A COMPUTATIONAL TECHNIQUE TO FACILITATE THE EXPOSURE OF COLOR REVERSAL MATERIALS ON GRAPHIC ARTS CAMERAS

David Q. McDowell*

Abstract: It is often desirable to be able to expose a color reversal material on a conventional graphic arts camera. Traditionally the only choices available for the required color balance correction have been the use of multiple-filter CC filter packs or additive exposure through narrow-band filters. Neither approach is particularly attractive. This paper describes a computational technique to allow a "white light" exposure to be combined with two trimming exposures (through narrow-band filters) to expose color material in conventional cameras. The resultant exposures are significantly more efficient than those by either of the traditional options.

Introduction

There is a growing interest in and need for the capability to create reflection prints (second originals) from reflection input using direct reversal materials. One particular example is the need to to convert nonflexible reflection originals into a form more compatible with the color separation scanner. Another example is the color "stat" market. Most work of this type will require the copy board and film sizes common to graphic arts cameras. In addition, the requirements for precise control of magnification and exposure suggest the use of this class of equipment. The availability of materials such as Kodak Ektachrome 14 paper and

---

*Eastman Kodak Company

Kodak Ektaflex PCT reversal film allows the user to expose on equipment that has either reversing optics or conventional optics.

The one feature not readily available on a graphic arts camera, however, is control of the "color" of the exposing light reaching the film or paper. Such control is required to obtain correct color balance in the output. The choice often made in the photofinishing industry is to use color correction (CC) filters over either the lights or the lens. Since most graphic arts cameras use four 500- or 1000-watt pulsed xenon lamps, the use of CC filters over the lamps is not feasible. It is also difficult to use CC filters over the lens; in addition to concerns relating to dust and dirt, large gelatin filters add flare and degrade optical quality. They are also cumbersome to use, since many graphic arts cameras use lenses 3 to 5 inches in diameter. A second option sometimes considered is the use of three separate exposures through filters such as the standard color separation filters. This presents no significant technical problem. The major drawback is that the exposures required are so long that the total time required to complete a set of three exposures is often uneconomical.

A third option is a technique called semiadditive exposure. In this procedure, an initial white-light exposure (which affects all three layers of the film) is adjusted to produce the correct density in the layer that is "fastest" under the conditions involved. With most color photographic products and the pulsed xenon lights used in graphic arts cameras, this is the blue-sensitive layer. Two additional exposures are then given through color separation filters to "trim" the color balance - a green-light exposure and a red-light exposure. This technique makes efficient use of the available light and allows short exposure times; it also avoids the need for a large selection of filters. The most significant drawback is the problem of computing the required combination of exposures. This presents a problem in initial setup as well as in selectively adjusting color balance for particular prints. Compensating for the exposure change associated with variations in magnification compounds the problem. It was our goal to provide the computational procedures and techniques to allow efficient use of this semiadditive technique.

Computational Program Requirements

In development of the computational program concepts, the following goals were established:

1) Insofar as possible the program should be self-calibrating.

2) Measurements and data entry by the user should be minimized.

3) The computational program should operate in two phases - an initial calibration phase that is densitometrically determined and a selective adjustment phase that is subjectively determined.

4) Results of the subjectively determined exposure adjustments should be able to modify the test data to "correct" the reference base for subsequent exposure computations.

As we investigated possible approaches, several other requirements became obvious. For example, the typical reciprocity characteristics of color products meant that reciprocity had to be included in our computational approach. We also decided that average contrast was enough of a variable that this characteristic had to be determined as part of the calibration. Subjective color correction was to be through the use of the subjective viewing filters such as the Kodak color print viewing filter kit (R-25) or user experience. Further, the program should adjust color balance while maintaining a constant visual density. The program should also provide overall density adjustments and allow for the density of an unsharp camera-back mask if one is desired. The ability to compute the exposure change associated with changes in magnification was also a major requirement for graphic arts cameras. These considerations together with the above requirements then formed the basis for our computational program approach.

Computational Concepts

In dealing with direct reversal paper products that are being used to reproduce reflection copy materials, a realistic calibration goal is to have the system adjust exposures to produce a print density that matches the density of a neutral test patch. This test patch should be representative of the highlight area of the print to minimize the effect of any deviations from unit contrast. Typically, a density of 0.4 to 0.7 is realistic. To measure actual effective average contrast, a second test patch is needed; a density of 1.0 to 1.4 is below the shoulder of the sensitometric curve but separated enough from the highlight patch to provide a reasonable estimate of sensitometric slope. As can be seen in Figure 1, a typical white-light exposure causes the test patch to be reproduced at different densities in each color. The density difference between the test patch and its reproduction in the blue-sensitive layer can be interpreted as the log exposure correction required in the white-light exposure. Similarly, the density difference between the blue and the red or green can be interpreted as a relative speed difference between these layers (for the white-light illumination system involved) that must be compensated for by the separate trimming exposures. In practice we found that the slope of the green layer was sufficiently representative of all three layers to use it as the sole measure of slope.

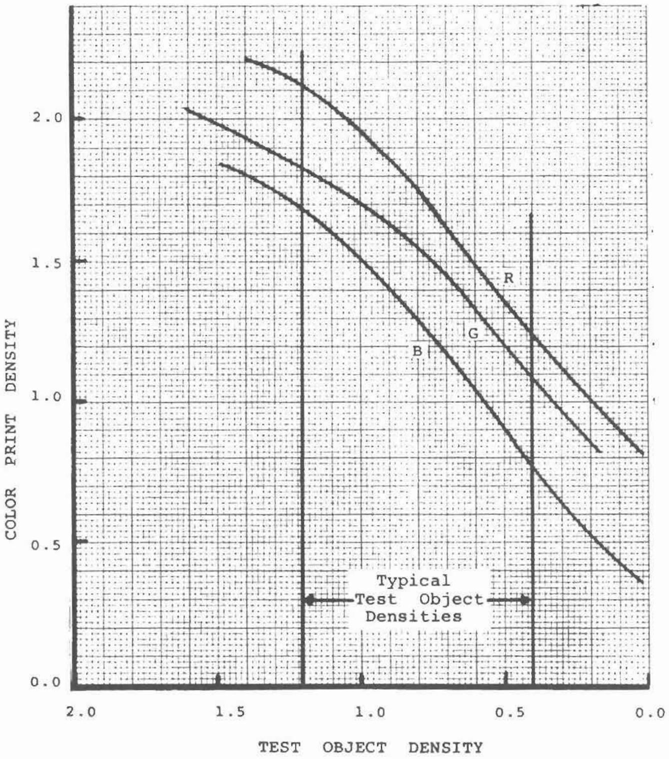

Figure 1. Results of Typical White-Light Test Exposure

Figure 2 shows the results of adding a red and a green filter exposure (3 exposures to the same film) to the white-light exposure of Figure 1. The blue densities of the test patches have not changed. The density changes in the red and the green can be converted to log E differences through the slope information and represent a measure of the relative effectiveness of the filtered-light exposure relative to

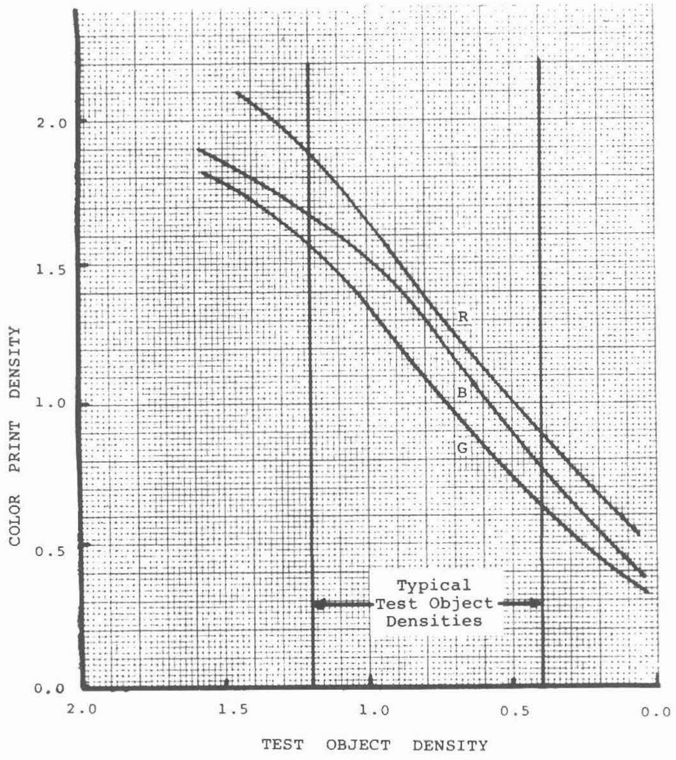

Figure 2. Results of Typical Test Exposure Using White + Red + Green

the white-light exposure of the same layer. These two pieces of information can then be used to compute the correct combination of white, red filter, and green filter exposures to produce a neutral reproduction at the same density as the low-density test patch. In practice, Kodak Wratten filters No. 25 (red) and No. 58 (green) provide a reasonable match to the spectral sensitivities of the film.

Although the above techniques allow exposures to be computed to match, densitometrically, a reproduction to an original (at a given density level), in practice this is not enough. It is important to allow a user also to include subjective evaluations as input to the computational process. Desired changes can be expressed as cyan, magenta, and yellow as well as red, green, and blue color corrections. To meet the requirement that color balance changes not change average or visual densities, the net changes can be adjusted so that the average of the cyan and magenta changes requested is zero (i.e., the equivalent cyan and magenta changes requested are averaged and subtracted from the cyan, magenta, and yellow changes). These changes can then be converted to equivalent exposure changes and applied to the appropriate computation step.

In addition, overall density changes can be converted to a required exposure change. Because the red and green trimming exposures are computed as a function of the white-light exposure, the required density (relative exposure) change needs only to be applied directly to the white-light exposure. The computation of the trimming exposures will automatically include any overall changes.

To include the effects of reciprocity, all input exposure times are converted into effective time (by the technique described in Reference 1) before being used in the computations, and the results are converted back to real time before use. In this technique an equation of the form

$$y = ax2\ bx + c$$

is used to fit the reciprocity characteristics of the product in the area of interest. In this equation y is expressed as log relative speed and x is log exposure time. In practice two parameters are required, a and -b/2a (which is referred to as TO), and the conversion equations used are:

$$\mathrm{Log}_{10}\ T' = \mathrm{Log}_{10}\ T - a\ (\mathrm{Log}_{10}\ T - \mathrm{Log}_{10}\ TO)^2$$

$$\mathrm{Log}_{10}\ T = (a\ \mathrm{Log}_{10}\ TO + 0.5 - (0.25 + a\ (\mathrm{Log}_{10}\ TO - \mathrm{Log}_{10}\ T'))^2)\ /a$$

where T represents real time and T' represents effective time.

Computational Procedures

The input data, computational sequence, and equations used are described in the following sections.

Input Data: The input data used in these computations and the associated symbols used in the equations described in later sections are as follows:

Test Size (Expressed as %)	OS	
Reference Sample		
High Density	TSH	
Low Density	TSL	
Test Exposure Time Used		
White Light	EW	(EW1)*
Green Light	EG	(EG1)*
Red Light	ER	(ER1)*

*These values are used to represent the effective times after reciprocity correction.

Test Densities - White-Light Exposure	
Green High Density	GWH
Green Low Density	GWL
Blue Low Density	BWL
Red Low Density	RWL
Test Densities - Three-Color Exposure	
Green Low Density	G2L
Red Low Density	R2L
Mask Density (in low-density test patch)	MD

CC Density Change Desired	
Cyan	CC(C)
Magenta	CC(M)
Yellow	CC(Y)
Red	CC(R)
Green	CC(G)
Blue	CC(B)
Reproduction (New) Size	NS
Desired Density Change	DC

Equations:

The computations required are as follows.

Relative Exposure Constants

$$S = (TSH - TSL)/(GWH - GWL)$$

$$C1G = (GWL - BWL) * S$$

$$C1R = (RWL - BWL) * S$$

$$C2G = (EW1/EG1) * [10^{(S*(GWL - G2L))} - 1]$$

$$C2R = (EW1/ER1) * [10^{(S*(RWL - R2L))} - 1]$$

where S is a measure of the slope of the sensitometric curve, C1- is the effective speed difference to "white-light" between the blue layer and the red or green layer, and C2- is the relative effectiveness of the filtered exposure compared to the white- light exposure.

CC Filter Data Manipulation

$$N(C) = CC(C) + CC(G) + CC(B)$$

$$N(M) = CC(M) + CC(R) + CC(B)$$

$$N(Y) = CC(Y) + CC(R) + CC(G)$$

$$CAVG = [N(M) + N(C)]/2$$

$$CCN = [N(C) - CAVG]/100$$

$$CM = [N(M) - CAVG]/100$$

$$CY = [N(Y) - CAVG]/100$$

where N( ) are the net cyan, magenta, and yellow filter changes requested, and CCN, CM, and CY are the values that result after the net changes have been normalized to the average of the cyan and magenta.

Size Change Computations

$$SC = [(NS + 100)/(OS + 100)]^2$$

where SC is the exposure change required to compensate for the difference in effective f/no between the test magnification and the magnification being used.

Exposure Computations

$$LEW = \log_{10}(EW1 * SC) + [S * (BWL - TSL - DC - CY)] + MD$$

$$LEG = LEW + \log_{10}[(1/C2G) * (10^{(S*(CY - CM) + C1G)} - 1)]$$

$$LER = LEW + \log_{10}[(1/C2R) * (10^{(S*(CY - CCN) + C1R)} - 1)]$$

where LE- are the log effective exposure times required.

Calibration Data Update

$$EW' = EW * 10^{[-S * (DC + CY)]}$$

$$C1G' = C1G + [S * (CY - CM)]$$

$$C1R' = C1R + [S * (CY - CCN)]$$

EW', C1G' and C1R' are the "corrected" values for these parameters and allow subjective data to be used to modify the test data to provide a more satisfactory reference.

Implementation

These equations can be implemented on a variety of computational devices. A simple basic language program with minimal window-dressing is less than 4 kilobyte in size. These computations are also well within the capabilities of keystroke programmable machines such as the TI 59 or the HP 41c.

Literature Cited

Archer, H. B.
1977. "Calculation of Multiple Halftone Exposure Times for Three-Point Control," TAGA Proceedings, pp. 1834-217.