

April 2, 1968

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3,376,426

COLOR DETECTION APPARATUS FOR MULTIPLE COLOR PRINTING

Original Filed Feb. 23, 1962

6 Sheets-Sheet 1

FIG. 1

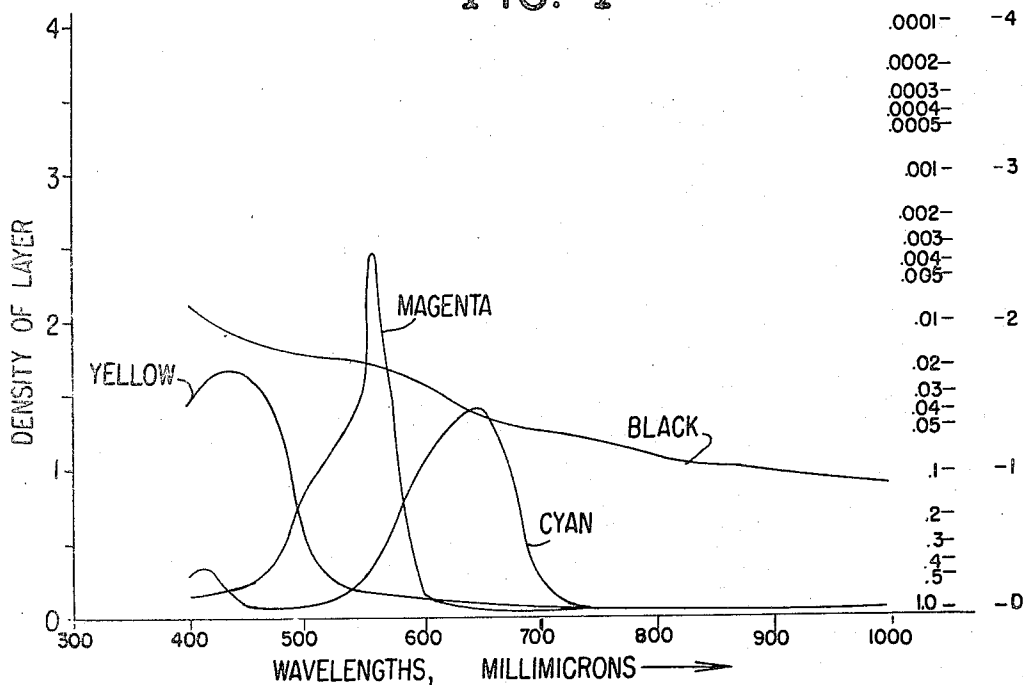
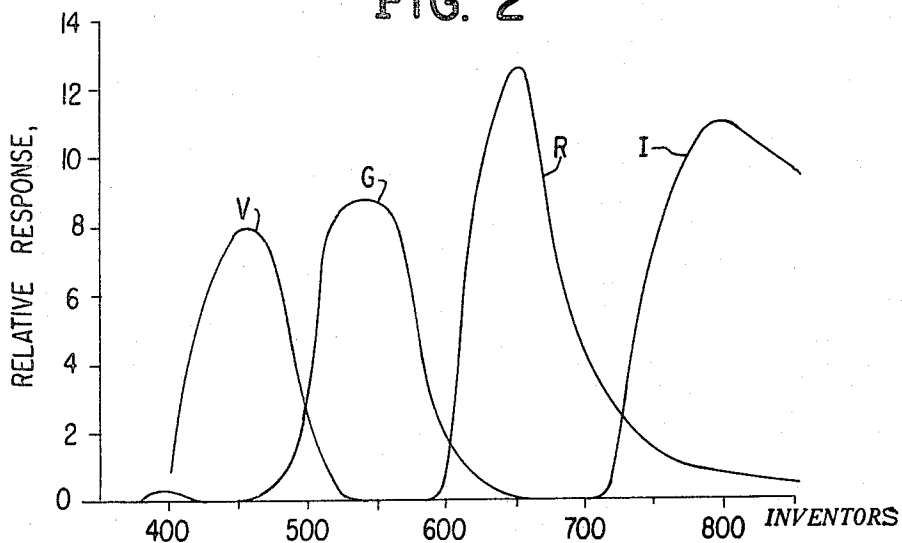


FIG. 2



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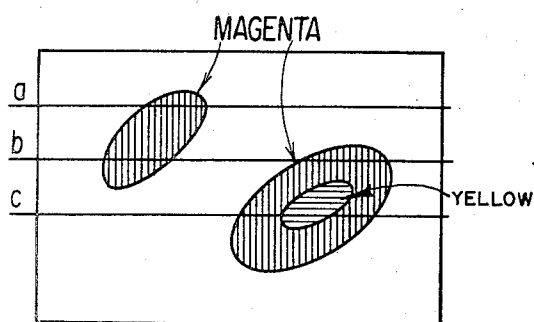


FIG. 3

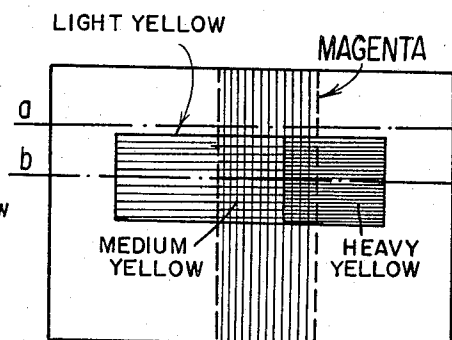


FIG. 6

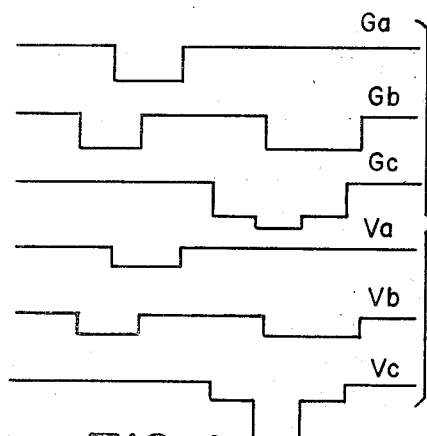


FIG. 4

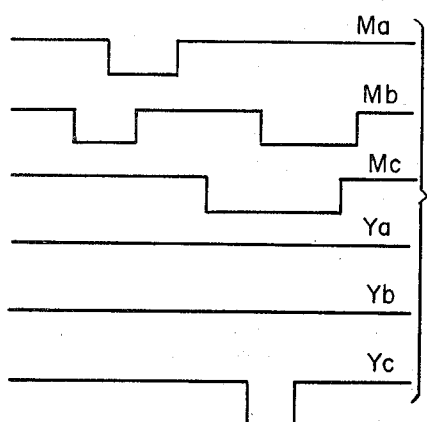


FIG. 5

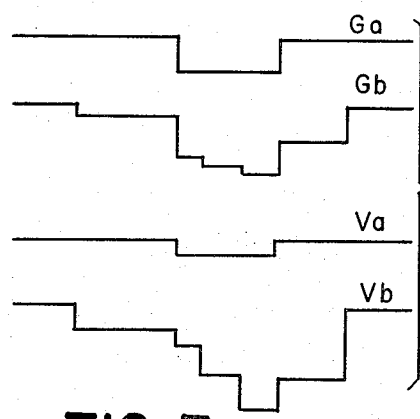


FIG. 7

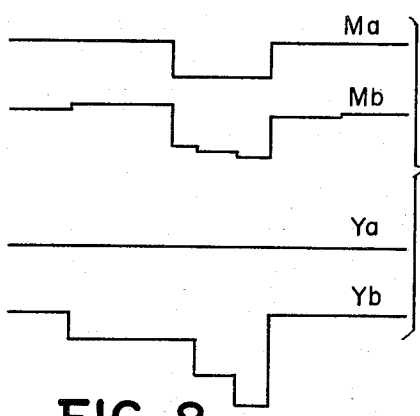


FIG. 8

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FIG. 9

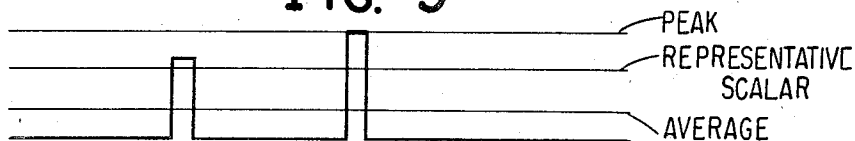


FIG. 10

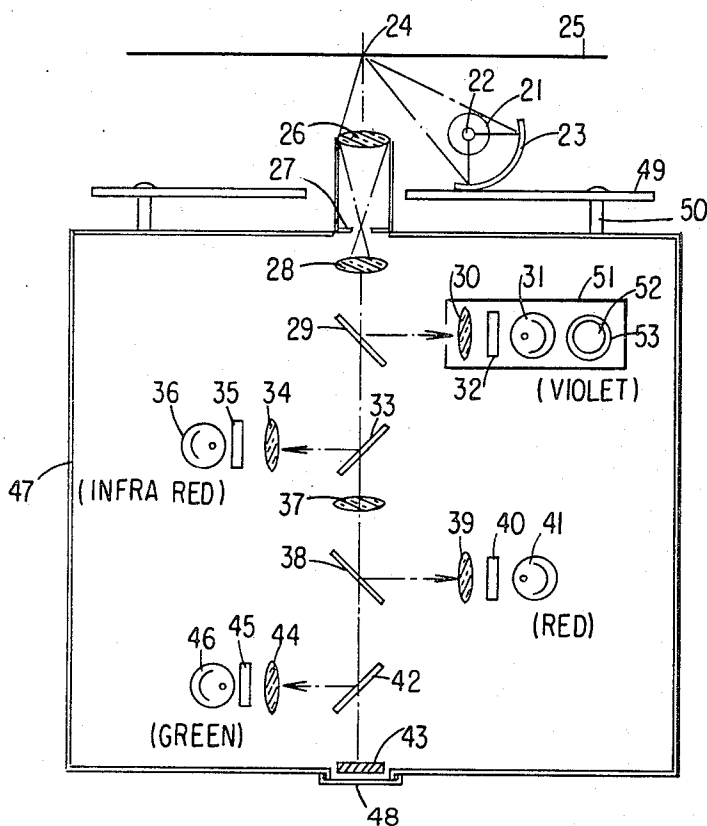
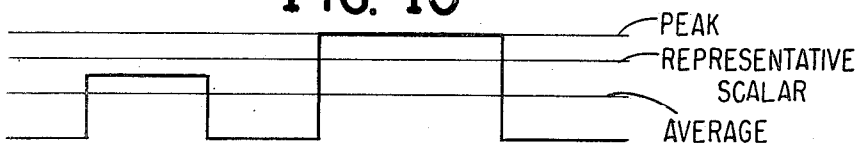


FIG. 11

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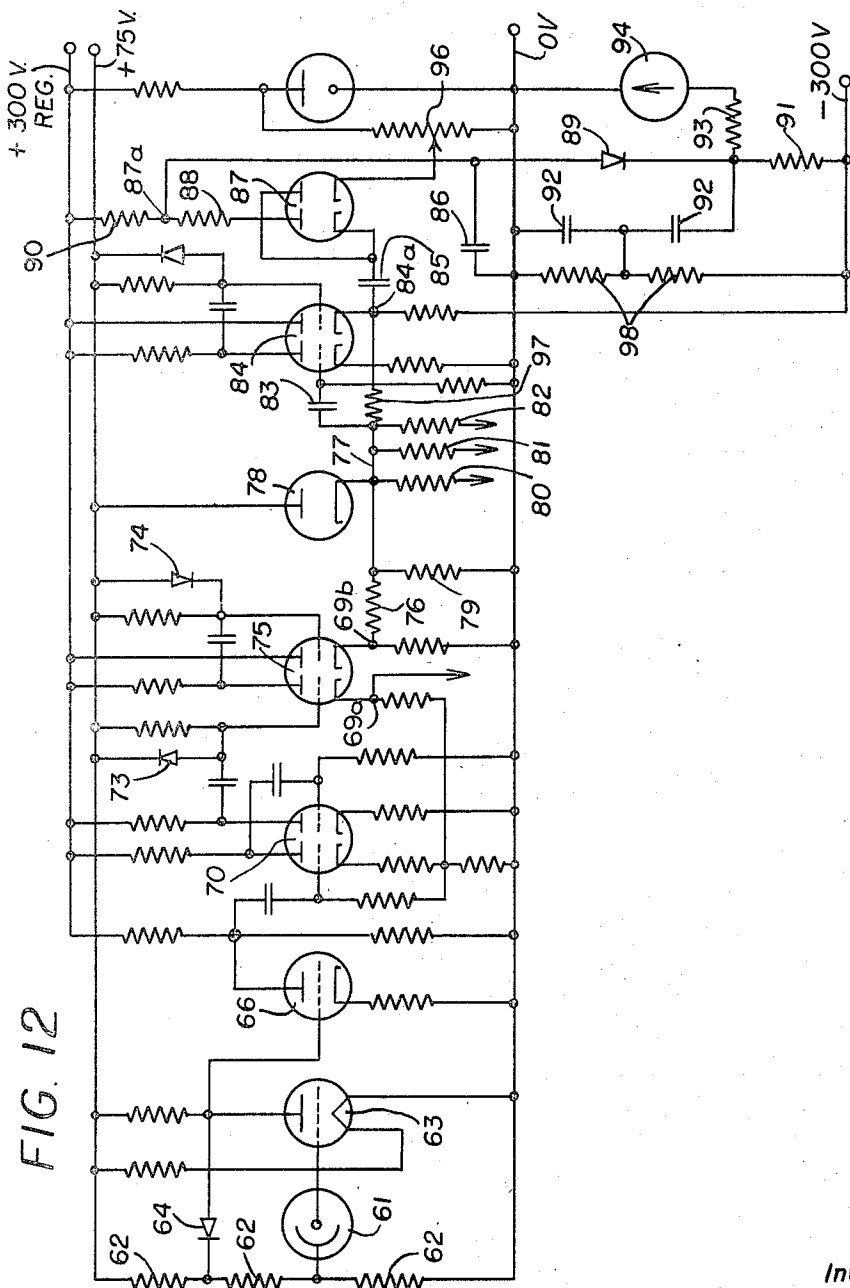


FIG. 12

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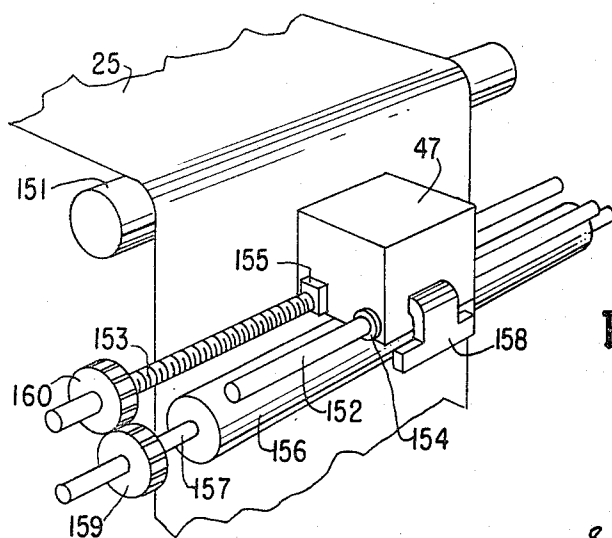


FIG. 13

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FIG. 14

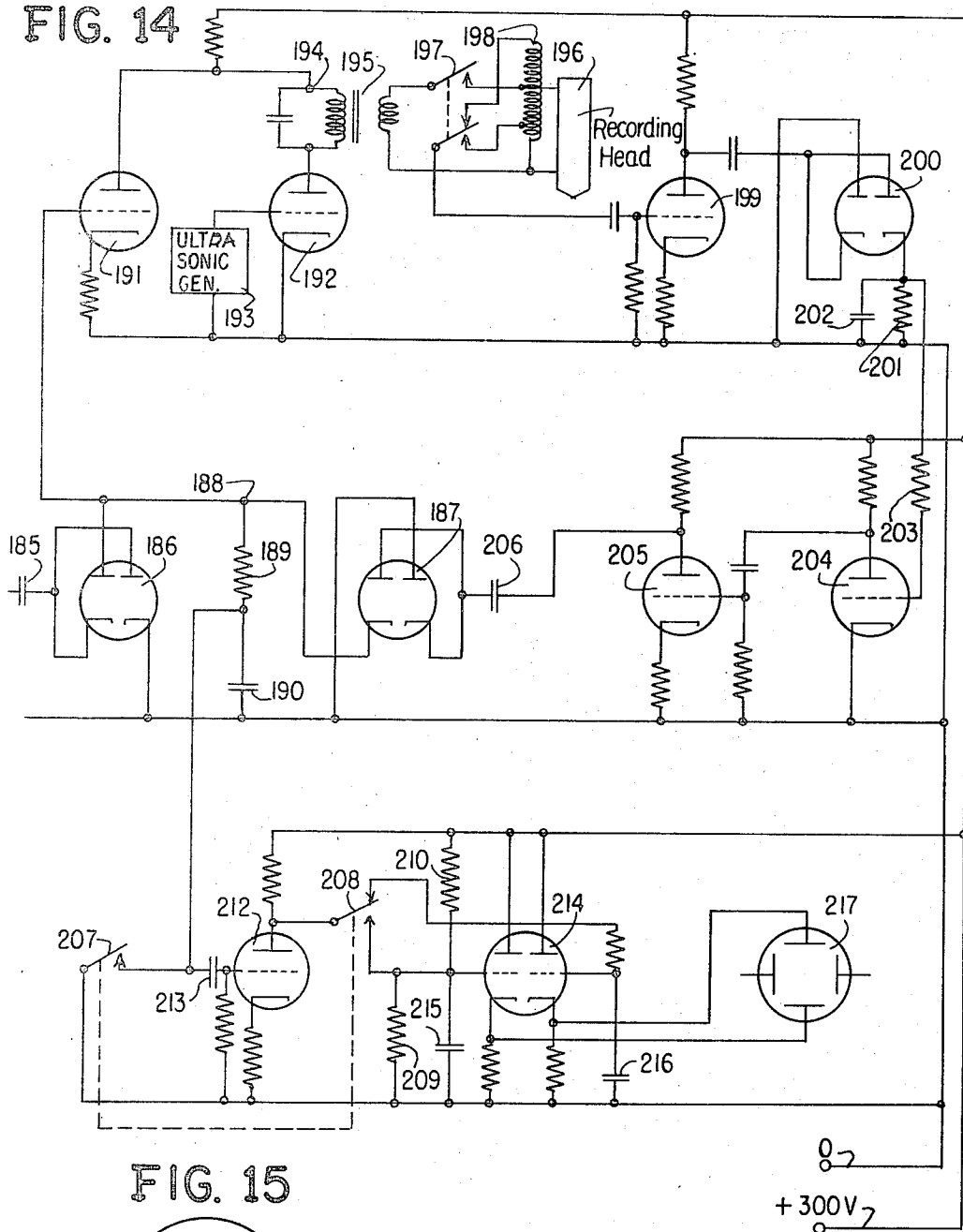
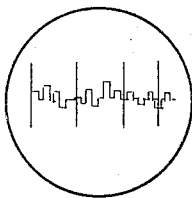


FIG. 15



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COLOR DETECTION APPARATUS FOR
MULTIPLE COLOR PRINTING

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Continuation of application Ser. No. 453,537, Apr. 16, 1965, which is a continuation of application Ser. No. 174,694, Feb. 23, 1962. This application Nov. 4, 1966, Ser. No. 592,227

20 Claims. (Cl. 250—226)

This application is a continuation of our application Ser. No. 453,357, filed Apr. 16, 1965, which was a continuation of our application Ser. No. 177,694, filed Feb. 23, 1962.

This invention relates to automatic inspection means for monitoring the appearance of a number of non-spectrum colored inks comprising an image applied to a web. More particularly, in an important aspect, this invention relates to means for continuously and rapidly monitoring the densities of each of the non-spectrum colored inks comprising a multicolored pattern which is printed on a rapidly moving web.

Photoelectric devices for inspecting a web for discolorations, flaws in the material and other relatively coarse characteristics are well known; however, they have not heretofore been adapted successfully to monitor changes in appearance of colored inks printed on the web in applications such as 4-color magazine printing.

The reason for this is that the photoelectric transducer, such as the phototube, is not sensitive to color in the psychophysical manner that the human observer is. Instead, it is sensitive to electromagnetic radiation in discrete ranges of wavelengths of the light spectrum. A photoelectric transducer comprising proper filters can be made to respond to light of a particular frequency which, if in the visible band, would be observed by a human as one of the spectrum colors. It is in this limited sense that a photoelectric transducer can be described as being sensitive to red, blue, or green light, or light of any of the other spectrum colors, which, in the case of this description, includes "colors" outside the visible spectrum, such as a particular range of wavelength in the infra-red portion of the spectrum. A photoelectric transducer, however, cannot be made selectively sensitive to a non-spectrum color such as magenta, cyan, yellow or black, the colors commonly used in magazine printing. The reason is that magenta is the psychophysical resultant of the mixture of red and blue lights. Thus a photoelectric transducer sensitive to red light of 650 millimicrons wavelength cannot distinguish between a red light of that wavelength and a magenta light comprising a 650 millimicron red component and a 450 millimicron blue component.

In certain applications, however, the density of magenta ink, which is an indication of its appearance to a human observer, can be monitored by measuring the amount of incident green light which is absorbed by the ink. One of these applications, to be described below in detail, is 4-color magazine printing using magenta, cyan and yellow transmissive inks and carbon black ink on a white web. In this case the density of the magenta ink is an inverse function of the amount of green light which is reflected back from the white web through the transmissive magenta ink.

Accordingly, it is the principal object of this invention to provide a method and means for monitoring the appearance of a plurality of non-spectrum color inks applied to a web.

Another object of the invention is to provide a method and means for accomplishing the principal object when

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one of the inks, such as black, has a high density in the infra-red range of light wavelength.

Still another object of the invention is to provide a method and means for accomplishing the above objects when the inks are applied to a rapidly moving web.

A further object of this invention is to provide non-spectrum color monitoring apparatus including a combined subtractive and additive suppression matrix responsive to spectrum colors.

An additional object of this invention is to provide color monitoring means having a magnetic memory synchronously operative with the repeated printing of a colored pattern on a web.

These and other objects and advantages of this invention will appear from the following description of a preferred embodiment of this invention adapted for use with a 4-color magazine printing press using cyan, magenta and yellow transmissive inks and carbon black ink.

In the drawings:

FIG. 1 is a graph of the density characteristics of the yellow, magenta, cyan and black inks chosen for printing one magazine.

FIG. 2 is a graph of the photoelectric transducer response characteristics of a particular combination of phototubes and optical filters for use with inks having characteristics similar to those shown in FIG. 1.

FIG. 3 is a diagrammatic plan view of a web printed with two different colors, magenta and yellow.

FIG. 4 is a graphic representation of the electrical signals obtained from two of the phototubes in the scanner when scanning along the lines *a*, *b*, and *c* of FIG. 3 as a function of time.

FIG. 5 is a graphic representation of the output signals received from the suppression matrix as a result of applying the signals of FIG. 4 to the suppression matrix input, as a function of time.

FIG. 6 is a diagrammatic plan view of a page printed with magenta and yellow inks, the yellow ink being printed in three different tones.

FIGS. 7 and 8 correspond to the FIGS. 4 and 5.

FIGS. 9 and 10 represent two time curves or oscillograms of two matrix output signals and three scalars commonly used to indicate the appearance of printed inks.

FIG. 11 is a diagrammatic sectional view through the scanner of this invention.

FIG. 12 is a circuit diagram of the amplifier, matrix and scalar generator of this invention for one of the colors.

FIG. 13 is a perspective view showing an arrangement in which the scanner housing is driven laterally across the web and a magnetic recorder is synchronized to the scanner for recording scanner signals.

FIG. 14 is a circuit diagram of a modified form of the invention comprising an addition to FIG. 12 which may be used in connection with the embodiment of FIG. 13.

FIG. 15 is a view of the face of cathode ray tube showing the display provided by the circuit of FIG. 14.

In order to obtain the desired quality of color printing from a letterpress, it is necessary to have the various printing cylinders properly engraved and the application of ink to each cylinder carefully metered. Metering is controlled by a ratchet acting over the entire width of the web and by keys, each acting only over a web width of approximately two inches. The ratchet and all keys have to be set to apply the right amount of ink. In the past, color patches of each color have been printed on certain designated portions of the pattern for the purpose of photoelectric inspection of their color. These color patches must not detract from the appearance of the picture of the material to be printed or they must be cut out and wasted before ultimate use of the printed mate-

rial. One such patch corresponding to each key is usually not feasible economically.

This present invention does not rely on specially printed color patches, but inspects the printing as it actually appears in the completed form. The photoelectric signals obtained from this inspection are submitted to an electrical analysis which yields specific information on the lack or surplus of each colored ink.

This analysis comprises the following steps: A number of observation tracks along the width of the web are observed photoelectrically by concentrating light thereon. Each track is called an "inspection zone." The light reflected from the non-spectrum colored inks within an inspection zone is broken up into a number of spectrum components which are the color complements of the non-spectrum inks. Each of the spectrum complements is fed to a separate phototube. The output signals of these phototubes are processed so as to obtain signals which are indicative of the intensities of the several spectrum components incident on the individual phototubes. Since these spectrum components are the color complements of the non-spectrum colored inks being applied to the web, the measurement of the density of each non-spectrum ink is being accomplished by a measurement of the absorption of its color complement. These signals are fed into a suppression matrix which suppresses those portions of each signal which contain spurious information, such as that portion of a signal which is representative of the overlapping of colors. From each of these resulting signals a scalar quantity is derived which is indicative of the lack or excess of the respective color ink in the inspected track. These scalars are displayed in a way which aids the pressman in making readjustments in the density of any of the colors. A number of preselected tracks can be inspected simultaneously by using one such

num or even a local maximum. In this example, the distinctive maximum density of black was chosen at 800 millimicrons which is not even the range in which a local maximum occurs. The term "distinctive" means measurably distinct which in this case would preclude a choice for black at most points on the visible portion of the spectrum.

FIG. 2 depicts the spectral response curves obtained with lamp-mirror-filter-phototube combinations to be more fully described in connection with FIG. 11. These combinations are referred to as V (violet), G (green), R (red), and I (infra-red) according to the spectrum color to which they are maximally reactive. The abscissas again represent wavelength in millimicrons and the ordinates indicate values linearly proportional to the signal output of each of the respective phototubes and their associated optical and electrical circuits in response to exposure of each phototube to light of a given wavelength. With the aid of the curves of FIGS. 1 and 2, the response of the various phototubes to paper printed with the various non-spectrum inks can be determined as described hereinafter.

First, the area under each of the curves of FIG. 2 is calculated, as this area is indicative of the photoelectric response of the respective phototube to white paper. Next, each ordinate of a curve of FIG. 2 is multiplied by the reciprocal of the antilogarithm of the respective ordinate of one of the curves of FIG. 1. The resulting ordinates are used to determine the area under the curve obtained with these ordinates. This area will be proportional to the photoelectric response of each phototube to white paper printed with the selected non-spectrum color. If this operation is performed for all the combinations, response figures such as the ones shown in the table below can be obtained:

	White	Yellow	Magenta	Cyan	Black
Violet response.....	1	.062	.496	.765	.014
Green response.....	1	.66	.12	.52	.021
Red response.....	1	.84	.895	.257	.048
Infra-Red.....	1	.91	.91	.91	.09

system for each track, but, in a preferred embodiment of the invention, a single unit can inspect one track after another by moving laterally across the width of the web, preferably, by the width of one inspection track for each revolution of the printing cylinders.

FIG. 1 represents the spectral curves of the densities of samples of yellow, magenta, cyan and black ink printed on white paper. Hereinafter, references to a web of "white paper" and to "white level" signals relate to the fact that it is conventional for the printing web generally to be of white paper and therefore readily enabling a "white" or base signal level. It is to be understood that webs of other color and material could also be easily employed, with appropriate adjustment of parameters of this invention.

The abscissas of curves in FIG. 1 represent wavelength in millimicrons. The ordinates indicate units of density of ink applied to unprinted white paper. These curves show that the yellow ink has a maximum density in the 400 to 500 millimicron range of wavelength, the magenta ink has a maximum density in the 500 to 580 millimicron range, the cyan ink has a maximum density in the 580 to 680 millimicron range and the black ink has a high density throughout the visual band and also in the infra-red band. A given ink has its distinctive maximum density occurring at a wavelength at which it has a relatively high density compared, either with its own density in another range or with the density of another ink in the same range. This maximum density need not be an absolute maxi-

As those generally knowledgeable in fields of light, optica and color appreciate, red, blue, and green are the three primary or additive primary spectrum colors; whereas, cyan, yellow, and magenta are respectively the corresponding three complementary or subtractive primary non-spectrum colors. Accordingly, light reflecting from any one of these complementary colors will contain an increasingly smaller component of its associated primary color as the density of that complementary color increases. Stated differently, as the density of a non-spectrum complementary color increases, the absorption of its associated primary color also increases proportionately. This invention has applied this phenomena to a specific combination of elements to provide valuable ink density data.

As above stated, blue is one of the primary colors and cyan is one of the complementary colors. Since both visually appear to be blue, cyan being blue-green, the printing trade frequently employs the name "violet" in lieu of the name "blue." Hence, the terms "blue" and "violet" as employed herein, are to be considered synonymous in their reference to the additive primary color blue.

In a preferred embodiment of the invention, a four channel scanner generates an output voltage proportional to the logarithm of the ratio of the momentary photoelectric current to the photoelectric current during passage of the highest reflection (usually white) portions of the web. Accordingly, the voltage obtained from the four channels of the scanner at the passage of these solid sample colors would be:

	White	Yellow	Magenta	Cyan	Black
Violet scanner output.....	0	1.2	.3	.12	1.85
Green scanner output.....	0	.18	.92	.28	1.68
Red scanner output.....	0	.08	.05	.59	1.32
Infra-Red scanner output.....	0	.04	.04	.04	1.05

If more or less ink is applied, then these signals will vary. It is seen that change of density coverage of any one ink will influence more than one of these responses. According to the invention, a resultant signal which is primarily a function of the coverage of one of the inks, is generated by mixing the scanner output signals in a suppression matrix.

For example, to eliminate the violet scanner response to magenta, and black inks, a suitable fraction of the green and infra-red scanner output signals is subtracted from the violet scanner output signal to generate a signal responsive essentially to the coverage of the yellow ink. Similarly, suitable fractions of all other scanner output signals are subtracted from the green, red and infra-red output signals to generate signals responsive essentially to the coverage of the magenta, cyan and black inks, respectively. A noted exception to the subtractive operation of the suppression matrix is with respect to the violet scanner response to cyan, in which a suitable fraction of the red output signal is added to the violet scanner's output to complete the yellow density response signal. It will be noted that inclusion of infra-red inspection according to the present invention makes it possible to discriminate black printing from a mixture of yellow, magenta and cyan printing which can appear as black insofar as inspection with light in the visible band is concerned.

FIG. 3 represents a portion of a web, say one page of the printed material, having portions uniformly printed with a first color, say yellow, on the area shown shaded with horizontal lines, and with a second color, say magenta, on the area shaded with vertical lines and the area upon which yellow was printed. It should be noted that the area covered by both the yellow and magenta inks will appear as red. The letters *a*, *b*, *c*, denote the centerlines of three tracks, chosen at random, along which this sheet may be inspected. These tracks may extend to a width of, say one-tenth of an inch right and left of these centerlines.

FIG. 4 represents the time curves of the violet and green phototube output signals obtained by scanning these tracks. *Va*, *Vb*, *Vc* represent the violet output signals and *Ga*, *Gb*, *Gc* represent green output signals. These curves show the violet phototube's high sensitivity to the presence of yellow ink and the green phototube's high sensitivity to the presence of magenta ink. These curves also show the secondary sensitivity of the violet phototube to the presence of magenta ink and that of the green phototube to the presence of yellow ink. To eliminate these secondary sensitivities, the photoelectric output signals are transmitted (after amplification) to a suppression matrix which will subtract from the violet signal a part of the green signal and also subtract from the green signal a part of the violet signal. The output signals of the matrix are shown in FIG. 5. It is seen, that by proper selection of the factors of the matrix, the violet photoelective output signal and the green photoelective output signal are transformed respectively into yellow and magenta printing signals designated *Ya*, *Yb*, *Yc* and *Ma*, *Mb*, *Mc*.

FIG. 6 represents a sheet, similar to FIG. 3, but here the yellow ink (represented by horizontal lines) is applied in three tones of different density (represented by closer shading for heavier tone). Magenta ink is applied at a constant tone over the area identified by vertical shading.

FIG. 7 represents the time curves of the photoelectric signals obtained by scanning tracks *a* and *b* of this pattern. If these time curves are applied to the same matrix used for obtaining the time curves of FIG. 6, output signals as shown in FIG. 8 will be obtained. In these curves of FIG. 8, compensation is perfect only for the densities of the inks for which the matrix has been calibrated, while for other densities a slight secondary effect of the unwanted color may persist.

This undesired side effect can be dealt with in various ways. Nonlinear matrices, which will subtract different fractions of the unwanted signal at different levels can be

provided. Another economical way is to subtract from each signal a derivative of another signal which is proportional to the derivative of the unwanted signal. A nonlinear matrix may also be used for subtracting different fractions at different values of wanted and of unwanted signal level. In practice, however, it will usually suffice to adjust the herein preferably embodied linear matrix for correct response at one maximum level of density.

Up to this point consideration has been given only to time curves of phototube signals which, after passing the matrix, gave output signals indicative of the densities of each of the inks used. Oscillograms or curves of these signals will expand or contract as the area of the image is changed. It would be difficult to ascertain from observing these curves the amount of ink which is to be added or removed from the inspected track. To obtain clear and easily interpreted information of the desired type, scalar values, which increase or decrease according to changes of the amounts of the inks applied to the web and their appearance, are generated from these matrix output signals. Such scalar values can be generated from the output signals in various ways. Two very useful scalars are those which are functions of the peak value or the average value of the matrix output signal. However, other scalar values indicative of the application and appearance of the inks readily may be obtained by means such as a detection circuit having a resistor in series with a diode. This provides a simple and efficient means to alter the relative weight of peak value and average value components which produce the scalar. FIGS. 9 and 10 represent two time curves with their average, peak, and a representative scalar value indicated by the height of each identified horizontal line.

Thus far, the concepts of spectral curves, oscillograms or time curves, and scalars have been explained as applied to the invention. Hereinafter, the mechanical structures and electrical circuits of the preferred embodiment of the invention will be set out in detail.

FIG. 11 is a schematic cross sectional view of a scanner for the inspection of the web and the generation of photoelectric signals indicative of the coverage of the printing thereon. A lamp 21 having a filament 22 is mounted on the scanner. A spherical or elliptical mirror 23 concentrates the light of filament 22 onto an inspection zone 24, past which a web 25 moves in a direction perpendicular to the axial plane of the scanner. An achromatic objective lens 26 focuses an image of the small portion of the web within the inspection zone through a mask 27 and a lens 28 onto a dichroic mirror 29. The dichroic mirror 29 reflects light of wavelength below 500 millimicrons and transmits light above 500 millimicrons. A simple lens 30 concentrates the light reflected by mirror 29 on a circular portion of the cathode of a phototube 31 which is maximally sensitive to violet light. Between the mirror 29 and phototube 31 is situated a filter 32 which removes certain undesired spectral components. In this manner, the phototube may be said to generate a "violet" signal.

A dichroic mirror 33 which reflects light above 700 millimicrons and transmits light below this, is located in the optical path of the light transmitted through mirror 29. A simple lens 34, and a filter 35, focus the light reflected from mirror 33 onto a phototube 36, which generates an "infra-red" signal. A simple lens 37 is used to collimate the beam of light.

A dichroic mirror 38 reflecting light above 580 millimicrons and transmitting light below that wavelength, lens 39, filter 40, and phototube 41 generate the "red" signal.

A dichroic filter 42, which reflects most of the remaining light, but transmits some which forms an image on a ground glass plate 43, is located in the optical path of the mirror 38. Lens 44, dichroic mirror 45, used as a filter, and phototube 46, generate the "green" signal.

The optical components of the scanner are enclosed within a light-tight enclosure 47. The ground glass plate 43 is covered by a cover 48 which can be removed for in-

specting the correct alignment of many of the optic elements lying between the inspection zone 24 and this ground glass plate, and replaced to prevent the intrusion of stray light during normal operation. The lamp 21 is placed outside the housing 47 to prevent stray light from affecting the phototubes and to avoid heating of the phototubes. The four phototubes are shielded by individual shielding canisters one of which is shown at 51. Each phototube has an adjacent preamplifier electrometer tube 52 surrounded with a metallic shield 53 which provides both electrical and optical shielding.

FIG. 12 represents the circuit diagram of a circuit constructed according to the invention. It is powered by a power supply, not shown, which may be common to a number of such amplifiers and which supplies filament voltage to the amplifier tubes and the direct voltages required. The values of the latter are indicated in FIG. 12 adjacent the appropriate leads. The notation "REG" signifies a voltage regulated by voltage regulating tubes or a combination of voltage regulating tubes and amplifier tubes or the like. In this figure, 61 represents a phototube, which is the equivalent of one of the phototubes 31, 36, 41 or 46 of FIG. 11. Each of these phototubes is connected to an amplifier similar to the one shown in the presently discussed FIG. 12. A voltage divider 62 supplies an anode voltage to the phototube. A diode 64 connected to the voltage divider prevents the anode of electrometer tube 63 from assuming a voltage above its rated value if unusual conditions should drive tube 63 into cut-off condition. An additional amplifying stage, comprising triode 66, follows the electrometer tube amplifying stage. A twin triode 70 provides two further stages of amplification and is followed by a phase splitter, comprising the duo-triode 75, having a pair of cathode follower outputs 69a and 69b of opposite phase relation.

Thus, the output signal of phototube 61, substantially amplified, appears at output terminals 69a and 69b. At any given instant, the magnitudes of the signals appearing at 69a and 69b are equal, but their polarities are opposite; hence, if the signal at 69b is positive-going, the signal at 69a, is negative-going.

From the cathode follower output 69b, a resistor 76 leads to an area or point 77, to which one end of each of the resistors 79, 80, 81, 82 and of capacitor 83 is connected. The other terminals of resistors 80, 81, 82 are connected to the outputs 69a of the amplifiers of the other three colors of the same track, each resistor being connected to a different amplifier. Inversely, the output 69a of tube 75 of each of the other amplifiers is connected to the opposite terminal of the respective resistors of the three other amplifiers. These connections, symbolized by arrowheads and resistors 76, 80, 81 and 82 and their counterparts in the other amplifiers, are denominated as the suppression matrix.

The circuit of FIG. 12 functions in the following manner: Phototube 61 is exposed to one of the spectrum components of the light reflected from the inspection zone and generates a voltage curve as shown in FIGS. 4 or 7. Its anode is connected to a point carrying a positive voltage with respect to ground and its cathode is connected to the grid of electrometer tube 63, whose filament is grounded. There exists no other galvanic connection to the phototube cathode, so that whatever the photocurrent may be, it flows through the grid-to-cathode path of tube 63. This current generates a signal across this grid-to-cathode path which is proportional to the logarithm of the ratio of the instantaneous value of the photocurrent to the white level amount in accordance with principles explained in U.S. Patent No. 2,517,554. This signal appears amplified at the anode of tube 63. Due to the low amplification factor inherent in the triode connection of the tube used, its anode can be direct-coupled to the grid of the following tube 66, and an oscilloscope connected to this anode will display the oscillogram or time curve of the signal generated by the phototube 61, which is a func-

tion of the densities of the inks as applied to the web at the inspection zone.

Through amplification in tubes 66, 70 and 75 the signal generated by phototube 61 will appear amplified at the cathodes of tube 75. The greater the density of the non-spectrum ink on the portion of the web seen by phototube 61, the more positive will the signal be which appears at the output terminal 69b. Its most negative voltage (pertaining to the passage of white portions) is limited to a few volts above the 75 volt level by clamping diodes 73 and 74 connected between the 75 volt supply and each of the grids of tube 75. An identical signal of opposite polarity with similar white level appears at the output terminal 69a of tube 75.

Each of these signals in the four amplifiers represents one of the ranges of wavelength of light reflected from the web, i.e., violet, green, red or infra-red. Each signal contains information relating the densities of all the inks. To obtain information on the lack or excess of one ink, irrespective of lack or excess of the other inks, the suppression matrix previously described is employed. In this embodiment of the invention, the matrix comprises four interconnected sets of resistors 76, 80, 81, 82 in each amplifier. In each set, these resistors are all connected to the junction point 77.

In the violet amplifier, resistor 76 connects junction point 77 to the violet density curve output terminal 69b on the second cathode of 75 of its own circuit, whereas, resistors 80, 81, 82 connect it to the cathode output terminals 69a of tubes 75 of the other (green, red, infra-red) amplifiers inspecting the same inspection zone. By proper selection of these resistance values, the signal at point 77 can be made a function primarily of the excess or lack of yellow ink. Correspondingly, the signals at points 77 of the green, red, infra-red amplifiers can be made functions primarily of the excess or lack of the magenta, cyan and black ink respectively.

For the mirror-filter-phototube combinations described in connection with FIG. 11, satisfactory results have been obtained with the following resistor combinations: R76=.33 megohm; violet amplifier 0.6 megohm to green, -3 megohms to red, 0.5 megohms to infra-red; green amplifier, 3 megohms to violet, 2.2 megohms to red, .39 megohm to infra-red; red amplifier no resistor to violet, 7 megohms to green, .33 megohm to infrared; infrared amplifier: no resistor to violet or green, 2.2 megohms to red. All of these resistors are connected to the first cathode 69a of the respective tube 75, except that the 3 megohm resistor from the violet amplifier is connected to the second cathode 69b of tube 75 of the red amplifier. This fact is marked by the minus sign ahead of the value of this resistor. The reason for the necessity of adding rather than subtracting this red correction to get true yellow information lies, it is believed, in the manner in which the presence of magenta ink above yellow ink may add to the reflection of certain spectrum components, especially insofar as small variations of heavy printing of this latter ink are concerned.

In the present system it has been found necessary to eliminate the possibility of some combination of correction signals from interfering with the white level of the main signal. This is accomplished by bringing the white level of junction point 77 to 75 volts with the aid of resistor 79 and clamping diode 78.

The density signals are transformed into representative scalars in the following manner. In each amplifier, tube 84 amplifies the signal appearing at point 77; the resulting signal appearing at the right hand cathode 84a of tube 84. Feedback resistor 97 insures that the amplifier stage will have the desired linear response. The signal at 84a is fed by way of capacitor 85 into the peak-to-peak detector series diodes 87. In this embodiment, in which it is desired to obtain a representative scalar value less dependent on the peak values of density, as shown in FIGS. 9 and 10, a resistor 88 is connected in series with and a

capacitor 86 in parallel to the series diodes 87. A representative scalar signal, which is function of the lack or excess of one of the inks, now appears at junction 87a of resistors 88 and 90 and capacitor 86. This junction is connected through scalar detecting diode 89 to meter 94. This meter indicates the deviation of the representative scalar value from zero which is a function of the excess or lack of the monitored ink.

Meter 94 is a zero center instrument. Its midpoint indicates that the representative scalar signal equals the reference signal which is determined by adjusting potentiometer 96. Accordingly, the meter 94 reads zero when a perfect copy is being scanned. Resistors 90, 91 and 93, along with the +300 volt and -300 volt lines, comprise the meter 94 bias supply. Meter readings are obtained by making the meter sensitive to the difference in magnitudes of two currents flowing in opposite directions in the meter. The first current is constant and flows from ground through the meter 94, resistor 93 and resistor 91 to the -300 volt line. The second current may be analyzed as having a magnitude dependent on the magnitude of the scalar signal and flowing from the +300 volt line through resistor 90, diode 89, resistor 93 and meter 94 to ground. Resistors 98 and capacitors 92 comprise a filter which together with the diode 89 form the scalar detecting circuit.

By means of this last detecting circuit the waveform appearing at the junction 87a is "detected" into a D.C. level suitable for causing the meter 94 to indicate a stable scalar value. The actual current flowing through the meter will be controlled by diodes 87.

At a time when the press prints satisfactory copies, each of the potentiometers 96 in each of the four scalar detecting circuits is adjusted until its meter 94 returns to its zero center. Thereupon, each potentiometer is locked in this position and thereafter the operator adjusts the keys or other controls on the press until all meters return to their zero center, again indicating perfect copy.

It is not necessary to have a number of scanners in fixed lateral position, and, in a preferred embodiment of the invention, a scanner is moved laterally across the width of the web for generating scalars for essentially the entire printed surface. FIG. 13 represents schematically such an arrangement.

In this view, the housing of the scanner 47 is mounted on a guide shaft 152 which is positioned across the entire width of the web 25. The web is supported by a guide roller 151. The guide shaft 152 slidably engages a suitable passageway 154 in the scanner housing 47 and a threaded shaft 153 engages a nut 155 which is fixed to the scanner housing 47.

A gear 160 is connected to the shaft 153 and to the printing cylinders such that the members move scanner housing 47 by the width of one inspection track, for example, one tenth of an inch, for each revolution of the printing cylinders. When scanner housing 47 reaches the end of the width of the web, a mechanism (not shown), reverses the direction of the drive and causes scanner housing 47 to move back in the opposite direction.

In this manner, the scanner inspects one track of the web after the other and repeats this inspection (in the opposite direction) after it has inspected all tracks. A 72" wide web inspected by 0.1" tracks would thus be reinspected after each 720 revolutions of the printing cylinders.

To further augment the monitoring of the densities of the non-spectrum inks so that they can be maintained to proper standards, the present invention provides for a magnetic drum memory which first stores data representative of proper ink density across the entire web and then compares this data with the density of the ink being applied to the moving web.

As shown in FIG. 13, a cylinder or drum 156, having its surface covered with magnetizable material, is mounted on a shaft 157 which supports a gear 159 that is coupled

to the gear 160. In this manner, each revolution of the printing cylinders synchronously rotates the cylinder 156 and the shaft 153. Secured to the scanner housing 47 is a bank of four magnetic recording and pickup heads 158, which is in close proximity to the cylinder's magnetizable surface so that as the rotating shaft 153 causes the scanner housing to traverse the width of the web, the bank of magnetic heads similarly traverses the rotating cylinder 156.

The bank of magnetic recording and pickup heads is so arranged that each head records or reads on a helix .025" wide. Thus, the magnetic heads will have a different location for any lateral position of the scanner and for any angular position of the printing cylinders. Hence, the magnetic information stored at any location of the cylinder 156 will be opposite the same head which stored this information each time the scanner is in the same lateral position inspecting the same inspection track when the printing cylinders are in the same angular position.

The arrangement of FIG. 13 may be used with the same optical arrangement of the scanner head as shown in FIG. 11, and with an amplifier similar to the one shown in FIG. 12 connected with each phototube thereof. To record data concerning the desired density of non-spectrum inks to be applied to a moving web and to compare the recorded data with the dynamically varying densities of these inks as they are being applied to the web, this circuit can be altered by disconnecting capacitor 85 and by connecting the second cathode of twin triode 84 to the capacitor 185 of an arrangement as shown in FIG. 14.

In this figure, series diodes 186 and 187 are connected to a junction point 188. A triode 191 is direct-coupled to the junction point 188 and anode modulates triode 192. The grid of triode 192 is connected to a source of ultrasonic oscillations 193, such as a piezo-electric crystal-resistor, and the resonant circuit 194 in its plate circuit is tuned to the frequency of the oscillations from the generator 193. The tuned circuit 194 comprises a transformer 195 the secondary of which can be connected to or disconnected from a recording head 196 by one pole of a double pole switch 197. The recording head 196 is also connected to a step-up transformer 198. The second pole of switch 197 connects the input of tube 199 to the top of transformer 198 when transformer 195 is disconnected from the recording head and connects the input of tube 199 to a low tap of 198 when transformer 195 is connected to the recording head 196. The output of tube 199 is connected to series diodes 200. The output of the series diodes 200 is connected to the resistance-capacitance combination 201 and 202 and through resistor 203 to grid of triode 204. Triode 204 drives triode 205, the output of which is applied through capacitor 206 to series diodes 187.

Contact sets 207 and 208 are two contact sets of a mechanical switch which is actuated by mechanical means, not shown. Contact set 207 can connect ground to the junction of capacitor 190 and resistor 189. This junction is also coupled to the grid of tube 212 through capacitor 213. Contact set 208 can connect the plate of tube 212 to one or the other grid of the two cathode followers provided by the twin triode 214. The cathodes of tube 214 are connected to the vertical deflection plates of a cathode ray tube 217.

The pattern appearing on the face of cathode ray tube 217 is shown schematically in FIG. 15. In this figure, the abscissas correspond to the various lateral portions of the web. The heights of the trace above or below the zero line at the various abscissa are scalar values which indicate excess or lack of ink each corresponding to one of the ink supply regulating keys. The horizontal zero line is not shown superimposed in FIG. 15 so as not to obscure the trace, but can be seen between many of the square waves of the trace. The vertical lines are markers injected after, say, every five keys for easy identification of the various keys on this pattern.

The arrangement described in connection with FIGS. 13, 14 and 15 functions in the following manner when a new form (a new set of printing cylinders engraved for printing new information) is inserted into the printing press.

First, all previous information is erased from cylinder 156. Next, the pressmen adjust all keys until they attain printing which is satisfactory in all respects. When this is achieved, they throw switch 197 into the record position, connecting transformer 195 to the recording head 196. The switch is left in this position until the scanner has traveled once over the entire width of the web. After this, the switch 197 is thrown to its other position so that no new information is recorded on cylinder 156.

With switch 197 in this second position, the information recorded on the cylinder is transmitted via transformer 198 to tube 199. From then on, new information from the web as it is being printed, is correlated with the information recorded on cylinder 156. This correlation yields voltages at junction 188 positive or negative with respect to the junction point of resistors 209 and 210 (as will be explained later) which charge capacitor 190. Each time the scanner reaches the end of the lateral region served by one key (and the start of the lateral region served by the next key), the twin switch 207, 208 discharges capacitor 190 toward ground. The capacitor 190 starts anew in its assuming charges positive or negative according to excess or lack of ink in the inspection track inspected. The discharge of 190 causes a voltage surge which is transmitted via capacitor 213 to tube 212. This signal is amplified and applied through contacts 208 to the left grid of 214 and to capacitor 215. This signal is then applied to one vertical plate of cathode ray tube 217, which will be kept at a steady vertical deflection potential by reason of the charge in capacitor 215, until the next move of contact set 208.

As will be noted, the charge on capacitor 190 will stay unchanged between two closings of switch 207 if and only if the average voltage of point 188 over this period is zero. This average voltage will be zero if the signals impressed through capacitors 185 and 206 to diodes 186 and 187, respectively, are equal. This equality for perfect copy is achieved by causing the signal appearing on the output of tube 205 to be identical with the signal obtained from the perfect copies inspected when switch 197 was set to recording.

It should be apparent from the above description that the invention is capable of considerable variation and change well within the spirit and scope of the invention. Some of the applications of the invention have been discussed and others are deemed of sufficient importance to mention without further detailing the structure thereof.

The web 25 as described has not been categorized as opaque intentionally. It may be translucent or transparent or it may be absolutely opaque. In many instances, instead of reflecting light from the printed matter on the web, it may be more convenient or efficient to illuminate the inspection zone from the rear of the web and have the scanning device react to the transmitted light. This would require little or no change in the specific structures illustrated, beyond the change in the location of the illuminating means 21.

The invention herein is not limited to the indication of color condition, that is lack or excess of certain pigments. Since the indication is absolute, if it can be used to drive a meter, obviously it can be used to energize structure which will add or subtract from the pigment, the latter effect being obtained, for example, by adding solvent. Under such circumstances, the judgment of the operator may be dispensed with.

The claims are to be interpreted to include such application.

What it is desired to claim is:

1. A density monitor for colored inks applied to a web, said monitor providing bidirectional scalar indications of

variation from normally desired density of each of a plurality of inks as they are being applied to the web, said monitor having means responsive to the amount of light absorption of each of said inks, comprising:

- 5 means for defining a discretely illuminated portion of said ink applied web and for receiving therefrom discrete spectrum components of the light reflected from said web in proportion to the density of the applied inks;
- 10 said receiving means having means for separately responding to representative wavelengths of each of said spectrum components and for transducing into electrical signals the quantum of each spectrum component in a manner which is primarily indicative of the density of its associated applied ink;
- 15 primarily subtractive suppression matrix means coupled to said responding means for receiving all of said electrical signals, operating upon them in a primarily subtractive corrective mode, and removing from each said signal the influence of the inks associated with the other of said signals;
- 20 said matrix means having a plurality of discrete outputs each of which receives from said matrix means energizations separately manifesting the density of each of said inks; and
- 25 a plurality of bidirectional scalar generating and indicating means each respectively coupled to one of said plurality of matrix outputs;
- 30 each said bidirectional scalar means having means for generating a signal characteristic of the desired density of its associated ink and coacting this characteristic signal with said matrix output energizations to provide dynamic bidirectional indications of the density of the then being applied ink as compared with its desired density.
- 35 2. A density monitor as defined in claim 1 in which: said primarily subtractive suppression matrix also has means providing additive mode correction to a certain portion of said electric signals.
- 40 3. A density monitor as defined in claim 1 in which: said primarily subtractive suppression matrix has a plurality of pairs of input terminals; the terminals of each pair are of opposite polarity and are coupled to clamping means defining a voltage level representative of the web color prior to the application of any of said inks; and
- 45 each pair of terminals is associated with one of said inks.
- 50 4. A density monitor as defined in claim 3 in which: each of said input terminals is part of a unidirectional conductive device which is intercoupled to the terminal of opposite polarity of each of the other pairs of input terminals via a plurality of discrete resistive elements; and
- 55 each resistive element has a position and value for determining the magnitude and algebraic sign of said corrective mode.
- 60 5. A density monitor as defined in claim 4 in which: the position of one of said resistive elements is such that it provides an algebraically additive correction to said otherwise subtractive matrix.
- 65 6. A density monitor as defined in claim 1 in which each said bidirectional scalar generating and indicating means comprises:
 - 70 a peak to peak detector having its input coupled to one of said matrix outputs;
 - a bidirectional meter coupled on one side to the output of said detector and coupled on the other side to ground;
 - a rectifier resistively coupled in series between said detector output and said one side of said meter; and
 - resistively coupled bias sources of opposite polarity coupled to opposite ends of said rectifier and providing a pair of oppositely directed paths through

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said meter, one of said paths containing a constant current and the other path passing through said rectifier and having a magnitude dependent upon the magnitude of the density representing energizations from its matrix output.

7. A density monitor as defined in claim 1 in which: one of said inks is black; and said receiving and responding means comprises means maximally responsive to wavelengths beyond the visible portion of the spectrum.
8. A density monitor as defined in claim 7 in which: said receiving and responding means comprises dichroic elements optically coupled to a phototransducer selectively responsive to wavelengths in the infra-red range.
9. A density monitor as defined in claim 1 further comprising:
 - means for recording and storing information corresponding to the desired ink density on a plurality of said discrete web portions;
 - means for subsequently reading this stored information and simultaneously comparing it with the energizations from said matrix outputs for the corresponding discrete web portions; and
 - means for indicating the results of said comparing.
10. A density monitor as defined in claim 1 and in which said web is advanced longitudinally at a predetermined rate, further comprising:
 - a housing for said receiving and responding means; and
 - means mounting said housing adjacent said web and driving said housing transverse to said web at a rate proportional to the advancing rate of said web.
11. A density monitor as defined in claim 10 further comprising:
 - a magnetic drum memory mechanically linked to said mounting and driving means for rotating said drum at a rate related to the transverse driving of said housing; and
 - magnetic reading and recording means mechanically linked to said housing and electrically coupled to said matrix outputs.
12. A density monitor as defined in claim 11 further comprising:
 - electronic means coupled to said reading and recording means for enabling it to record on said drum memory data representative of the desired density of inks to be applied across the web;
 - comparator means coupled to said reading and recording means and to said matrix outputs for synchronously comparing the density data recorded on said drum with the energizations from said matrix; and
 - optically persistent recording means coupled to said comparator means for providing at any one time information concerning the variations from desired density of the inks in a plurality of said discrete web portions.
13. A color monitor for providing an indication of the appearance of each of a plurality of different non-spectrum colored inks applied to a web to form an image, the indications being representative of the densities of the inks applied to the web, each ink having a maximum density in a range of wavelengths which is distinctively different from the ranges of wavelengths at which the respective maximum densities of the other inks occur, which comprises:
 - means for illuminating a discretely small portion of the web having said applied image;
 - a plurality of photoelectric transducers disposed in the optical path of the light coming from the web, there being as many transducers as non-spectrum inks it is desired to monitor;
 - each said transducer having means maximally reactive to the light coming from the web in one of the different ranges of wavelengths for generating an output signal which is a function of the densities of each

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- of the inks in the range of wavelengths in which the transducer is maximally reactive;
- one of said transducers being maximally reactive to and being optically coupled to elements reactive to the range of infra-red wavelengths for monitoring the density of non-spectrum black ink;
- matrix means connected to suppress that portion of each transducer output signal which is a function of the densities of all of the inks but that ink having its distinctive maximum density in the range of wavelengths at which the corresponding transducer is maximally reactive;
- said matrix means having a plurality of terminals and the output signals, after suppression, appearing at these terminals; and
- scalar generating means connected to the matrix means terminals for providing quantitative scalar indications of the difference between the appearance of each of the inks as applied to the web and the desired appearance in response to the resultant output signals.
14. The method of monitoring the density of inks as they are being applied to a web, the increasing density of each said ink corresponding to an increasing absorption by the ink applied web of the spectrum color complement of the ink, comprising the steps of:
 - illuminating a discrete portion of the ink applied web;
 - receiving from the web portion separate dynamic indications of the density of each ink in terms of the amount of absorption of its spectrum color complement;
 - generating separately signals which are functions of the separately received density indications,
 - suppressing in a primarily subtractive mode the portions of each of said separately generated signals which are attributable to all the inks except that which is attributable to a respective one of said inks, and
 - producing bidirectional scalar responses to each of the separately generated and subtractively suppressed signals, each said response being a scalar indication of the comparative difference between the density of each of the applied inks and its desired density.
15. The method of monitoring as defined in claim 14 further comprising the steps of:
 - recording and storing information related to the desired density of the inks on a plurality of discrete portions of the web;
 - subsequently reading the stored information and simultaneously comparing it with the scalar responses related to corresponding discrete web portions; and
 - indicating the results of said comparing in a visually perceptive manner.
16. The method of monitoring the appearance of an image comprising a plurality of different colored inks applied to a web, each ink having a maximum density in a range of wavelengths which is distinctively different from the range of wavelengths at which the respective maximum densities of the other inks occur, one of said inks being black and having a distinctive range of wavelengths in the infra-red range, by means comprising a plurality of photoelectric transducers disposed in the optical path of light coming from the web, there being as many transducers as inks it is desired to monitor, each transducer having means maximally reactive to the light from the web incident upon the transducer in one of the distinctively different ranges of wavelengths for generating an output signal which is a function of the densities of each of the inks in the range of wavelengths to which the transducer is maximally reactive, a separate one of the transducers being respectively reactive to each of the distinctively different ranges of wavelengths of light from the web the method comprising the steps of:
 - illuminating a portion of the web having the applied image;

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generating output signals which are functions of the densities of the inks applied to the web, by scanning with the photoelectric transducers the light coming from the web;

suppressing that portion of each transducer output signal which is a function of the densities of all of the inks except that ink having its distinctive maximum density in the range of wavelengths to which the corresponding transducer is maximally reactive; and generating scalars in response to the resulting transducer output signals, each of which is an indication of the difference between the appearance of one of the inks being monitored and the desired appearance.

17. A color monitor for providing an indication of the density of each of a plurality of different non-spectrum colored inks applied to a rapidly moving web, each ink having a maximum density in a range of wavelengths which is distinctively different from the ranges of wavelengths at which the respective maximum densities of the other inks occur, which comprises:

means for illuminating a discretely small portion of the web, said portion defining a narrow, generally longitudinal, uninterrupted zone with respect to the moving web within the image bearing surface of said rapidly moving web, said zone repeatedly incorporating contrast producing areas for each of said inks, said areas having a significantly lighter density; and a plurality of photoelectric transducers disposed in the optical path of the light coming from said zone, each said transducer having means maximally responsive to the light coming from said zone in one of the different ranges of wavelengths for generating an output signal which is primarily a function of the differ-

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ences between densities of each of the inks in said zone and said contrast producing areas therein for the range of wavelengths in which the transducer is maximally responsive.

18. A color monitor as defined in claim 17 in which: one of said transducers is maximally responsive to the range of infra-red wavelengths for monitoring the density of non-spectrum black ink in contrast to a combination of colored inks providing a black appearance.

19. A color monitor as defined in claim 17 further comprising:

matrix means connected to suppress that portion of each transducer output signal which is a function of the densities of all of the inks but that ink having its distinctive maximum density in the range of wavelengths at which the corresponding transducer is maximally responsive.

20. A color monitor as defined in claim 19 in which: said matrix means includes a plurality of terminals, said output signals, after suppression, appearing at these terminals and further comprising:

scalar generating means connected to the matrix means terminals for providing in response to the resultant output signals quantitative scalar indications of the difference between the density of each of the inks as applied to the web and the desired density.

No references cited

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,376,426

April 2, 1968

Joseph C. Frommer et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 33, "elemtromagnetic" should read -- electromagnetic --. Column 4, line 12, after "(infra-red)" insert a comma. Column 5, line 9, "magenta," should read -- magenta --. Column 8, line 10, "substracted" should read -- subtracted --; line 18, "web," should read -- web; --; line 28, "circuit," should read -- circuit; --. Column 12, lines 16, 37 and 41, "subtractive", each occurrence, should read -- subtractive --. Column 16, line 22, "cmoprising" should read -- comprising --.

Signed and sealed this 4th day of November 1969.

(SEAL)

Attest:

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Commissioner of Patents