THEORETICAL DETERMINATION OF OPTIMUM SPLIT-FILTER EXPOSURES FOR COLOR-CORRECTION MASKS[*1]

Jang-fun Chen[*2]

Abstract

Workers have found that a split-filter mask made by consecutive exposures through red, green, and blue filters provides better color correction than a mask exposed through a single filter. Nevertheless, split-filter masking has never been adopted in the direct screen separation method. This may be due to the difficulty of determining the optimum red:green:blue split-filter exposures. This paper addresses the problem of determining the optimum split-filter ratios needed to expose masks for the direct screen separation method.

Optimum exposure ratios were determined with the assistance of a digital computer by systematically trying out 231 different combinations of red, green, and blue exposures using the improved Yule-Pollak equation for calculating the effect of split-filter exposures. The computer analysis also provided the required curve shape of the split-filter mask for each separation.

It was found that a red-blue split-filter mask and a red-green split-filter mask are sufficient for the green and blue separations respectively. For the red separation, a red-green-blue, three-filter split mask provides improved color correction. The analysis showed that there was considerable latitude in the ratios of the split-filter exposures. For example, a 15 percent difference in red exposure in making the mask for the red separation can still yield equally good results. The mask for the red separation was found to have the highest contrast of all the three masks.

Introduction

The primary object of color correction is to compensate for the unwanted spectral absorptions of cyan,

---

[*1] Condensation of a MS thesis presented to School of Printing, Rochester Institute of Technology.

[*2] 1982-83 TAGA fellowship recipient.

magenta, and yellow inks. The conventional remedy for these unwanted densities is to use a mask to 'modify' the densities of original colors.

Workers have found that a split-filter mask made by consecutive exposures through red, green, and blue filters provides better color correction than a mask exposed through a single filter. This is due to the fact that the split-filter mask provides, in a single piece of film, the equivalent of more than one mask per separation.

A two-filter split-filter mask exposure has been recommended by Kodak for indirect separation. However, the exact ratios for the two exposures must be determined through trial and error by a camera operator. In addition, changing filters during film exposure involves more steps and, consequently, makes the determination of a suitable split-filter mask very time-consuming. Thus, split-filter masking has rarely been adopted in the direct screen separation method. This paper addresses the problem of determining the optimum split-filter ratios needed to expose masks for the direct screen separation method.

The two objectives of this paper are: (1) to determine the optimum split-filter exposure ratios (red: green: blue) for creating a desired mask, and, (2) to define the curve shape of the optimum split-filter mask in each separation.

Optimum exposure ratios were determined with the assistance of a digital computer by systematically trying out 231 different combinations of red, green, and blue exposures using the improved Yule-Pollak equation for simulating the effect of split-filter exposures. A second degree mathematical model was chosen to represent the required curve shape of the split-filter mask for each separation. And a least-squares technique was used to select the best-fit of data.

In the past, the concept of actinic density has been used to determine quantitatively the required mask densities. The actinic density of a color patch is equal to the visual density of a non-selective gray patch in the original which photographs like the color patch. Further, it can be thought of as identical to relative Log exposure since it is always referenced to a step of the original gray scale. The actinic density of a color patch depends upon the filter(s) and the type of film used in photographing it. Effective actinic density(EAD) is actinic density which has been corrected for flare.

In the following sections, the effect of split-filter exposures on the EAD's of color patches is first illustrated. And, the use of the improved Yule-Pollak equation to calculate the EAD of a given color patch from any combination of red, green, and blue filter exposures is described. Next, the strategy for deriving the required mask density (RMD) is presented. This is followed by using a mathematical model to represent the required curve shape of the split-filter mask for each separation. In addition, the technique to optimize the model is also explained. Finally, based upon the results found by the computer analysis, two subsequent analyses are made: i.e., the latitude in the choice of the best split-filter ratios and how much color correction can be achieved from the optimum curve shapes determined by the analysis.

Effect of split-filter exposures on the EAD's of color patches

To illustrate the effect of different split-filter ratios on the EAD's of various color patches, six masks were made using different ratios of red and green exposures. The color original consisted of seven patches: cyan, magenta, and yellow solids and their two- and three-color overprints. Table 1 lists the EAD's of these color patches for the six different sets of the red/green ratios; this data is plotted in Figure 1.

Figure 1 shows that very large changes in effective actinic density occured in four of the seven patches. Interestingly, the EAD's of the yellow and blue patches change the least. This suggests that the EAD's of these two patches might also be modified if a split-filter blue exposure were used along with the red and green split exposures. It is for this reason that <u>three</u> split-filter exposures-- red, green, and blue-- were used in making the desired color correction.

Table 1

Effective actinic density of each color patch resulting from various proportions of split-filter (red and green) exposure

Masking[*1] Film #	Split-filter exposure (%)		Effective Actinic Densities of color patches						
	Red	Green[*2]	Yel.	Cyan	Green	Red	Mag.	Blue	3-c
1	0	100	.04	.37	.45	1.15	1.13	1.25	1.30
2	20	80	.00	.45	.54	.55	.51	1.15	1.25
3	40	60	.00	.61	.66	.35	.35	1.16	1.20
4	60	40	.00	.63	.71	.24	.23	1.05	1.24
5	80	20	.00	.77	.84	.18	.14	1.12	1.25
6	100	0	.00	1.01	1.11	.00	.00	1.16	1.23

*1 Kodak Pan Masking Film 4570.
*2 Kodak Wratten Filter #25 and #58.

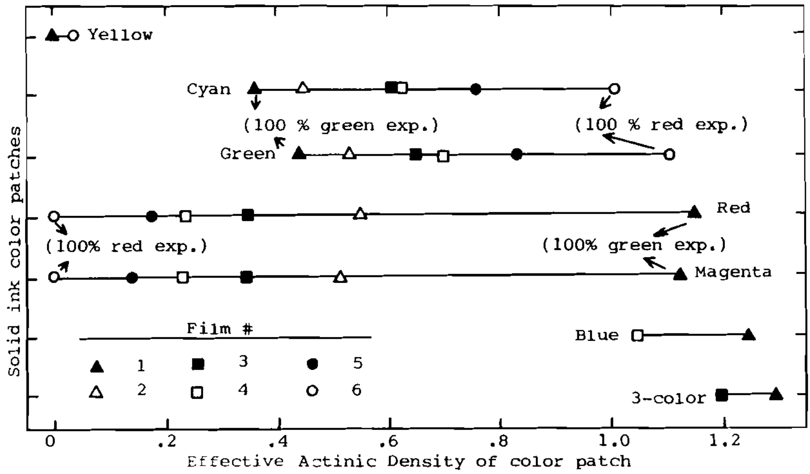

Figure 1

Effect of a series of red-green split-filter exposure

The solid lines illustrate the obtainable effective actinic density ranges of color patches by red-green split-filter exposures to masking films. Some points are not shown in yellow, blue, and 3-color patches due to limited space.

Calculation of the effect of the split-filter exposures

Both Yule[*1] and Pollak[*1] gave a similiar equation to calculate the resulting EAD of a color patch. In order to use this equation, the single-filter EAD of a color patch must be experimentally determined for a given masking film. This single-filter EAD must be converted to "effective actinic reflectance"(EAR)[*2].

Yule mentioned that reciprocity failure[*3] can affect the accuracy of calculations. Neither Yule nor Pollak, however, have modified their original equations to account for reciprocity failure. For more precise "simulation" of split-filter exposures, the equation must incorporate a correcting factor for reciprocity failure. Hence, an improved equation was derived and is given below for the case of three consecutive exposures through red, green,

---

[*1] See reference 1&2

[*2] $EAR=10^{-EAD}$

[*3] Failure of reciprocity law describes the phenomenon that the sensitivity of a photographic emulsion may vary with the changes in the illumination level and the exposure time.

and blue separation filters. Each term in the equation is weighted by its fractional exposure.

$$D = -\operatorname{Log}\left(r \cdot R_r^f + g \cdot R_g^f + b \cdot R_b^f \right)^{1/f} \qquad (1)$$

where D = resulting EAD of a color patch;
r, g, and b = the fractions of the exposure given to the split-filter mask through red, green, and blue filters respectively;
$r + g + b$ = 1 (or 100%);
R_r, R_g, R_b = effective actinic reflectance of the color patch through red, green, and blue filters respectively;
f* = the correction factor for the reciprocity failure of the masking film used.

This equation can be used to calculate the EAD's of color patches for any given set of split-filter exposure ratios. Since changing the EAD's of the color patches will affect the density on the mask film, one must now determine the film densities required for the mask. For this theoretical study, it is necessary to seek a method to derive the required densities on mask film.

Deriving the required mask densities

For each color separation (or "printer"), solid ink color patches are divided into two groups-- wanted, and unwanted colors.

The wanted colors for a given "printer" are those patches in the original that need to have colorant supplied by that printer. For example, the yellow printer must supply yellow to reproduce those patches in the original that contain yellow, that is, the yellow(Y), green(CY), red(MY), and the three-color overprint(CMY). These are the wanted colors for the printer. Moreover, these wanted colors should photograph like the so-called "black" patch, that is, the same amount of colorant from that "printer" should print in the color patches as in

---

*DuPont referred to reciprocity quotient as "Q factor" which is actually the same as "f" in equation (1). Moreover, DuPont reveals that CRONAR continuous tone film has Q factor 1.3. Therefore, rather than running a tedious experiment testing reciprocity failure, this value was taken as an approximation for the value of "f".

the "black" patch. Therefore, they should all possess equal blue filter densities with the "black" patch.

The unwanted colors are the color patches in the yellow printer that require no yellow colorant to reproduce them, cyan(C), magenta(M), blue(CM). Hence, these color patches should photograph like the "white" patch and also should match the "white" in blue filter density. Figure 2 illustrates the wanted and unwanted colors in all three color separations. Nevertheless, without help from a mask, the density (or EAD) equivalency among the "black colors" and among the "white colors" will never occur because the available inks have unwanted spectral absorptions. The mask is thus designed to produce both wanted and unwanted colors with equal

ORIGINAL COLOR PATCHES

C	M	Y	MY	CY	CM	CMY

YELLOW PRINTER

Wanted colors (contains Y)			Y	MY	CY		CMY
Unwanted colors (without Y)	C	M				CM	

CYAN PRINTER

Wanted colors (contains C)	C				CY	CM	CMY
Unwanted colors (without C)		M	Y	MY			

MAGENTA PRINTER

Wanted colors (contains M)		M		MY		CM	CMY
Unwanted colors (without M)	C		Y		CY		

Where C = Cyan
M = Magenta
Y = Yellow
MY = Magenta+Yellow (Red)
CY = Cyan+Yellow (Green)
CM = Cyan+Magenta (Blue)
CMY = Cyan+Magenta+Yellow

Figure 2

Wanted- and Unwanted-colors in each color separation densities (EAD's) respectively. This is the basic concept used to derive the following required mask densities (RMD's).

In an ideally-masked separation, there are two levels of EAD: WEAD(wanted-color effective actinic density) and UEAD(unwanted-color effective actinic density). The WEAD can be viewed as an ideally-masked "black" patch, and the UEAD as an ideally-masked "white" patch. The "black" and "white" are the aim points for wanted- and unwanted-colors, respectively.

The difference between WEAD and the actual EAD (experimentally determined through the halftone separation negative) of a wanted color is defined as the required mask density for the wanted color. Note that the RMD is the density on the mask. The derivation can be shown in a simple mathematical equation:

RMD for wanted color = (WEAD) - (actual EAD of wanted color in the unmasked separation) (2)

By the same token, the RMD for the unwanted color can be derived as shown:

RMD for unwanted color = (UEAD) - (actual EAD of unwanted color in the unmasked separation (3)

The red, green, and blue separations each have a different set of wanted and unwanted colors. Therefore, it is necessary to calculate a set of RMD's for each separation. The calculation for RMD's can be graphically illustrated as shown in Figure 3.

As mentioned earlier, the actual EAD's of color patches in the separation were experimentally determined. However, two ideal aim points (WEAD, and UEAD) were hypothetically assigned(see reference 10):

WEAD = 1.50 for all three separations;
UEAD = 0.81 for red separation;
UEAD = 0.57 for green separation;
UEAD = 0.48 for blue separation.

Optimization and required mask curve shape

At this point, one has a way to calculate the required mask densities(RMD's) and a way to change the effective actinic densities(EAD's) for color patches. Once calculated, the RMD's are fixed, but to what values should the EAD's be changed? This dilemma can best be illustrated with a graph.

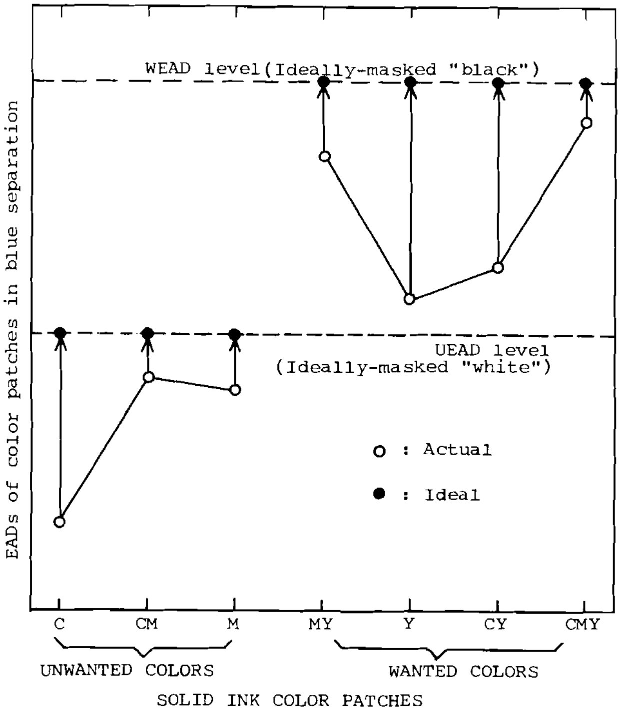

Figure 3

Determination of the Required Mask Densities

The length of the arrows represent the required mask densities for the blue separation. The direction of the arrows denotes that density must be added to each actual point to arrive at the ideal level of WEAD or UEAD.

Since, by definition, EAD's are referenced to the original gray scale, they can be thought of as identical to relative Log exposure. From this, it follows that the EAD's which are plotted on the X-axis can represent the relative Log E of the masking film. The RMD's which are plotted on the Y-axis are the densities required on the masking film. Therefore, the plot of RMD's against EAD's is identical to the D-Log E curve of the required mask.

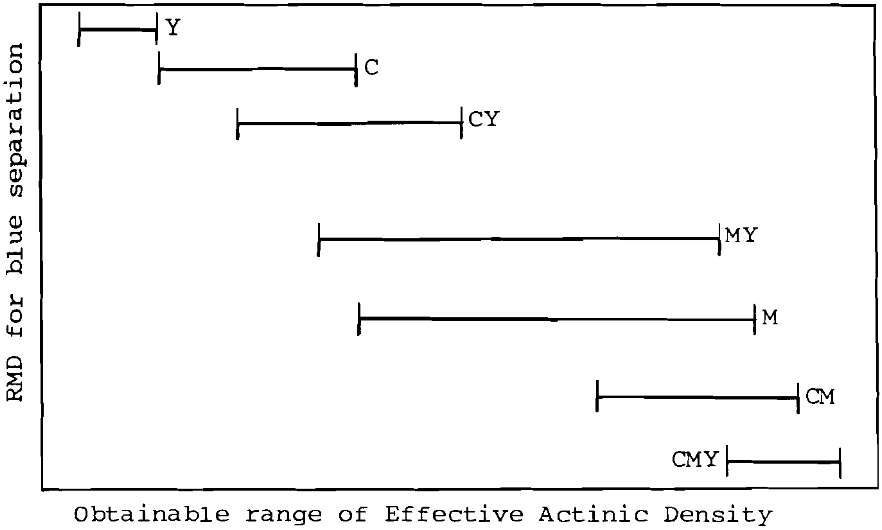

Figure 4

Plotting RMD's (for blue separation) against the various obtainable EAD's of color patches for any given set of split-filter exposures.

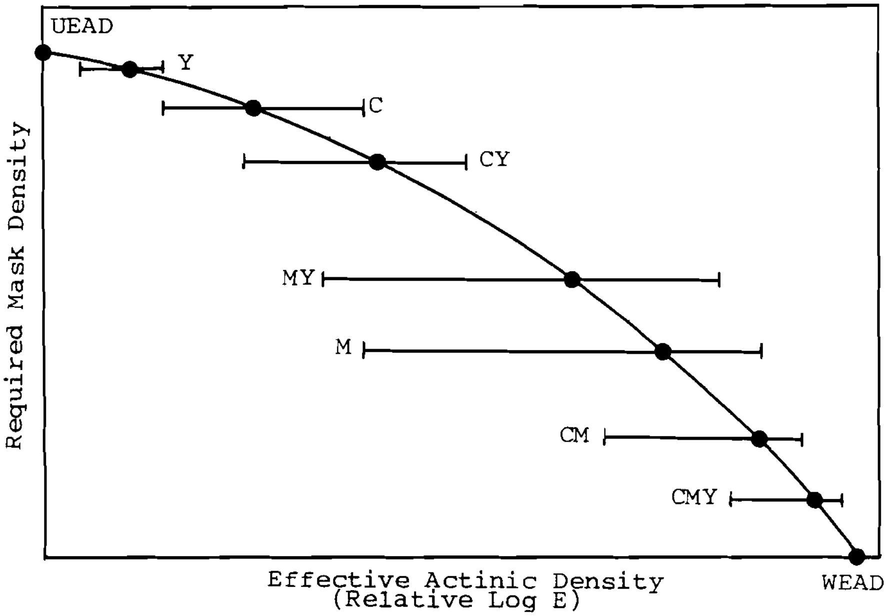

Figure 5

Possible curve shape may be attained by merely shifting EAD's of color patches.

The above concept then provides a criterion for choosing the optimum set of split-filter exposures; the optimum set is the one that shifts the EAD's of the mask so that its curve shape is achievable by conventional mask films. Figure 5 illustrates this concept by plotting a possible curve that falls within the range of EAD's carried over from Figure 4.

In establishing the curve shape, the WEAD (the ideally-masked "black" patch) and UEAD (the ideally-masked "white" patch) may be included in addition to the seven color patches. These additional data points act as the two end points for the curve plotted.

As can be observed from Figure 5, the RMD is actually a function (shown by the curve shape) of the EAD's. This shape (the relationship) can be represented by a second degree equation:

$$RMD = A + B(EAD) + C(EAD)^2 \qquad (4)$$

where A, B, C are coefficients

Having established the D-Log E criterion, the question now is how can red, green, and blue split-filter ratios be chosen to properly shift the EAD's so they line up to look like such a D-Log E curve? The best method may be to systematically try out all combinations of red, green, and blue filters (each of which is incremented by 5%); thus gives 231 combinations to be tested as shown in Figure 6.

No.	%Red	%Green	%Blue
1	0	0	100
2	0	5	95
:	:	:	:
29	5	35	60
:	:	:	:
102	25	30	45
:	:	:	:
201	65	25	10
:	:	:	:
231	100	0	0

Figure 6

Systematical combination of split-filter exposure for %red, %green, and %blue. Note that the total number of possible combinations are 231.

Equation (1) is used to calculate the EAD's that would result from each combination. A second degree mathematical model was chosen to represent the D-Log E curve of the mask film and a least-squares technique was used to fit the RMD versus EAD data; standard error of analysis served as a measure of how well the data fit the model.

Results and Analysis

The optimum split-filter ratios found by the computer analysis are:

Split-filter mask for	Optimum split-filter r:g:b
red separation	85 : 10 : 5
green separation	95 : 0 : 5
blue separation	5 : 95 : 0

Note: Kodak Wratten filter #25, #47B, and #58 were selected for representing red, blue, and green filters respectively.

The optimum split-filter masks for the green and blue separations do not need the third split-filter component since a two-filter split-filter exposure is sufficient to create the desired mask. On the other hand, the mask for the red separation requires a three-filter split-filter exposure where the red filter exposure plays a major role in making the mask.

To explore to what extent these optimum ratios can be manipulated while retaining the same color correction, the computer program was modified to print all the regression results for the 231 split-filter ratios that was tested. In other words, by simply examining the standard errors from the 231 regression analysis, one is able to observe the latitude in the choice of the best split-filter ratios. Note that the standard error has been used to measure of "goodness of fit" in the analysis. Statistically speaking, the smaller standard error represents the better fit.

To facilitate the observation, the 231 standard errors are rearranged in a form as shown in Figures 7, 8 and 9.

In each figure, a line was drawn to include the lowest standard error and the standard errors that are no greater than 0.003 of the lowest standard error. The 0.003 tolerance is arbitrary chosen. Observe that, instead of using a single set of optimum split-filter r:g:b ratios, there are a number of r:g:b ratios which are equally good. This implies that there is latitude in using the optimum split-filter r:g:b ratios. For instance, in the red separation (Figure 9), the optimum split-filter mask can be made in which the red filter ratio can vary between 75 to 90 percent, a range of 15 percent. Similiar

(%) GREEN																					
100	.078																				
95	.080	.076																			
90	.082	.078	.078																		
85	.083	.080	.079	.081																	
80	.085	.081	.080	.082	.085																
75	.086	.083	.082	.083	.086	.090															
70	.088	.085	.084	.084	.087	.091	.096														
65	.091	.088	.086	.086	.088	.092	.097	.102													
60	.094	.091	.089	.088	.090	.094	.098	.103	.108												
55	.098	.095	.092	.091	.092	.095	.099	.104	.109	.113											
50	.102	.099	.096	.094	.095	.098	.101	.106	.110	.115	.119										
45	.106	.103	.100	.098	.099	.100	.104	.107	.112	.116	.120	.124									
40	.112	.108	.105	.103	.102	.104	.106	.110	.114	.118	.122	.125	.128								
35	.117	.114	.110	.108	.107	.108	.110	.113	.116	.120	.123	.127	.130	.133							
30	.123	.120	.116	.113	.112	.112	.113	.116	.119	.122	.125	.128	.131	.134	.136						
25	.130	.126	.121	.119	.117	.117	.118	.119	.122	.125	.128	.131	.133	.136	.138	.140					
20	.136	.132	.128	.125	.123	.122	.122	.123	.125	.128	.130	.133	.135	.138	.140	.142	.144				
15	.142	.138	.134	.131	.128	.127	.127	.128	.129	.131	.133	.135	.138	.140	.142	.144	.145	.147			
10	.148	.144	.140	.137	.134	.133	.132	.132	.133	.135	.136	.138	.140	.142	.144	.145	.147	.148	.150		
5	.154	.150	.146	.143	.140	.138	.137	.137	.137	.138	.140	.141	.143	.145	.146	.148	.149	.150	.152	.154	
100	.154	.156	.152	.148	.145	.143	.142	.141	.141	.142	.143	.144	.146	.147	.149	.150	.151	.152	.154	.155	.158
BLUE (%)	100	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100 RED (%)

Figure 7

Standard error value associated with each set of split-filter ratios that was tested in regression analysis for blue-separation mask.

The region of optimum split-filter ratios are included in dotted line.

(%) GREEN																					
100	.172																				
95	.169	.160																			
90	.168	.157	.152																		
85	.167	.156	.149	.145																	
80	.167	.155	.148	.142	.139																
75	.166	.154	.146	.140	.136	.133															
70	.166	.153	.145	.139	.134	.130	.127														
65	.165	.153	.144	.137	.132	.127	.124	.121													
60	.165	.152	.143	.136	.130	.125	.121	.117	.115												
55	.165	.152	.143	.135	.129	.123	.118	.114	.111	.110											
50	.165	.151	.142	.134	.128	.122	.116	.112	.108	.106	.104										
45	.165	.151	.142	.134	.127	.120	.115	.110	.105	.102	.100	.099									
40	.166	.151	.141	.133	.126	.119	.113	.108	.103	.099	.096	.095	.094								
35	.166	.151	.141	.133	.125	.119	.112	.106	.101	.097	.093	.091	.089	.089							
30	.167	.151	.141	.133	.125	.118	.112	.105	.100	.095	.091	.088	.085	.084	.084						
25	.167	.150	.140	.132	.125	.118	.111	.105	.099	.094	.089	.085	.087	.080	.079	.080					
20	.168	.150	.140	.132	.125	.118	.111	.105	.099	.093	.088	.083	.080	.077	.075	.075	.075				
15	.169	.150	.140	.133	.126	.119	.112	.105	.099	.093	.087	.082	.078	.075	.072	.070	.070	.070			
10	.170	.150	.140	.133	.126	.119	.113	.106	.100	.093	.088	.082	.078	.074	.070	.068	.066	.065	.065		
5	.171	.149	.139	.132	.126	.120	.114	.108	.101	.095	.089	.083	.078	.073	.069	.066	.063	.061	.060	.060	
100	.179	.149	.139	.132	.127	.121	.116	.110	.104	.097	.091	.085	.080	.075	.070	.066	.062	.059	.056	.054	.054
BLUE (%)	100	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100 RED (%)

Figure 8

Standard error value associated with each set of split-filter ratios that was tested in regression analysis for green-separation mask.

The region of optimum split-filter ratios are included in dotted line.

(%) GREEN																					
100	.177																				
95	.172	.152																			
90	.171	.146	.139																		
85	.171	.144	.132	.129																	
80	.172	.143	.129	.121	.121																
75	.173	.143	.127	.118	.113	.114															
70	.175	.143	.127	.116	.108	.105	.107														
65	.176	.144	.127	.115	.106	.100	.098	.100													
60	.178	.145	.127	.115	.105	.097	.092	.091	.094												
55	.180	.146	.128	.115	.104	.096	.089	.085	.084	.088											
50	.182	.147	.129	.115	.105	.095	.087	.081	.078	.077	.082										
45	.184	.148	.130	.116	.105	.096	.087	.080	.074	.071	.071	.076									
40	.186	.149	.131	.118	.107	.097	.088	.079	.073	.068	.065	.065	.070								
35	.188	.150	.132	.119	.108	.098	.089	.081	.073	.066	.061	.059	.060	.065							
30	.190	.151	.133	.121	.110	.101	.091	.083	.075	.067	.061	.056	.053	.054	.060						
25	.192	.152	.135	.123	.113	.104	.095	.086	.078	.070	.063	.056	.051	.049	.049	.055					
20	.195	.154	.137	.126	.116	.107	.099	.090	.082	.074	.067	.059	.053	.048	.045	.045	.051				
15	.198	.155	.139	.129	.120	.112	.104	.096	.088	.080	.073	.065	.058	.051	.046	.042	.042	.047			
10	.202	.158	.142	.133	.125	.118	.110	.103	.096	.088	.081	.073	.066	.059	.052	.046	.041	.040	.045		
5	.210	.163	.148	.139	.132	.125	.119	.112	.106	.099	.092	.085	.077	.070	.063	.056	.049	.044	.041	.047	
100	.233	.177	.160	.151	.144	.138	.132	.126	.119	.113	.106	.099	.093	.086	.079	.072	.064	.057	.050	.047	.056
BLUE (%)	100	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100 RED (%)

Figure 9

Standard error value associated with each set of split-filter ratios that was tested in regression analysis for red-separation mask.

The region of optimum split-filter ratios are included in dotted line.

observations can be made for the masks for green and blue separations (see Figure 7 and 8). In practice, such latitude is expected to make the exposure of masks less critical.

Curve shape of optimum split-filter masks

Having chosen the optimum split-filter ratios, the curve shape of the optimum split-filter mask can be drawn as shown in Figure 10. The curves in Figure 10 illustrate the best compromise color-correction among color patches in each separation and the desired characteristics of every mask.

A comparison of the positions of the circled color patch points with respect to the split-filter mask curve (Figure 10) allows one to predict the degree of color correction for the individual color patches. Points that fall close to, or right on, the curve indicate that the color patches represented by these points are properly corrected. Overcorrection is shown when the curve is above a point; undercorrection when the curve is below a point.

Using this means of assessment on the split-filter mask for the blue separation (Figure 10 (a)), one would expect that the Y, M, and CM color patches will be

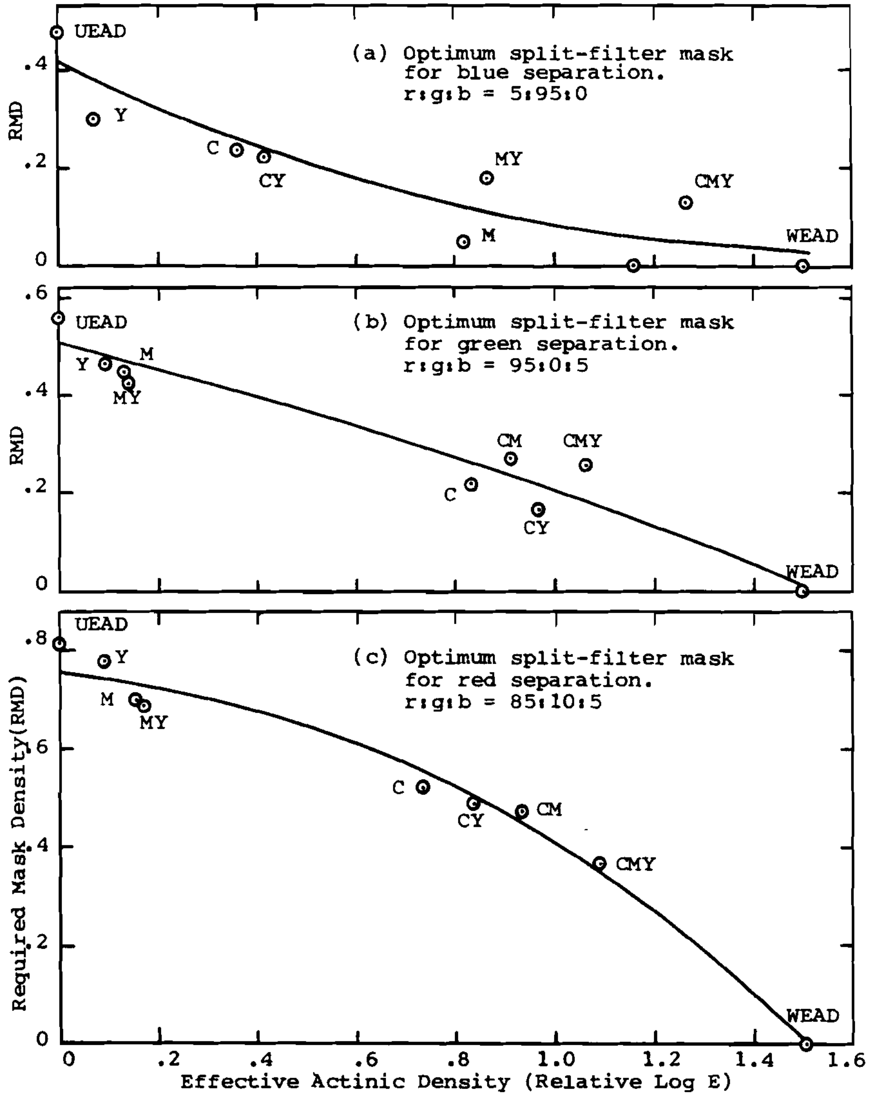

Figure 10

Curve shape of optimum split-filter mask for each separation overcorrected while the MY and CMY patches will be undercorrected. The curve fitting these data points is merely fair. The use of higher order mathematical models may improve the goodness of fit. Notice that the optimum split-filter ratios for making the mask consist of a 95% green filter exposure, a 5% red filter exposure, and 0% blue filter exposure. Since there is latitude in making the split-filter exposures (see Figure 7), it is suspected that the 5% red filter exposure has a very small influence on color correction. Consequently, it is suggested that one make the mask for the blue separation without giving the red-filter split exposure. Incidentally, if the red-filter split exposure is eliminated, the result proves to be similar to the conventional direct screen masking method where a single blue filter exposure is usually recommended to make the mask.

The mask curve shape for the green separation (Figure 10(b)) shows a slight undercorrection in CM and CMY patches and a minor overcorrection in C and CY patches. The curve fit in this case is better than in the previous one. This mask is made with 95% red-filter and 5% blue-filter exposures; no green-filter exposure is needed. This indicates that the major color correction occurs in the C and CY patches since they are affected the most when the mask is exposed to the red light. The 5% blue-filter exposure can be eliminated in situations where applicable. The reason why a green-filter exposure is not needed is because the M and MY color patches that would be most affected by such an exposure do not require correction; they are already quite close to the curve in Figure 10(b).

Turning to the red separation, the optimum split-filter mask shows its curve shape as fitting the data points extremely well (see Figure 10(c)). The split-filter mask requires a predominately red-filter exposure. It is not surprising, however, because the cyan-printer has traditionally required a red-filter mask for contrast reduction rather than color correction. On the other hand, the minor portions of green-filter and blue-filter exposures may both have influence on color correction. Comparing to the other two split-filter masks, the red separation mask offers superior color correction as far as the curve shape is concerned.

An additional observation of the curve shape of the masks shows that each mask utilizes a different portion of the D-Log E curve. The blue separation mask curve shape consists of the lower straight line portion and the toe while the mask curve shape for the green separation is nearly straight. For the red separation, mask curve shape seems to use the shoulder and upper straight line portion, see Figure 10.

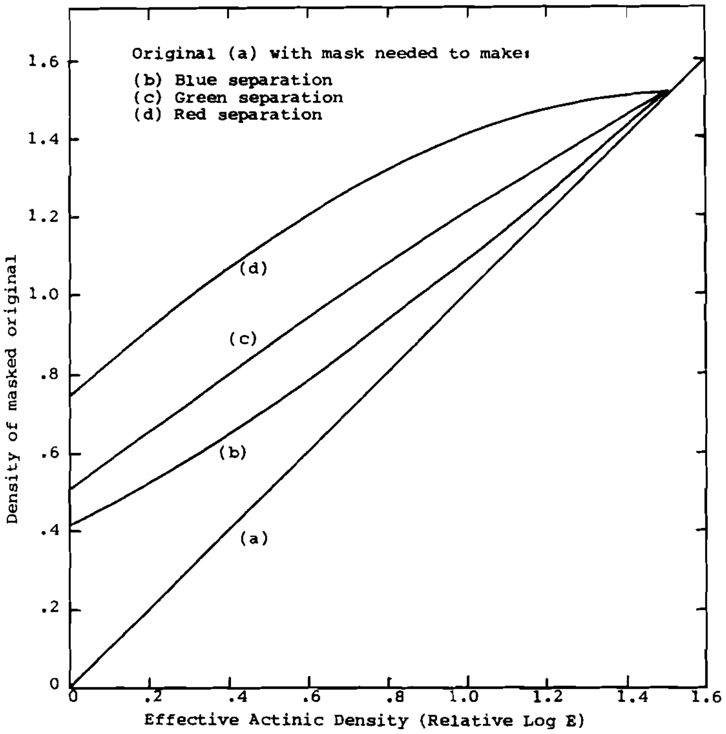

Figure 11

Original with the individual optimum masks added to show curve shape of the combination. The original is represented as a 45-degree straight line.

Figure 11 shows the combination of these optimum mask curve shapes and the 45 degree reference line which represents the original. This combination can be interpreted as the curve shape of the masked original. Comparing the three curve shapes, it is found that the masked red separation gives higher contrast in the highlight and midtone area.

Conclusions

Based upon the foregoing results and analysis, the following conclusions can now be drawn:

(1) The conventional difficulty of determining the optimum split-filter exposure ratios can be easily overcome by a computer-assisted approach described in

this paper. Moreover, it was discovered that, for a given set of process inks, the choice of optimum split-filter exposure ratios is not critical. In the practical application, such latitude allows an easier control of split-filter exposures.

(2) It has shown by the computer analysis that using parabolic correlation to represent those optimum split-filter mask curve shapes is adequate except for the mask for blue separation. It is expected that the use of a higher order mathematical model may improve the curve fit for the mask.

As far as the three optimum curve shapes are concerned, the results of this study prove to be similiar to the customary mask requirment where the red separation mask possess higher contrast than the other two.

Acknowledgements

The author wishes to thank Mr. Brent Archer for his guidance in developing the whole concept of the study. Appreciation is also expressed to Mr. Irving Pobboravsky for his encourgement and numerously valuable instructions in the preparations of the final manuscript. Special thanks go to Mrs. Yu-lien Chen, my wife, who did all the typing for the paper.

References

1. J. A. C. Yule, Principles of Color Reproduction, John Wiley & Sons, New York, 1967, p. 34 & p. 42.

2. F. Pollak, "Two Procedures for Split-Filter Exposures in Color Reproduction", Printing Technology, pp. 65-75 (1961).

3. J. A. C. Yule and F. R. Clapper, "Basic Considerations in Reflection Copy Color Reproduction", TAGA Proc. 10, pp. 163-174 (1958).

4. R. Gutteridge Jr., "A Method of Computing The Mask Characteristics Required for Accurate Color Reproduction in Photomechanical Processes", P. S. & E., 16, pp. 214-220 (1972).

5. A. D. Rickmers and H. N. Todd, Statistics: An Introduction, McGraw Hill, New York, 1967.

6. DuPont Co., "Basic Photographic Sensitometry", DuPont Publication No. A51500, p. 25.

7. Brent H. Archer, Personal Communications, 1981.

8. I. Pobboravsky, "Theoretical Determination of Color Error", TAGA Proc. 12, pp. 127-224 (1960).

9. Eastman Kodak Co., Graphic Arts Handbook, 1975, pp. 185-213.

10. J. Chen, "Theoretical Determination Of Optimum Split-filter Exposures For Color-correction Masks." M.S. degree thesis, Rochester Institute of Technology, 1982.