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Gunto et al.

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[45] **Apr. 24, 1973**

[54] **MEANS AND METHODS FOR EXPOSING PHOTOELECTROSTATIC MATERIALS**

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[22] Filed: **Feb. 16, 1970**

[21] Appl. No.: **14,851**

Related U.S. Application Data

[62] Division of Ser. No. 653,090, July 13, 1967, abandoned.

[52] **U.S. Cl.**.....**355/67,** 240/11.4 R, 313/229

[51] **Int. Cl.**.....**G03b 27/54**

[58] **Field of Search**.....355/67; 240/11.4 R; 313/229

[56] **References Cited**

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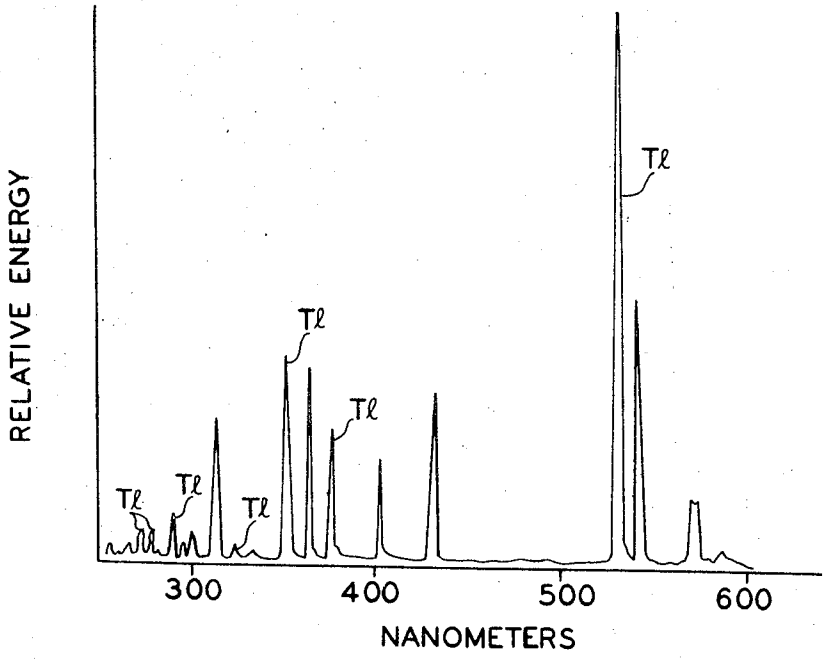
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Assistant Examiner—Monroe H. Hayes
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[57] **ABSTRACT**

Exposure of the conventional dye sensitized zinc oxide resin binder copy material is accomplished with a radiation source that emits a high level of energy at 535 nanometers. The photoelectrostatic copying method involves illuminating the original to be reproduced with a mercury-vapor type lamp which has been modified to include thallium vapors through the introduction of thallium halide into the lamp envelope. A high intensity green light is emitted which performs as a monochromatic energy source and finds particular application when reproducing originals having more than one color indicia thereon so that all colors are reproduced in accordance with their relative brightness on the original.

4 Claims, 6 Drawing Figures



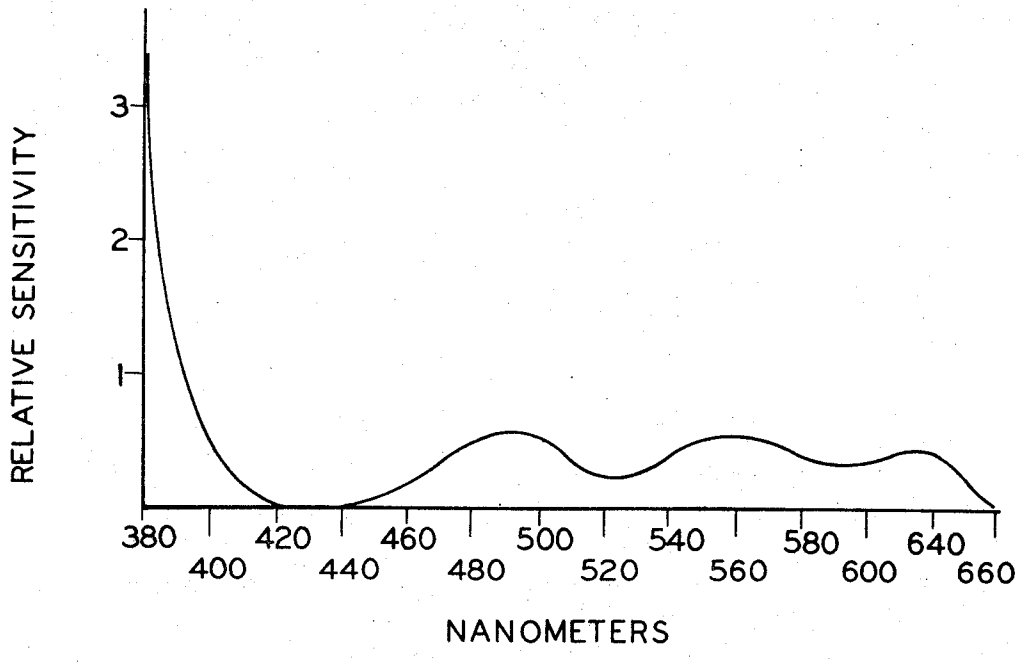


FIG. 1

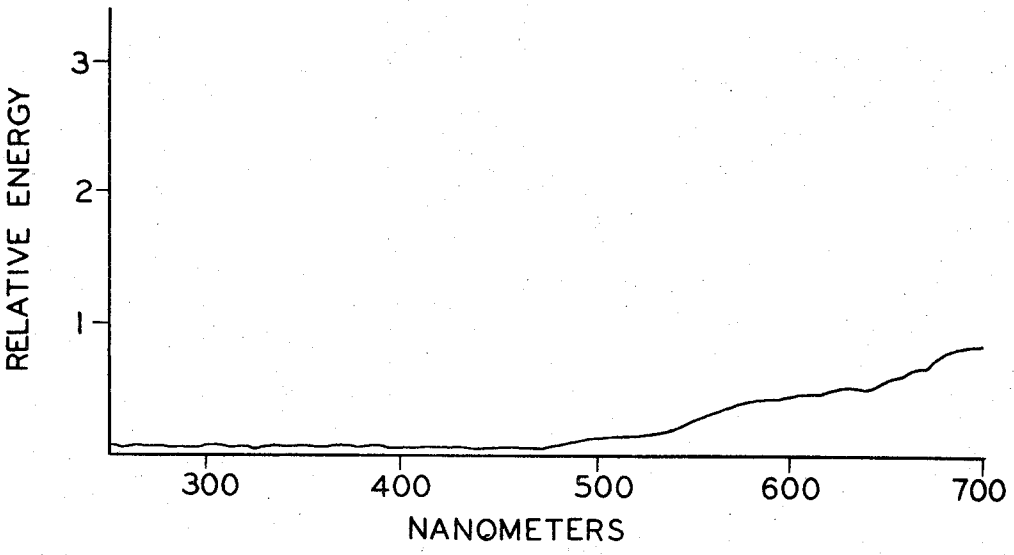


FIG. 2

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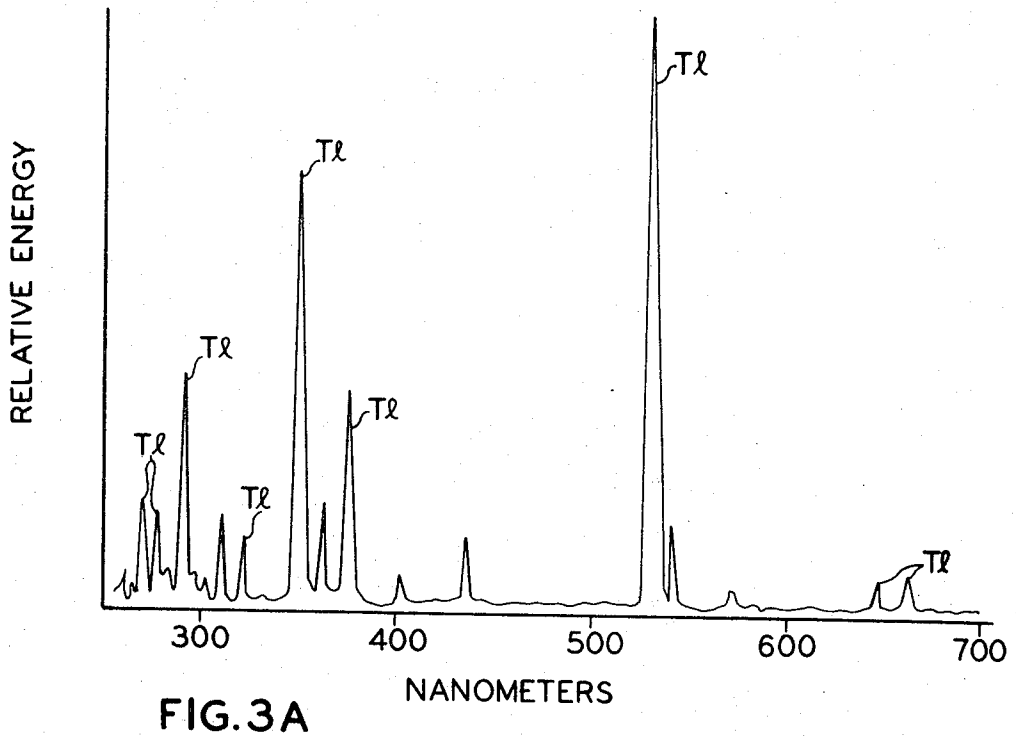


FIG. 3A

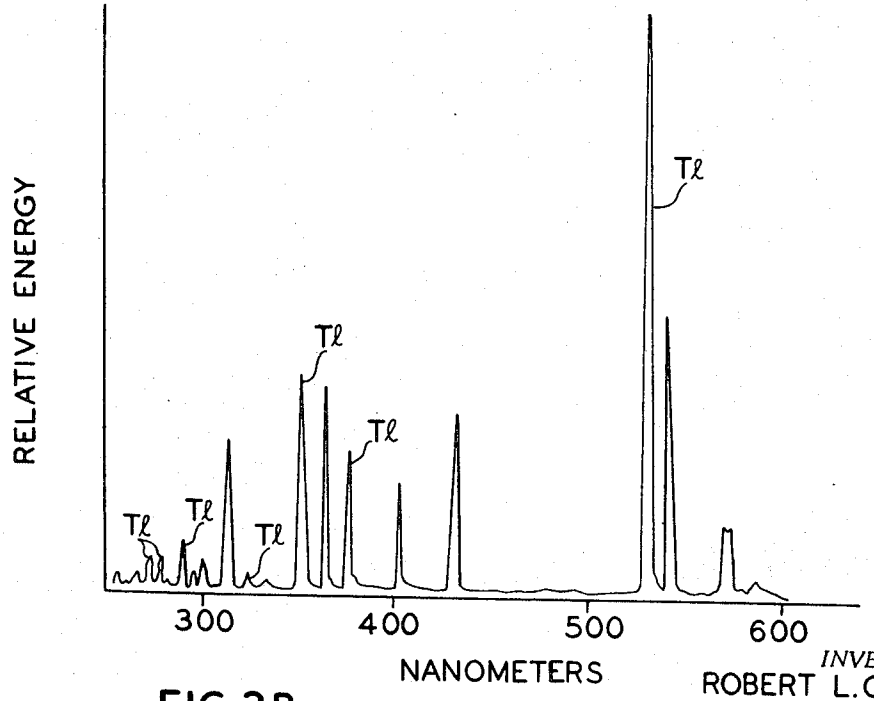


FIG. 3B

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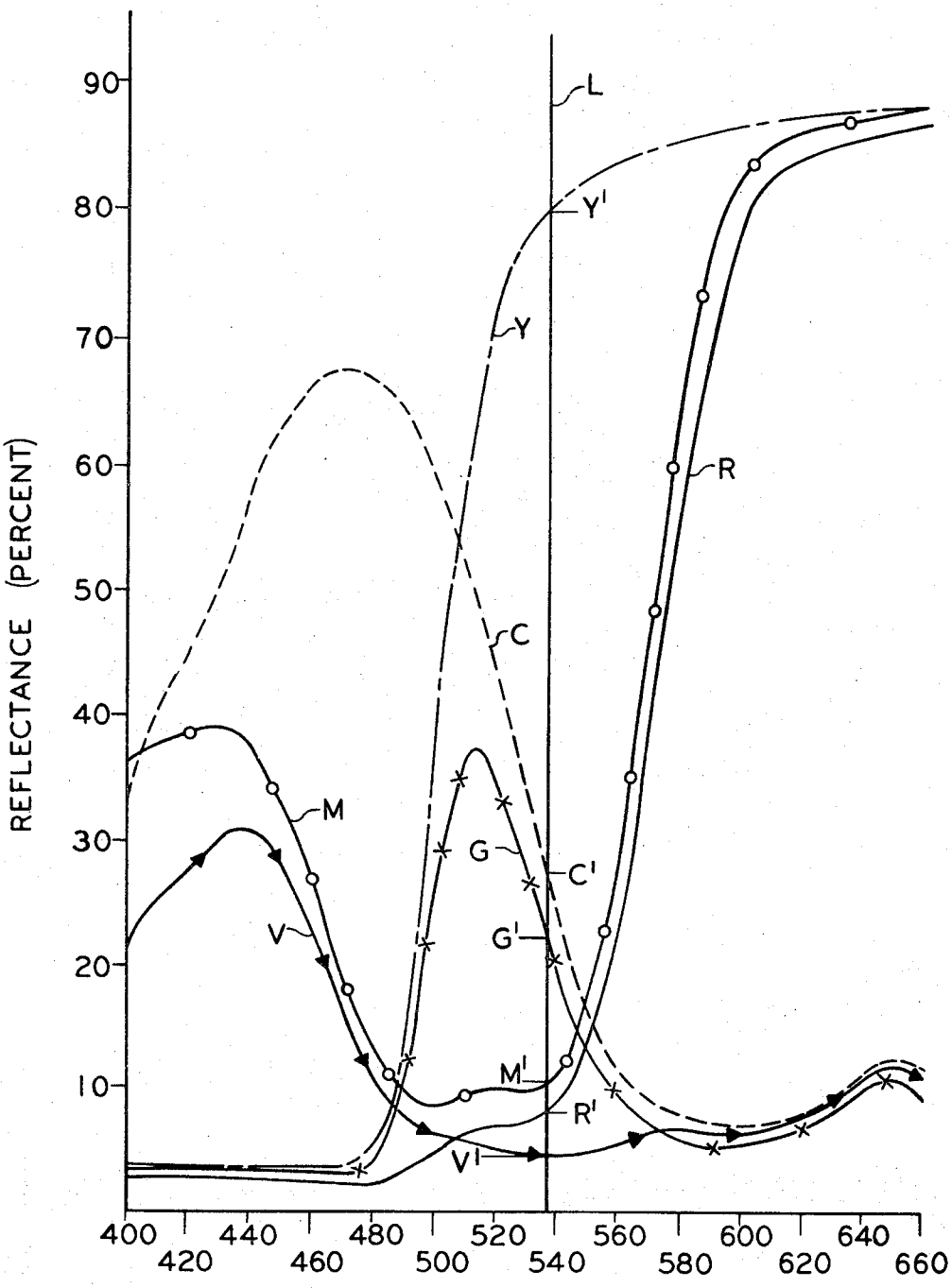


FIG.4

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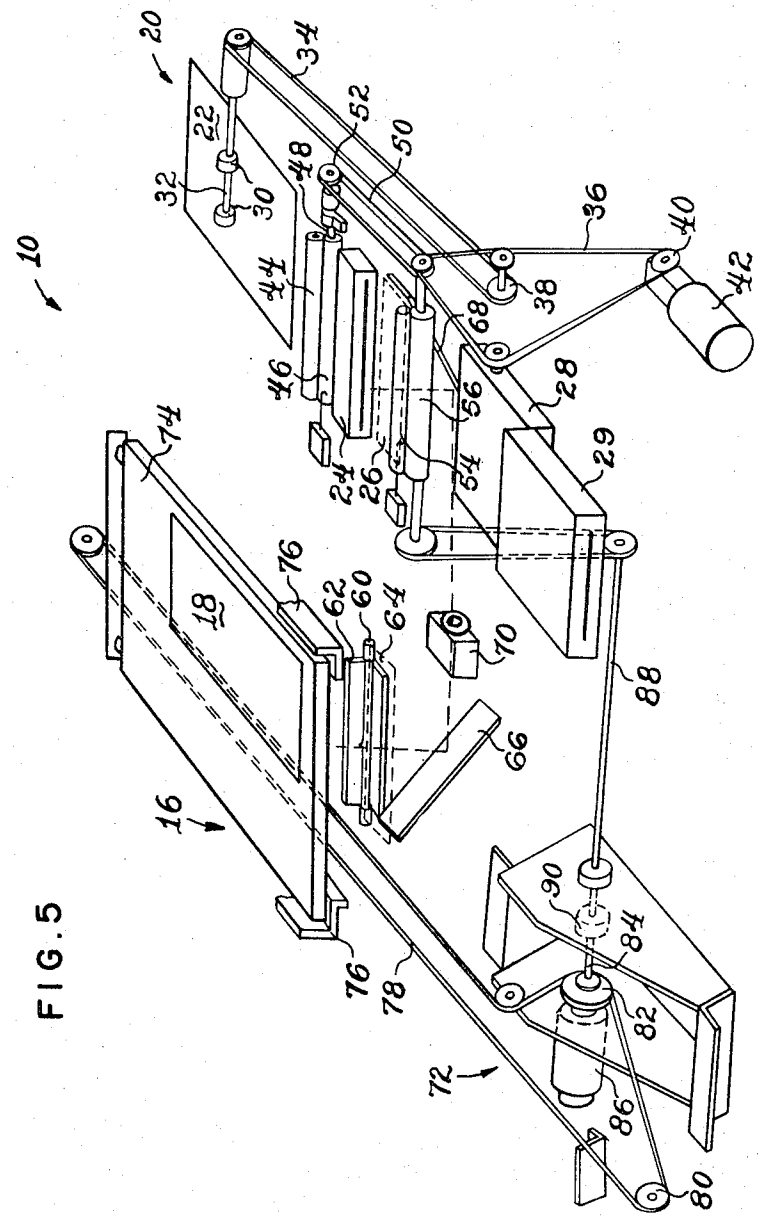


FIG. 5

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MEANS AND METHODS FOR EXPOSING PHOTOELECTROSTATIC MATERIALS

This application is a division of co-pending application Ser. No. 653,090, filed July 13, 1967 now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to photoelectrostatic copying and more particularly to the method and means of making a reproduction of a multi-colored original which involves the use of a specially adapted illuminating source capable of spectrally recognizing all the colors comprising the original so that true reproduction of the image may be cast or projected onto a photoelectrostatic member.

The photoelectrostatic copying process involves the steps of electrostatically charging in the dark a photoelectrostatic member, such as a base support on which is coated a photoconductive insulating layer, exposing said charged surface to a pattern of light and shadow produced by irradiating a graphic original with a suitable illuminating source. The areas on the photoconductive layer which have been struck by the radiant energy are rendered conductive and the charges in those areas are dissipated within the photoelectrostatic member leaving a latent electrostatic image on the surface which corresponds to the pattern of light and shadow.

The latent image is developed by applying electroscopic particles, usually highly colored thermoplastic resin particles, which adhere to the portions of the latent image-bearing surface that correspond to the image portions of the original. The powder image may then be fixed to the base support by any of the well-known fixing techniques.

The photoelectrostatic members in general use in this art comprise a photoconductive insulating material, such as finely divided particles of zinc oxide dispersed in an electrically insulating film-forming resin binder and applied to a flexible base support such as paper or other material having the proper degree of conductivity. The response of the zinc oxide resin binder system as a receptor of radiant energy in this process is most important. The spectral response of the photoconductive, white zinc oxide binder recording member peaks sharply in the near ultra-violet region of the spectrum with sensitivity extending into the blue end of the visible region of the spectrum.

It has been found desirable to extend the spectral response of the photoelectrostatic members, of the zinc oxide resin binder, by the addition of certain organic dyes. A detailed description of dye-sensitization of such photoelectrostatic members may be found in U.S. Pat. No. 3,052,540, issued Sept. 4, 1962 to H.G. Grieg.

Dye sensitization of the zinc oxide resin binder is desirable in order to extend the spectral response of the photoelectrostatic member to include the visible range of the spectrum. Photoelectrostatic members sensitized in the visible range of the spectrum has permitted the use of incandescent filament-type energy sources instead of being limited to ultra violet sources. The technique of extending the spectral sensitivity of the photoelectrostatic member and illuminating it with an incandescent filament lamp having a matching spectral energy distribution has been successful in the photocopying art because of the simplicity and convenience of

using such incandescent lamps. However, they have not been without certain deficiencies. The incandescent illuminating sources are inefficient since they emit a great deal of energy in the infra-red range of the spectrum and emit only a relatively small proportion of electromagnetic radiation which can be utilized by the photoelectrostatic member for the purpose of producing latent images thereon.

SUMMARY OF THE INVENTION

It was found that a radiant energy source which approximates the operation of a monochromatic energy source in the visible range of the spectrum will photocopy a wide variety of colors appearing on the original and the copy will have shades of gray to black images in direct relation to the reflectivity of the colors at the wave length of the dominant emission. The dominant emission should be in the central portion of the luminosity function curve of the eye, i.e., 520 – 590 nanometers, so that the sensitized copy sheet is illuminated with energy that is optimum for the human eye. In this manner the apparent brightness of the original is consistent with its actual brightness in the usual white light. Reference to multicolored originals includes typewritten copy bearing a pen-ink signature, red markings on a letter, or the use of colors in an ordinary letter head.

It is the general object of this invention to provide improved reproduction methods and means in which a multi-colored graphic original will have all the intelligence thereon recognized and reproduced by the system.

It is another object of this invention to provide improved reproduction methods and means in which a mercury vapor-type radiant energy source is employed which emits a high concentration of energy at a wavelength in the visible portion of the spectrum.

It is another object of this invention to provide improved reproduction methods and means using a radiant energy source which is specially adapted to irradiate a multi-colored graphic original from which is reflected a pattern of light and shadow and which radiant energy source is capable of recognizing all the intelligence on said original evidenced by the reproduction of the graphic subject matter onto the photoelectrostatic member.

It is a specific object of this invention to provide an improved reproduction method using a radiant energy source adapted to emit a high energy level at a wave length in the visible range in conjunction with a photoelectrostatic member, which energy source provides the advantages of a monochromatic system.

BRIEF DESCRIPTION OF THE DRAWINGS

A complete understanding of the invention and of these and other features and advantages thereof may be gained from consideration of the following detailed description taken in conjunction with the accompanying drawings wherein one embodiment of the apparatus of the invention is illustrated. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description and are not intended to limit the invention.

In the drawings:

FIG. 1 is a curve of the spectral sensitivity of a conventional dye-sensitized member;

FIG. 2 is a spectral curve showing the emission characteristics of the prior art filament-type illuminating source;

FIGS. 3A and 3B are spectral emission curves for the illumination source of this invention operated at different voltage levels;

FIG. 4 is a series of curves representing the spectral reflectance of various colors which commonly appear on originals;

FIG. 5 is a schematic drawing of a copy apparatus employing the radiation source of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The problem of reproducing all the intelligence on a graphic original, particularly one that is multi-colored, has been approached through one of three possible theoretical methods.

1. Use of a light-sensitive material which is equally responsive to all wave lengths, with a radiation source having a spectral energy distribution that is identical to the luminosity function curve of the human eye.
2. Use of a radiation source which emits equal energy at all wave lengths with a light-sensitive material having a spectral sensitivity curve that is identical to the luminosity function curve of the human eye.
3. A combination of light-sensitive material and radiation source wherein the product of radiant energy emitted by the source and the sensitivity value of the material at each wave length produces a curve that corresponds to the luminosity function curve of the human eye.

The first and second methods are purely theoretical while heretofore known copying systems attempt to follow the third method. The method and apparatus of the instant invention provide a solution to the problem of reproducing an original containing different colored inks through a fourth method exposure.

Referring to FIGS. 1 and 2, there is shown respectively the curve for the spectral sensitivity of a conventional electrophotographic paper and the spectral emission curve of a conventional filament-type lamp, respectively. An example of typical illuminating source used in this art heretofore is a lamp sold by Sylvania, identified as their 10 lamp, No. 1500, tubular lamp 2 ½ having a 12-inch lighted length rated at 1500 watts, 230 volts.

The spectral energy distribution of this lamp plotted in terms of wave length versus relative energy produces a continuous curve, as shown in FIG. 2. It will be observed that the curve is continuous from 250 nanometers to 750 nanometers. A large part of the energy is in the near infra-red portion of the spectrum which is in the range of from 670 – 750 nanometers. There is only a small portion of the available radiant energy in the visible portion of the spectrum which is effective to produce a latent electrostatic image.

The deficiencies of using an incandescent source of the type described is best illustrated by relating it to the spectral sensitivity curve of a typical photoelectrostatic member, as shown in FIG. 1. This curve is typical of a member which has been prepared in accordance with the aforementioned U.S. Pat. No. 3,052,540. It will be observed that the curve shows sensitivity to radiation at various wave lengths including some sensitivity in the visible red range of from 600 – 630 nanometers. The illumination source (FIG. 2) shows a steadily increasing emission from violet to red. The sensitivity of the system, that is, one which uses a material having the sensitivity curve shown in FIG. 1 and a radiant energy source having a distribution curve shown in FIG. 2, may be represented by taking the product of the two curves. Such a sensitivity curve would show the system to have its greatest sensitivity at about 620 nanometers represented by the product of the lamp emission and copy paper sensitivity at this wave length. The peak sensitivity is in the red portion of the spectrum.

In summary, it can be said that the prior methods of exposing the electrophotographic papers have suffered because of their continuous spectral sensitivity curves and radiant energy sources that do not closely complement the sensitivity curve of the paper. As a result, an original subject having a variety of colored entries, such as cyan, green, red, violet, yellow and magenta, will not be reproduced in its entirety. Using a system such as first described, the red, yellow and magenta hues will not be recognized by the illuminating source, i.e., the radiant energy is reflected by the yellow, magenta and red colors and thereby dissipates the electrostatic charge on the photoelectrostatic member.

The use of a source such as a mercury-vapor lamp will cause the cyan color to go unrecognized, while the colors such as yellow, red and green will reproduce as black images.

The effect of illuminating a colored original with the lamp of this invention is analogous to the effect observed in viewing various colors under monochromatic light in a darkened room. In the circumstance that the light is from a sodium vapor source, the eye would observe the color yellow as "white", white would appear "white", and the colors red, green and black would range from "gray" to "black". It is therefore desirable to emulate this system wherein all the colors will be reproduced and their appearance on the reproduction will be in the approximate order of brightness appearing on the original.

The use of a radiant energy source that has an intense emission at a wave length that is within the central portion of the luminosity function curve of the eye (520 – 590 nanometers), and preferably falls at approximately the peak position of the luminosity curve (555 nanometers), would result in the optimum photocopying process using an electrophotographic member that is responsive to radiation at the specific wave length of the intense emission line of the source. The radiation source is effective as a monochromatic radiation source.

It was found that a radiation source having a high intensity emission at a wave length corresponding as closely as possible to the luminosity function curve of the human eye, gave an increased range of color response, i.e., the ability to reproduce red, magenta and yellow colors, as well as cyan green and violet. Such an illuminating source is basically a mercury-vapor type lamp to which has been added another metal, such as thallium in the form of thallium iodide, to give the desired spectral emission. The mercury-thallium discharge results in a primary or dominant emission peak at 535 nanometers and a secondary emission of 546 nanometers. A lamp useful in the practice of this

invention is available from the Sylvania Electroproducts Corporation, Inc., Manchester, N.H.

The spectral energy distribution is represented in FIGS. 3A and 3B showing a dominant emission of very high intensity at 535 nanometers. The introduction of thallium iodide into the mercury type lamp produces other emissions at 351.9 nanometers and at 322.9 nanometers. The spectral emission lines produced by the mercury discharge appear at 405, 436, 546 and 578 nanometers. The mercury emission is greatly depressed in relation to the thallium emission and in particular the thallium line appearing at 535 nanometers. The appearance of the various mercury and thallium peaks other than the dominant peak at 535 in the spectral energy distribution shown in FIG. 3 are less significant in the photoelectrostatic copying method of this invention.

The illuminating source is prepared by introducing metal halides along with mercury as the active metals, comprising the discharge medium of the lamp. The mercury-vapor-arc envelope is made of fused silica having a diameter of about 6 – 12 mm, and the envelope may be as large as 25 mm. Molybdenum foil-Tungsten electrode assemblies are pressed and sealed into the ends of the tube envelope. The electrode is a Tungsten coil wrapped on a Tungsten rod with the rod extending beyond the coil. The envelope with the electrode assemblies in position is then evacuated and the metal iodide, namely thallium iodide in the instant case, is introduced into the tube in addition to mercury in an atmosphere of argon gas under moderate pressure. A lamp, having a diameter of 6.8 mm, when connected in a circuit powered by a suitable power supply, consumes 120 watts of power per lineal inch and will generate an envelope wall temperature in the range of from 500° – 700°C yielding the high intensity emission spectral line at 535 nanometers. Operating under this condition of excitation, a spectral energy distribution trace was made (as shown in FIG. 3) using a spectroradiometer in which the band pass was 10 nanometers. The recorder employed to produce the trace was manufactured by the Hewlett-Packard Company, Mosely Model No. 135 using 8 ½ × 11 paper.

The trace of the spectral energy distribution, covering the range of from 250 – 750 nanometers, is presented in terms of the relative intensity of the energy at each wavelength. The height of each peak represents the relative energy value at that spectral line. Intensity of the radiation at a particular spectral line is measured in terms of the height of the peak and then comparing it to the peak at an adjacent spectral line. Using the band pass width of 10 nanometers and the particular recorder, the relative energy values may be relied upon to yield quantitative ratio values at the critical wave length. In the instant study the thallium line at 535 nanometers was compared to the adjacent mercury line at 546 nanometers in terms of the ratio of the heights of the two lines as they appear on a curve obtained from the spectroradiometer study using the 10-nanometer band pass. It will be appreciated that the operation of the light source anywhere in the range of from 40 – 200 watts per lineal inch (diameter 6.8 mm), will produce a wall temperature in the range of from 500° – 700°C and hence will result in a spectral energy distribution curve such as shown in FIGS. 3A and 3B. The envelope wall temperature must be in this range in order to have the thallium emit the required amount of energy.

Referring to FIGS. 3A and 3B, there is shown, respectively, the distribution curves for the radiation source of this invention operated at 125 watts per inch and at a lower level of 40 watts per inch. The curves are shown in a reduced scale from the actual curves taken from the recorder so that they may be more conveniently shown in the drawings. The height of the emission at 535 nanometers is measured as well as the height of the mercury line at 546. The ratio of the relative intensity values expressed in terms of the height of the 535 nanometer line to the mercury represents the monochromatic character of the radiation source. The greater the ratio the greater will be the monochromatic effect of the energy at 535 nanometers. The lower ratio values indicate that the radiation at other wavelengths such as at 400 and 436 are being emitted in sufficient quantity to dilute the effect of the thallium radiation.

The traces in FIGS. 3A and 3B were produced on a spectroradiometer using a 10-nanometer band pass. The spectroradiometer is adjusted to produce a trace in which the peak at 535 nanometers is at a predetermined height of six inches on the 8 ½ × 11 coordinate paper. With the spectroradiometer adjusted in this manner the peak heights at the various wave lengths are proportional to one another.

FIG. 3A represents the distribution curve of the radiation source of this invention operated at 125 watts per inch, 6.8 mm diameter envelope. The ratio of the heights of the peaks recorded at 535 nanometers and at 546 nanometers, based on actual measurement, is 6 : 1. It has been found that unique results in the photoelectrostatic copying process of this invention are observed only when the intensity of the emission at 535 nanometers is substantially greater than the intensity of the spectral line at 546 nanometers. At the higher intensity levels of the 535-nanometer line the secondary mercury lines at 546 nanometers and 436 nanometers tend to be suppressed. The range of operability expressed as the ratio of the height of the emission at 535 nanometers to the emission at 546 nanometers is from 1.75 : 1 to 10 : 1 with the preferred range being from 4.5 : 1 to 7 : 1. The ratio measured in FIG. 3A is 6 : 1 for the 125 watt/lineal inch level of operation is within the preferred range.

Referring to FIG. 3B, there is shown the trace of the distribution curve for a tubular lamp operated at 40 watts per lineal inch. At a lower power level the wall temperature is about 500°C which is the lower temperature limit at which the thallium metal is activated. It will be observed that the mercury lines at 546 and 436 show up with a greater relative energy level tending to become more effective. The ratio of the height of the thallium emission to the adjacent mercury line is 2 : 1 which is still in the range of operability.

As the ratio decreases below the 1.75 : 1 level, the lamp behaves as a mercury source so that emission at 436 is the dominant energy. The result is that yellow and magenta colors will reproduce as dark images and the green, blue and violet hues will reproduce as "white".

Referring to FIG. 4, there is presented a series of spectral reflectance curves for various colored inks and

the like over the spectral range from 400 – 660 nanometers. The curves are identified as Y, G, C, V, M, and R corresponding to the colors yellow, green, cyan, violet, magenta and red. At 535 nanometers there is drawn a line L corresponding to the dominant emission of the lamp above described.

Each of the curves intersect the dominant emission line somewhere along its height. The point of intersection measured along the ordinate represents the amount of reflectance from the surface when irradiated with radiation at 535 nanometers. The points of intersection are identified with the corresponding letter bearing a "prime" designation. Proceeding along the line L from zero reflectance, it will be observed that the first point is V' followed in succession by R', M', G', C', and Y'. The points at which the curves intersect the line L correlate to the degree of reflectance of that particular color in the system. V and R have the least reflectance and will reproduce as dark gray or black. C and G have reflectance values of 25 and 30 percent, respectively. Y has the greatest degree of reflectance, about 80% and, hence, will appear light gray to white in the final reproduction.

Referring now more specifically to FIG. 5 of the drawings, therein is illustrated a copy making apparatus 10 which embodies the present invention. The apparatus includes a slidably mounted assembly 16 for receiving a graphic original 18, such as a book, from which a copy is to be made. The assembly 16 is reciprocated into and out of a housing (not shown) to print the graphic original 18 to be scanned in order to develop a corresponding pattern of light and shadow. The left side of the apparatus includes a copy sheet feeding assembly 20 which feeds a photoelectrostatic copy sheet 22 in synchronism with the moving original 18 through a station 24 to receive a uniform electrostatic charge. This sheet is then moved past an exposing area 26 in synchronism with the movement of the original 18 so that the charged surface is selectively discharged in accordance with the pattern of light and shadow produced by scanning the original, thereby producing a latent electrostatic image.

The copy sheet 22 is then fed through a developer station 28 in which the latent image is developed into a powder image, and subsequent movement of the copy sheet 22 carries it into a fixing station 29 where the image is placed in permanent form.

The assembly 20 includes a pair of drive rollers 30 secured to a shaft 32 which rest on the uppermost copy sheet 22 of a stock of sheets to provide means for feeding a single copy sheet 22 from the assembly to the processing stations. The rollers 30 are driven by a series of belts 34, 36, passing around drive pulleys or sprockets 38, 40, which are driven by a main drive motor 42.

A pair of feed rollers 44, 46 advance the copy sheet into the charging station 24. Roller 46 is secured to a shaft 48 which is driven by the main drive motor 42 through the belt 50 and pulley 52. Rollers 54 and 56 receive the sheet as it leaves the exposing area 26 and advance it into the developing station 28 and the fusing station 29.

The exposing assembly includes a radiation source 60 which has been made as described herein above to include thallium iodide. The emission characteristics of the radiation source corresponds to the curve shown in FIG. 3A of the drawings. The quartz envelope of the radiation source 60 is mounted in a reflector 62 to focus the radiation on an illuminating area 64 disposed in the path of movement of the original 18.

The radiation reflected from the original 18 is transmitted by the optical system including reflective surfaces 66 and 68 on either side of a lens 70 forming an optical path between the illuminating area 64 and the exposing area 26.

The assembly 16 is moved by a drive assembly identified generally as 72 to a position in which the original is disposed adjacent the illuminating area 64 and the assembly is moved in synchronism with the movement of the copy sheet 22 past the exposing area 26 for selectively discharging the charged surface of the copy sheet 22.

The assembly 16 includes a transparent table 74 which is slidably mounted on rail elements 76. The drive means 72 includes a flexible element or connecting cable 78 secured at one end to the table.

The cable 78 passes around a pulley 80 and a pulley 82 secured to the shaft 84 of a return drive motor 86. The table 74 in the forward or copying direction is driven by motor 42 connected to the cable 78 through the shaft 88 acting through a clutch mechanism 90 which couples shaft 88 with shaft 84.

It should be understood that the colors or hues under consideration are not pure colors. However, the discussion will be applicable generally. However, where highly impure colors are employed, the actual reflectance data may vary from the data presented herein. It should be stressed that this data will fit most cases.

These same colors, red, yellow and magenta when exposed to the conventional radiation sources (FIG. 1) would escape recognition or very likely appear as a light gray reproduction. This will become apparent by referring to FIG. 4 and observing the high reflectance for these colors in the portion of the spectrum above 600 nanometers.

Since the zinc-oxide photoconductive particles are sensitive to radiation in the ultra-violet portion of the spectrum, that is 376 – 426, early attempts were made in this art to employ mercury-vapor lamps to expose the electrophotographic members. It was found that the colors yellow, green and red would reproduce as dark images and the cyan appear as white. Further, the use of certain ultra-violet absorptive materials employed in paper making cause the original subject to have a low reflectance and, hence, produce a copy with a darkened background. Referring again to FIG. 4, it will be seen that at 426 nanometers the curves Y, R and G have reflectance values less than 10 percent, and V less than 30 percent. The curve C at 426 nanometers would tend to reproduce as a light color. The mercury-vapor source would not distinguish the various colors Y, R and G according to their relative brightness, but they would all reproduce with the same degree of darkness of print. It should be pointed out that operating the lamp of this invention at ratios below 1.75 : 1 will have the effect of a mercury-vapor lamp.

A significant advantage in increased speed is realized in using the radiation sources of the instant invention. The combination of spectral emission in the ultra-violet

range together with the high intensity emission along the 535-nanometer spectral emission results in decreasing the exposure time necessary to produce a latent electrostatic image on the copy sheet.

Sensitivity studies using a photoelectrostatic member of the type described in U.S. Pat. No. 3,052,540 were carried out comparing the conventional incandescent source with the lamps used in this invention. The test procedures called for charging the member up to the same voltage level and first measuring the sensitivity expressed in volts per second to a thallium source at a given wattage input. The test was then repeated substituting the incandescent type source and varying the wattage input until the sensitivity measured in the first run was duplicated. The test results revealed that an 80 watt thallium source, 1.5 inches lighted length, gave a sensitivity of 610 volts per second at a charging level of 580 volts. The incandescent source required 400 watts of energy input, 1.5 inches lighted length, to realize the same sensitivity.

The speed increase is significant in that an electrophotographic member irradiated with a conventional lamp rated at 1500 watts, as herein above described, is processed at 15 feet per minute past an exposure window, and with the lamp of this invention rated at **800** watts the processing speed is increased to 30 feet per minute. Exposure was made on an electrostatic copier identified as a Bruning brand Model 2000 copier.

In summation it can be said the electrophotographic copying process of this invention permits the reproduction of a wider range of colored subject matter, produces reproductions in which the image brightness approximates the relative brightness of the original, and finally results in decreasing the time necessary to expose the electrophotographic material.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. In an apparatus for making reproductions of a graphic original comprising means for feeding photoelectrostatic copy material, a charging station for imparting a uniform electrostatic charge to said copy material, an illuminating station for casting radiant energy onto the graphic original to produce a pattern of light and shadow upon the charged copy material corresponding to the graphic subject matter on the graphic original, the improvement wherein said illuminating station is equipped with an elongated tubular-shaped radiation source of the mercury vapor-type having a thallium iodide additive and power supply means for supplying energy in the range of 40 watts – 200 watts per lineal inch to be consumed by said tubular member, said radiation source having a dominant emission at 535 nanometers and a secondary mercury emission at 546 nanometers, and a ratio of the dominant energy emission to the secondary emission is 1.75:1 to 10:1.

2. The apparatus as claimed in claim **1** wherein the ratio of the dominant energy emission to the secondary energy emission is in the range of from 4.5 : 1 to 7 : 1.

3. In apparatus for making copies of originals on copy material, comprising:

a copy handling assembly including copy material charging, exposing and developing stations spaced along a path and copy material feeding means for feeding the copy material along the path,

an illuminating station at which an original is illuminated to provide a light image that is applied to the copy material at the exposing station,

a supporting means for receiving an original and mounted for movement from a normal position in which an original is supplied to a displaced position to move the original through the illuminating station as the supporting means moves from the normal position to the displaced position, the improvement wherein said illuminating station is equipped with an elongated tubular-shaped radiation source of the mercury vapor type having a thallium iodide additive, said radiation source having a dominant emission at 535 nanometers and a secondary emission at 546 nanometers, the ratio of the dominant energy emission to the secondary emission being in the range of 1.75:1 to 10:1, and a power supply connected to said radiation source for supplying energy thereto in the range of from 40 to 200 watts per lineal inch to be consumed by said tubular radiation source.

4. Apparatus as claimed in claim **3** wherein said radiation source is a mercury-thallium vapor lamp in which the dominant emission at 535 nanometers corresponds to the thallium energy line and the secondary emission at 546 nanometers corresponds to the mercury energy line.

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