification of FIG. **11,** however, is shown with reference to unit A of the web fed press in FIG. **10.** Thus, web **50'** is carried by blanket cylinder **202** and lamp L is positioned to illuminate a series of transversely aligned patches on the web. The patches may include an ink patch surface area **60'** and an adjacent reference surface area **68'**. In this modification a photo sensor **220** is employed and positioned so as to sense a mark **222** located in the margin of web **50'** slightly forwardly of transversely aligned surface areas **60'** and **68'**. Sensor **220** serves in this modification to provide an output pulse upon sensing mark **222** and this output pulse is applied to synchronizer circuit SC', which is constructed in the same fashion as synchronizer circuit SC described in detail hereinbefore with reference to FIG. **7.** Consequently sensor **220** serves the same function as the cam arrangement illustrated in FIG. **1.**

Sensor **220,** however, is energized to sense mark **222** only during a period in which an electronic switch **224** is energized. Switch **224** may take various forms such as, for example, a simple transistor switch. Switch **224** is energized for a short time duration during each measuring cycle so that sensor **220** is energized for a period extending from a point in time just prior to the passing of mark **222** to a point in time just after the passing of aligned surface areas **60'** and **68'**. This is accomplished by applying a positive or binary "1" signal to switch **224** for a predetermined period of time. The binary "1" signal is obtained from a bistable multivibrator circuit **226** which, for example, may take the form of a pair of RTL NOR gates **228** and **230** connected together to define a bistable multivibrator circuit.

Circuit **226** operates in synchronism with blanket cylinder **222.** The blanket cylinder is mechanically connected to a rotatable wiper arm **232** of a potentiometer **234** having a resistance portion **236** which is arranged substantially in a circle so that the wiper arm rotates in a clockwise direction and an output signal taken from one end of resistance portion **234** exhibits a voltage V_0 which is a ramp function extending from a level of substantial ground potential at 0° rotation to substantially the level of the B+ voltage supply source at 360° rotation. The wave form of voltage V_0 is shown in FIG. **12.** The output voltage V_0 is applied to a first threshold level detector L1 which serves to provide an output signal at a point in time when the output voltage V_0 exceeds at first limit level V_1 as set by the wiper arm of potentiometer **238** connected to one input of threshold detector L1. The output signal taken from threshold detector L1 is converted into a momentary positive signal pulse by a pulse generator PG–1 for purposes of applying a positive or binary "1" signal to one input of NOR gate **228.** Output voltage V_0 is also applied to a second limit threshold detector L2 which provides an output signal at a point in time when voltage V_0 reaches a level V_2, as adjusted by the wiper arm of a potentiometer **240.** The output signal from the second threshold detector L2 is applied to a pulse generator PG–2 which applies a positive or binary "1" signal to the input of NOR gate **230.**

When output voltage V_0 reaches a level equal to that of voltage V_1 a binary "1" signal is applied to the input of NOR gate **228** causing the output of NOR gate **230** to apply a binary "1" signal to switch **224** and thereby energize photosensor **220.** Once photosensor **220** senses marginal mark **222** a signal is applied to the synchronizer circuit SC' which then, in the manner of synchronizer SC described in detail hereinbefore, energizes lamp firing circuit LF and enables the gates in each of the associated gated densitometer control circuits.

Circuit 226 remains in the stable state since a binary "1" signal was applied from the output circuit of NOR gate 232 to the second input of NOR gate 228. Consequently, the binary "1" signal applied to electric switch 224 is continued even though the binary "1" signal applied to NOR gate 228 was momentary. Once the output voltage V_0 exceeds voltage level V_2 then pulse generator PG–2 applies a binary "1" signal to the second input of NOR gate 230 causing the circuit to reset to its original condition, wherein the output circuit of NOR gate 230 carries a binary "0" signal and both input signals to NOR gate 228 are binary "0" signals. This binary "0" signal taken from NOR gate 230 serves to deactivate electric switch 224 to, in turn, deenergize photosensor 220. Thus, it is seen that depending on the adjustment of potentiometers 238 and 240, sensor 220 will be energized to respond to a marginal mark 222 for an adjustable portion of the angular rotation of the blanket cylinder 202. The description thus far has been given with the assumption that lamp L is energized only once per cycle of rotation of blanket cylinder 202. It is to be appreciated that if a group of test patches such as patch 60′ follow each impression on web 50′ then lamp L and sensor 220 will be energized once for each impression and this could well be two or more impressions per cycle of rotation of cylinder 202 and, hence, appropriate modifications in the circuitry shown in FIG. 11 should be made.

The invention has been described with reference to preferred embodiments, however, it is to be appreciated that the invention is not limited to same as various modifications may be made without departing from the spirit and scope of the invention as defined in the appended claims.

Having thus described my invention, I claim:

1. Apparatus for obtaining an indication of the density of color reproduction printed in ink of at least one color on sheet material and comprising:

means for, when energized, transmitting light to simultaneously impinge upon at least one test surface area of said sheet material printed with a colored ink and upon an unprinted reference surface area;

first and second light sensor means for respectively simultaneously receiving light reflected from said test surface area and said reference surface area and providing first and second electrical signals of magnitudes respectively representative of the amount of light received by said first and second sensor means;

means for supporting said sheet material so as to receive light from said transmitting means; and

control circuit means connected to said first and second sensor means and responsive to said first and second signals for providing an electrical output signal exhibiting a characteristic which varies in proportion to the level of the color density of said test surface area.

2. Apparatus as set forth in claim 1 wherein said supporting means comprises means for moving said sheet material past said transmitting means and said sensor means and light control means for periodically energizing said light means in synchronism with the movement of said sheet material.

3. Apparatus as set forth in claim 1, wherein said control circuit means includes gating means for activating said control circuit means only when a gating signal is applied thereto.

4. Apparatus as set forth in claim 3 including synchronizing means for applying said gating signals to said gating means.

5. Apparatus as set forth in claim 4 including light control means for energizing said light means in synchronism with said gating signals whereby said light means is energized in synchronism with activation of said control circuit means.

6. Apparatus as set forth in claim 4, wherein said gating means activates said control circuit means for a time duration dependent on the time duration of said gating signals and said synchronizing means comprises circuit means for providing each said gating signal for a predetermined period of time.

7. Apparatus as set forth in claim 2, having synchronizing means comprising third sensor means for sensing a mark located on said sheet material forwardly of said test area and circuit means for providing a gating signal in response thereto.

8. Apparatus as set forth in claim 7, including means for cyclically energizing said third sensor means for sensing a said mark for a predetermined period of time during each cycle of operation.

9. Apparatus as set forth in claim 8 wherein said sensor energizing circuit means is adjustable to vary said predetermined period of time.

10. Apparatus as set forth in claim 1 wherein said first and second light sensor means have a light receptive surface for receiving light reflected from said surface areas and means for directing air across at least one of said light receptive surfaces to maintain same relatively clean.

11. A method of determining the color density of color reproductions printed with colored ink on sheet material wherein a plurality of longitudinally spaced monitor areas are provided on said sheet material with each monitor area including an inked test surface area of a particular color and comprising the steps of:

transmitting light so as to simultaneously impinge upon a said test surface area on said sheet material and an unprinted reference surface area;

utilizing first and second light sensor means to simultaneously receive light reflected along a given angle from said respective areas to simultaneously provide first and second electrical signals of magnitudes respectively representative of the amount of light received by said first and second sensor means; and

utilizing said first and second signals for providing an output indication exhibiting a characteristic which varies in proportion to the level of the color density of said inked test surface area.

12. The method as set forth in claim 11 wherein the step of transmitting light includes periodically energizing a light source in synchronism with movement of said sheet material so as to sequentially transmit light to impinge upon said plurality of monitor areas.

13. The method as set forth in claim 12, wherein said first and second signals for each monitor area exhibit magnitudes representative of the instantaneous intensity level of light received by said first and second sensor means, respectively.

14. The method as set forth in claim 13, including the steps of integrating each of said first and second signals for a given period of time for each said monitor area and providing an output density signal representative of the color density of said test surface area as a function of said integrated signals.

15. The method as set forth in claim **14** including the steps of integrating said first and second signals for a plurality of said monitor areas and providing a steady state control signal having a magnitude dependent on the existing level of said output density signal.

16. The method as set forth in claim **15** including the step of utilizing said control signal for providing read out indications of the color density of said ink test surface area.

17. Apparatus for obtaining an indication of the density of color reproduction in ink of at least one color on sheet material and comprising:

means for transmitting light to impinge upon at least a test surface area of said sheet material printed with a colored ink and a reference surface area comprising gas discharge flash lamp means for flashing a high intensity light beam of short duration so that portions thereof impinge upon said test surface area and said reference surface area;

light sensor means for receiving said high intensity light as reflected from said surface areas and developing respective electrical output signals dependent upon the amount of light received;

means for supporting said sheet material so as to be located to receive light from said lamp means and reflect light to said light sensor means;

means connected to said sensor means for providing an output indication as to the color density of said test surface area in dependence upon said output signals; and

means for triggering said flash lamp means into conduction.

18. Apparatus as set forth in claim **17**, wherein said flash lamp means exhibits the characteristic of flashing a light beam of high light intensity and relatively even spectral distribution.

19. Apparatus as set forth in claim **17**, wherein said flash lamp means includes a self-extinguishing Xenon lamp.

20. Apparatus as set forth in claim **17**, including means for directing a portion of said high intensity light beam so as to impinge on said reference surface area simultaneously with said light beam impinging on said test surface area, and said sensor means includes first sensor means responsive to light reflected from said test surface area for providing a first output signal and second sensor means responsive to light reflected from said reference surface area for providing a second output signal for use in providing said indication.

21. Apparatus for obtaining an indication of the density of a color reproduction printed in ink on material by comparing the reflectivity of the printed ink with the reflectivity of the material comprising: a gas discharge lamp for flashing a high intensity light beam of short duration, means for supporting said material in position to receive light from said lamp, and measuring means for receiving light from said lamp reflected by printed and unprinted portions of said material for measuring the reflected light and providing electrical signals indicating the reflectivity of said printed portion and said material and means for comparing said signals to provide a density measurement, said measuring means comprising means for exposing a reference area to light from said flash lamp simultaneously with the exposure of said printed portion and sensor means for simultaneously and individually measuring light from said printed portion and said reference area to obtain electrical signals for providing an output electrical signal which is independent of intensity of light from said lamp.

22. In a method for determining the density of ink printed on a sheet material wherein light is directed to printed and unprinted portions of the sheet material and the light reflected from the portions is measured to provide electrical signals indicating the reflectivity of a printed portion and an unprinted portion of the material and the signals are utilized to obtain the ratio of the reflectivity of the printed material and the reflectivity of the unprinted material to obtain a measurement of ink density, the improvement which comprises minimizing the effect of variations in light intensity on measurements by directing light to a printed area and to an unprinted reference area and simultaneously measuring the light reflected from the areas to obtain electrical signals which are affected in the same manner by light intensity and utilizing said signals to provide an ink density electrical output signal having a magnitude proportional to the ink density of said printed portion and which is essentially independent of light intensity.

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