June 8, 1965 J. T. BICKMORE 3,188,208

SPECTRAL CONTRAST CONTROL IN XEROGRAPHY

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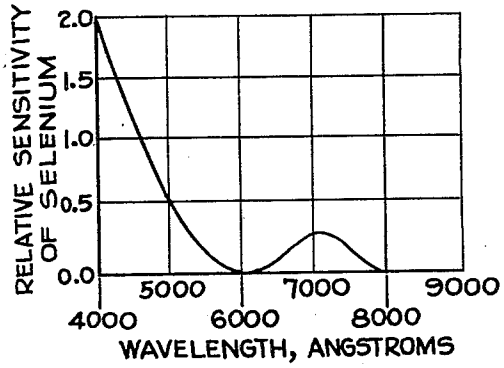


Fig. 1

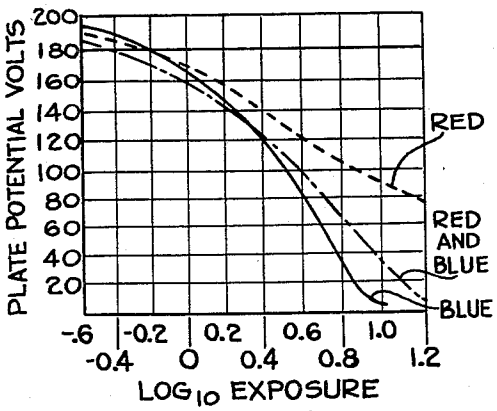
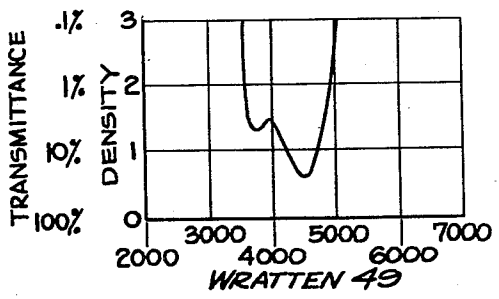
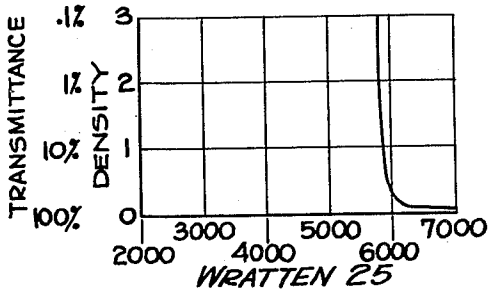
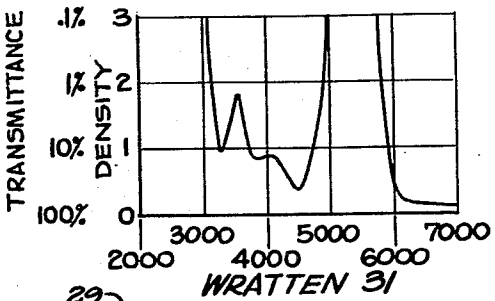


Fig. 2







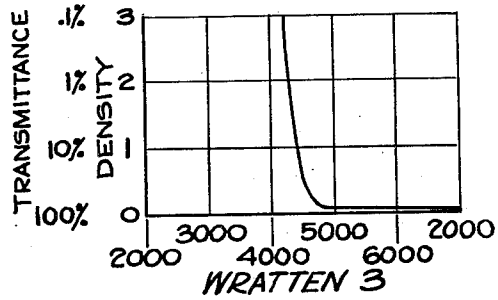


Fig. 3

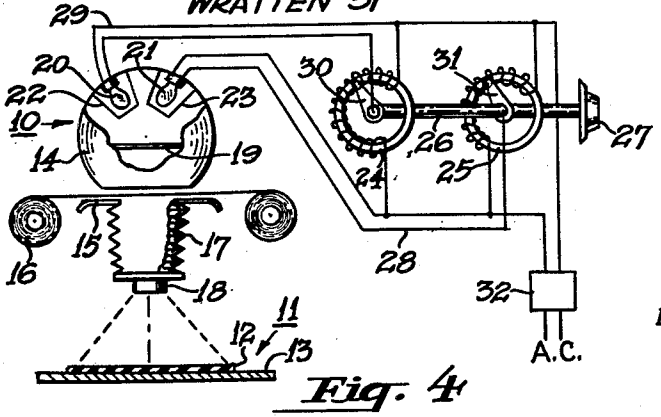


Fig. 4

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3,188,208 SPECTRAL CONTRAST CONTROL IN XEROGRAPHY

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3 Claims. (Cl. 96—1)

This invention relates to contrast control in xerography.

In a common form of xerography a positive electrostatic charge of the order of several hundred volts is placed on the selenium surface of a xerographic plate comprising a layer of vitreous photoconductive insulating selenium. The selenium will normally have a sufficient resistivity in the dark to retain the applied charge for a considerable period of time. The xerographic plate is then exposed to a pattern of light and shadow corresponding to an image to be reproduced. The selenium becomes more conductive in illuminated areas allowing the electrostatic surface charge to drain away in these areas, thus forming on the surface of the xerographic plate an electrostatic charge pattern corresponding to the image to be reproduced. This charge pattern, or electrostatic latent image as it is also called, is then made visible or developed through the attraction to it of finely divided electrostatically attractable particles. Many systems of xerographic image development are known and may be used in connection with the present invention, but two such methods are particularly suitable for the reproduction of high quality images with which the present invention is principally concerned. One of these methods comprises introducing to the surface of the xerographic plate a gaseous suspension of finely divided electrostatically charged particles, preferably pigmented particles. The other method comprises wetting or immersing the xerographic plate in a suspension of similar finely divided particles in an insulating liquid. In either method it has been found desirable to maintain a conductive equipotential electrode in close proximity to the selenium surface of the xerographic plate during development and to use a conductive support behind the selenium layer where such a layer is not already an integral part thereof. Where charged area development is desired, that is development in which the least illuminated portions of the plate, which retain the greatest charge, attract the greatest amount of developer material, the electrode will be maintained at a potential close to that of the conductive support of the xerographic plate. On the other hand, uncharged area development may be carried out by maintaining the electrode at a potential substantially that of the highest potential remaining on the selenium surface, and in this case those portions of the xerographic plate containing the least charge will attract the greatest amount of developer. The developer image may be viewtd on the xerographic plate or preferably the finely divided material comprising the image may be transferred in image configuration to another support, such as a sheet of paper, and viewed there.

It has been found in connection with xerographic image reproduction using vitreous selenium plates, particularly with charged area development, that the developed images are often excessively contrasty. To some extent, this may be a result of particular development techniques, but principally it results from the fact that the amount of exposure required to bring a selenium xerographic plate from a slightly discharged condition to a substantially discharged condition is too small. This characteristic of the selenium plate limits the tonal range of an original image which can be reproduced by xerography. This limitation in tonal range cannot be overcome by changing development techniques, because any development system can develop only those patterns of charge which are actually present on the xerographic plate as a result of exposure to a pattern

of light and shadow. If some parts of the pattern of light and shadow are not converted into variations in charge on the xerographic plate, they obviously cannot then be developed by any technique. While the particular excessive contrast referred to herein is a characteristic of vitreous selenium xerographic plates, such plates continue to be preferred for making high quality xerographic reproductions because they are more sensitive to light than other xerographic plates and can be made with greater uniformity and reliability and give higher quality images than are presently available with other types of plates. Methods have been proposed for reducing or controlling contrast in xerographic image reproduction, but these have generally been complex, requiring the use of special equipment, or substantially increasing the complexity of the procedure to be followed in making a xerographic image.

Accordingly, it is an object of the present invention to provide a simple technique of controlling contrast in xerography.

It is a further object of the invention to control the contrast obtained with selenium xerographic plates.

It is a still further object of the present invention to control contrast in xerography by controlling the spectral distribution of light used in exposing a selenium xerographic plate.

These and other objects will become apparent in the following description and claims and through the figures in which:

FIG. 1 is a curve showing the spectral sensitivity of a selenium xerographic plate;

FIG. 2 is a set of curves showing the light decay characteristics of a selenium xerographic plate; and,

FIG. 3 is a set of transmission curves of suitable filters for use in carrying out the invention.

FIG. 4 is a partially schematic representation of apparatus for carrying out the invention.

Turning now to FIG. 1, we see a curve relating the relative light sensitivity of a selenium xerographic plate to the wave length of light used in exposing the plate. It can be seen that there are two distinct regions of sensitivity. One such region is sessentially in the blue part of the spectrum, and extends from the ultra-violet up to about 5600 angstrom units. Going to longer wave lengths, there is a region in which the selenium shows substantially no photoconductive response to light. Finally, there is a second sensitive region in the red centered about 7,000 angstroms. It is apparent that the sensitivity to red light is very much less than sensitivity to blue light. It is believed that the blue sensitivity is principally due to the vitreous selenium itself. The shape and extent of the blue sensitivity have been found to be largely independent of the techniques used in preparing the xerographic plate. The red sensitivity, on the other hand, is believed to be due to the presence of selenium crystallites in the otherwise amorphous or vitreous selenium layer. Accordingly, the relative magnitude of the sensitivity to red light has been found to depend to a considerable extent on the techniques used in forming the selenium layer on the xerographic plate. Techniques for forming selenium xerographic layers are described in copending application Serial No. 526,781. Regardless of manufacturing techniques, however, the red sensitivity is always substantially less than the blue sensitivity. A suitable method of making selenium xerographic plates having enhanced red sensitivity particularly suited for the present invention may be found in U.S. Patent 2,753,278.

Although much time and effort has been spent in measuring and analyzing the properties of selenium xerographic plates and in attempting to influence those properties, it has not hitherto been observed that the red light photoconductive response of such plates is not only quantitatively different from the blue light response but qualita-

tively different as well. I have, however, found that there is such a difference and that this difference can be used to modify and improve the quality of xerographic reproductions obtained with selenium plates. These findings will be apparent from a consideration of FIG. 2 which contains three different curves showing the potential on a selenium xerographic plate as a function of the quantity of light received by that plate. Each of these curves was experimentally obtained by charging the plate, measuring the potential on the plate, exposing the plate for an increment of time to a constant intensity light source, measuring the potential on the plate, and repeatedly exposing and measuring. The curve identified as "blue" was made by exposing the plate to blue light as selected by a Wratten filter No. 49. The characteristics of these and other filters used are shown in FIG. 3. It is apparent that this filter transmits no red light and only relatively little of the blue light to which the plate is sensitive. Such a filter was chosen to compensate for the very much greater blue sensitivity of the plate as compared to red sensitivity. Because the xerographic plate is far more sensitive to blue than to red light, the blue curve in FIG. 2 is typical of the response of a xerographic plate when exposed to "white" light, even that from an incandescent lamp which, of course, is relatively rich in the longer wave lengths. It can be seen as a characteristic of a selenium xerographic plate when exposed to blue, or white, light that the curve is relatively steep and spans a relatively short range on the horizontal or log exposure axis. This is equivalent to saying that a selenium plate under normal exposure conditions is rather contrasty and has a short exposure range or short tonal reproduction scale.

The curve identified as "red" was made by a similar technique except that exposure was made to red light which had been selected by a Wratten filter No. 25. It is apparent that this filter transmits substantially all of the red light to which the plate is sensitive. It can be seen that this curve does not have as steep a slope and covers a larger span on the log exposure axis. It would appear from this curve that the contrast of a xerographic print could be reduced and its tonal range increased by making the exposure of the xerographic plate solely by red light. It will be noticed, however, that the red curve of FIG. 2 has started to level out at its right end and, as a matter of fact, the potential of the xerographic plate when exposed solely to red light will not fall much below 80 volts. Accordingly, the range of potential available in such a plate for effecting development is considerably reduced, and for this reason exposure to red light, while it does decrease contrast and increase the exposure acceptance range, may result in a developed image which has a high background density and which lacks clear whites. This may occur because the 80 volts minimum potential on the xerographic plate may cause a substantial attraction of the finely divided material used in development. I have, however, found that by combining the red light with a certain amount of blue light it is possible to reduce contrast and increase exposure acceptance range without compromising the performance of the xerographic plate in other respects. Such as result is shown by the curve labeled "red plus blue" in FIG. 2. This curve was made by selecting the light used for exposure by a combination of Wratten filters No. 3 and No. 31. An examination of the characteristics of these filters as shown in FIG. 3 shows that the combination will pass substantially all of the red light to which the plate is sensitive, but very little of the blue light. Hence, the amount of blue light used was very small in comparison to the red. It can be seen that this curve has a smaller and far more uniform slope than that for blue light and that it covers a much larger range on the log exposure axis and that the plate can be discharged to at least as low a residual potential as is obtainable with blue light. It should be noted that the slight difference in the initial potential of this curve as compared with the other two is merely due to the experimental difficulty in successively recharging a xerographic plate to precisely the same potential. This difference of about 6 volts has no effect on the results obtained. Obviously, the slope and characteristics of a curve such as the one labeled "red plus blue" can be controlled by varying the relative proportions of red and blue light used. Thus, as the proportion of blue light is increased the curve would approximate the blue curve and as the proportion of blue light is decreased the curve would approximate the red curve. Here and throughout this specification the terms red and blue are, of course, used to refer to the long and short wave length portions of the spectrum respectively, and not to the corresponding visual sensations.

Thus, in carrying out my invention a xerographic plate comprising a layer of vitreous selenium is first charged to a potential of several hundred volts and is then exposed to light of a controlled spectral distribution. The means of controlling the spectral distribution will depend upon the nature of the orginal image being reproduced, and of the apparatus used. If the xerographic plate is exposed in a camera to an outdoor scene, the photographer has no control over the illumination of that scene, and the light reaching the xerographic plate must be controlled by using a suitable filter at the camera. If the xerographic plate is exposed in a camera to a scene or object illuminated by artificial light then the spectral distribution of the light may be controlled either at the light source itself, or again by using filters at the camera. If the exposure is made by projection as in a photographic enlarger, then suitable filters may be used at the enlarger light source, at the enlarger lens, at the xerographic plate or at any other point in the optical system. Where artificial light sources are used it is possible to properly control the spectral distribution of the light without the use of filters where light sources of suitable color are used. Thus, the illumination could be provided by a combination of red and blue fluorescent lamps where the red lamps have substantially no output in the blue part of the spectrum and vice versa.

FIG. 4 is a partially schematic representation of one form of apparatus suitable for carrying out the invention. It includes generally a photographic enlarger **10** positioned so as to project a light image onto a charged xerographic plate **11**. Plate **11** comprises a selenium layer **12** on a support layer **13**. Enlarger **10** includes a lamp house **14**, a film gate **15** adapted to receive a film transparency **16**, bellows **17** and a lens **18**. Within the lamp house **14** are diffusing disc **19** and incandescent lamps **20** and **21** which are surrounded by filters **22** and **23** respectively. One of these filters should be a red filter and the other a blue filter, preferably of low transmission. Wratten filters No. 25 and No. 49 are suitable. Lamp **20** is connected to a toroidal auto transformer **24** by cable **28** and lamp **21** is connected to a toroidal auto transformer **25** by cable **29**. Each auto transformer has a contacting slider **30** and **31** respectively which are ganged on a common insulating shaft **26**. Knob **27** is provided on shaft **26** to turn the shaft and thereby control the apparatus. Both auto transformers are supplied with line voltage through a timer **32**. The auto transformers are so connected to the lamps, as shown in the drawings, that when knob **27** is turned the voltage applied to one of the lamps is increased, while that applied to the other is simultaneously decreased. Thus, turning knob **27** changes the ratio of red to blue light within the enlarger. When commercially available auto transformers are used there is a linear relation between the rotation of shaft **26** and the voltages applied to the lamps. Since there is a nonlinear relation between lamp voltage and light output it will generally be necessary to re-adjust timer **32** whenever knob **27** is re-adjusted in order to maintain an unvarying exposure of xerographic plate **11**. It is, however, possible to wind the auto transformers in a nonlinear fashion so as to produce a linear relation between the rotation of shaft **26** and the effective light outputs of

the lamps. Where this is done it is possible to adjust the transmission of filters **22** and **23** so that effective exposure of xerographic plate **11** is substantially uneffected by operational knob **27**. Where such adjustments have been made, it is necessary only to set timer **32** to a fixed value corresponding to the film being projected, and the contrast of the xerographic image formed form such projection may be varied simply by turning knob **27**.

Regardless of the means used for varying the spectral distribution of the light reaching the xerographic plate, the relative proportions of red and blue light are to be varied in accordance with the characteristics of the original image or subject being reproduced. Thus, if the subject is of relatively low contrast, it may be desirable to expose substantially to blue light alone, or to white light or the like which contains insufficient red to appreciably affect the plate. If, on the other hand, the subject is unusually contrasty, then exposure should be made by red light with only a minimum addition of blue. The relative amounts of red and blue light to be used for any particular type of subject will depend somewhat on the nature of the development process which is to be used subsequent to exposure and also on the characteristics of the particular xerographic plates being embodied. Thus, plates which have a relatively greater sensitivity to red light will require a lesser proportion of red light to obtain the desired results than would plates having a relatively lesser response to red light. In all cases, however, where a substantial reduction in contrast is desired, the amount of red light used must greatly exceed the blue.

What is claimed is:

1. In the method of contrast control in making a reproduction from an original wherein a photosensitive member is exposed to a pattern of light and shadow conforming to the original the color of which pattern is selected in accordance with the desired contrast and wherein the photosensitive member comprises an electrostatically charged vitreous selenium layer

(a) the improved method of extending the tonal acceptance range at least 50% in a positive to positive reproduction system which method comprises

(b) utilizing a photosensitive layer characterized uniformly on its surface by a photoconductive response in the blue portion of the spectrum extending to about 5,600 angstroms and a distinct and separate red photoconductive response centered at about 7,000 angstroms and

(c) exposing the photoconductive member to a pattern of light and shadow conforming to the orginial containing at least red light and at least some blue light in a substantially lesser amount than said red light, said blue light being just sufficient relative to the amount of red light to permit substantially complete charge dissipation on the photosensitive member.

2. In the method of contrast control in making a reproduction from an original wherein a photosensitive member is exposed to a pattern of light and shadow conforming to the original the color of which pattern is selected in accordance with the desired contrast of the reproduction and wherein the photosensitive member comprises an electrostatically charged vitreous selenium layer

(a) the improved method of extending the tonal acceptance range at least 50% in a positive to positive reproduction system which method comprises utilizing a photosensitive layer characterized uniformly on its surface by a photoconductive response in the blue portion of the spectrum extending to about 5,600 angstroms and a distinct and separate red photoconductive response centered at about 7,000 angstroms and

(b) exposing the photosensitive member to a substantially chromatically uniform pattern of light and shadow conforming to the original containing at least red light and at least some blue light in a substantially lesser amount than said red light and said blue light being just sufficient relative to the amount of red light to permit substantially complete charge dissipation on the photosensitive member.

3. In the method of contrast control in making a reproduction from an original wherein a photosensitive member is exposed to a pattern of light and shadow conforming to the original the color of which pattern is selected in accordance with the desired contrast of the reproduction and wherein the photosensitive member comprises an electrostatically charged vitreous selenium layer

(a) the improved method of extending the tonal acceptance range at least 50% in a positive reproduction system which method comprises utilizing a photosensitive layer characterized uniformly on its surface by a photoconductive response in the blue portion of the spectrum extending to about 5,600 angstroms and a distinct and separate red photoconductive response centered at about 7,000 angstroms and

(b) exposing the photosensitive member to a light and shadow conforming to the original pattern of a substantially black and white subject said light and shadow pattern comprising at least red light and at least some blue light in a substantially lesser amount than said red light said blue light being just sufficient relative to the amount of red light to permit substantially complete charge dissipation of the photosensitive member in the light areas of said light and shadow pattern.

References Cited by the Examiner

UNITED STATES PATENTS

2,739,079	3/56	Keck.	
2,803,542	8/57	Ullrich.	
2,808,328	10/57	Jacob	96—1
2,907,674	10/59	Metcalfe et al.	96—1 XR
2,962,375	11/60	Schaffert.	
3,003,870	10/61	Jarvis et al.	96—1

OTHER REFERENCES

The Focal Encyclopedia of Photography, Focal Press (1956), pages 454–460. (Copy in Scientific Library.)

Clerc, Photography—Theory and Practice, 2nd Ed. (1937), Pitman (1937), pages 144–156. (Copy in Scientific Library.)

Mees, The Theory of the Photographic Process, 2nd Edition, MacMillan, New York (1954), pp. 191–195.

The Focal Encyclopedia of Photography, Focal Press New York (1956), page 523.

The Focal Encyclopedia of Photography, Focal Press (1956), pages 259–262, and page 1247.

Sowerby, Dictionary of Photography, 18th Ed., Philosophical Library (1956), pages 153–157 and 309–313. (Copy in Scientific Library.)

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