STUDIES ON THE LEVELS OF UNDERCOLOR ADDITION AND BLACK PRINTER LEVELS IN GCR/UCA 4 COLOR LITHOGRAPHIC PRINTING

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ABSTRACT

Sigg [1] described Grey Component Replacement (GCR) as a four color printing reproduction technique, where in any given image location, "the least predominant of the three primary printing inks is used to calculate a partial substitution for some or all of the primaries by black". Early GCR images were judged to be commercially unacceptable. This condition is now eliminated or reduced by the practice of adding additional densities, Undercolor Addition (UCA), to each of the primary colors at the upper portion of their GCR tonal curve. GCR plus UCA has proven to be an effective combination to insure excellent commercial application.

By convention, colored or toned black inks are routinely used for printing black and white reproductions, as well as four color reproduction. If the black ink used is not neutral, or the dot ratios of the UCA three color combinations are not a balanced grey, an off-color image will occur. Each ink has its own spectrophotometric characteristics. The GCR/UCA scanner program must be especially adjusted to the ink and the press fingerprint at the individual printing location. The present methods of GCR/UCA determination employ densitometry and therefore the above difficulties may be overlooked.

It is the intent of this paper to compare densitometric and colorimetric techniques in determining the correct UCA levels for various GCR black printer values. It is hoped that this work will provide some insight into specifications and techniques to facilitate optimum GCR/UCA levels.

INTRODUCTION

The GCR printing process requires removing the neutral or grey component throughout a four color ink image, and its replacing it with additional black ink. This additional black ink (grey component) is added to the already computed black ink level. The grey replacement technique assumes a neutral black will be added to the already computed black. If the replacement black ink is not neutral, an off-color image will occur. By convention, colored or toned black inks are routinely used for printing black and white reproductions. In the case of black and white printing the intent is to make an image which is visually more pleasing. These same black inks are sold for use in four color reproduction.

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The UCA level for a given GCR is dependent on ink, paper and press fingerprint. Several different UCA determination targets are available for this purpose. It is important that the UCA target chosen is one whose UCA grey balance (yellow, magenta and cyan percent dot area ratios) correspond to the grey balance of the ink colors used. The use of standard ink sets (i.e. SWOP or ISO) and proper quality control of raw materials allow one to use standard UCA/GCR targets without worrying about the UCA grey balance. Improper UCA color balance will produce off color GCR/UCA images.

The type and design of the GCR/UCA target was pioneered by FOGRA [2]. The standard GCR/UCA target is one consisting of cross wedges producing a lattice like image. The X or horizontal axis of the target consists of patches of increasing black dot area, or GCR levels. The Y axis of the target consists of various UCA levels, dot area levels of yellow, magenta and cyan inks at selected dot ratios. The grey balance used in the FOGRA target is one determined as best for the ISO 2846 color ink standard.

The Graphic Communication Association (GCA) GCR study group developed a more expansive target using UCA dot area ratios derived from the SWOP (Specification for Web Offset Publication) ink colors. The UCA range covered by this fixture is from a total YMC dot area of 44-250% to and the black printer levels representing from 50% to 100% dot area. Both establishments use densitometry to determine the optimum levels of GCR/UCA. Densitometry, however, does not allow a color judgement. The results of such a determination may therefore be flawed.

SAMPLES

The original film target chosen for this work is, that produced by the Graphic Communication Association (GCA) and available as, the GCA PC UCA Target. This target covers a black separation range form 50-100% coverage in unequal increments and three color grey levels from a Total Area Coverage (TAC) of 44-240% in 15% increments. The samples used were obtained from a GCR/UCA target web offset printing test run for Spectrum 87. At that time select US printers were asked to add the GCA Target to the end of, an in specification, non GCR existing print run. A major conventional image of that same run was to be included in the signature. The same print conditions and inks used in the original print run where used for this test. The ink on paper image sites of this study were chosen at random. For purposes of this paper they will be referred to as Site XY and Site ZA. The spectrophotometric curves used at both sites are quite similar, however the paper stock used at site ZA is more yellow and matte than at site XY.

EVALUATION:

EQUIPMENT:

SPECTROPHOTOMETER

The Gretag SPM 100, available from Gretag AG Regensdorf Switzerland, was chosen because of its ability to provide spectrophotometric, colorimetric and densitometric responses from the same sample in one reading. Additionally, the 45/0 geometry of that machine is in keeping with previous conclusions [3] that spectrophotometry using 45/0 geometry more closely correlates with commercial graphic arts densitometry than does diffuse specular included or excluded geometry spectrophotometry. The standard spectrophotometer set up conditions in this study are those chosen in the previous reference[3] to insure consistency.

The Spectrophotometer standard operating conditions include:
1. 45/0 Geometry
2. 5000 Kelvins illumination to match those standards detailing graphic arts viewing conditions [4] .
3. 2 Degree CIE 1931 Standard Observer to recognize that graphic arts images are usually composed of complex small color areas which best correlate to this condition [5] .
4. Black Backing behind the sample[6] (Munsell N2) to recognize that graphic arts images are usually printed on both sides of a paper support and some cross talk can occur.

DENSITOMETER

The X-rite 418 densitometer with "Status T" filtration, manufactured by X-rite of Grand Rapids, Michigan was used as the standard densitometer in this test.

PROCEDURE

A statistical procedure called Response Surface Methodology [RSM] was used to analyze the data resultant from this study. The RSM technique allows the relationship between one or several measure responses and several input variables to be studied in an empirical way. The accumulated data from densitometric and spectrophotometric analysis of the samples was used to generate a quadratic equation describing the response's relationship to the input variables. This allows a contour plot of responses versus variables to be generated. The empirical model is an approximation of reality as described by a quadratic equation. The RSM contour plot is a 3 dimensional representation in a 2 dimensional plane. The contour map provides a means of envisioning the effect of the variables. The variables for this test are Total Area Coverage of the target's black separation, which is related to percent GCR, and the TAC of the three color percent dot area, which is related to UCA.

Techniques A, B, and C have been used for to evaluate printed images made from these targets. They are described as follows:

TECHNIQUE A:
1. Reading the "Status T" densities of the printed images.
2. Locating the test image positions of the GCR/UCA printed target where the resultant reflection densities match densities obtained from an conventional image area. Several different test area positions on the GCR target will fulfill that requirement. Each of the different image positions has a different black printer percent dot area. The percent dot area of the black printer relates to the GCR level.
3. Choosing the specific image patch which most corresponds to the GCR level desired.
4. Adopting the film output densities that produced the selected image as in-plant film separation densities and scanner targets.

TECHNIQUE B:

1. Reading the Status "T" densities of all the patches in the target.
2. Choosing the patches exhibiting the density of a conventional image.
3. Choosing the patch from those selected in step 2 corresponding to a TAC of YMCK of 300%.
4. Adopting the film output densities of that target as scanner aim points for GCR and UCA.

TECHNIQUE C:

1. Using spectrophotometry, analyze all the ink on paper printed images in the GCA PC UCA target.
2 Use the spectrophotometric data to obtain Status"T" densities R,G,B, and Visual densities.
3. Use the density data to obtain the Status"T" Hue-Error metric.
4. Use the spectrophotometric output to obtain CIE L*a*b* values.
5. Transform The CIE L*a*b* calculations into the Lightness,Hue Angle and Chroma metrics.
6. Plot the location of all the areas on the film target corresponding to a TAC of 280 and 300 percent.

The window provided by the TAC provides limits for the optimum UCA levels at various GCR or black separation levels.

RESULTS:

Figure 1 represents a mask made from, item 6, the GCA PC UCR target and indicates the target image patches which represent 280 and 300 percent TAC density values. The 280 and 300 percent levels represent conservative TAC limits for publication type web offset images.

Using Response Surface Methodology [RSM] a mathematical expression for the data from steps 1 (density) 2 (Hue-Error) and 5 (CIE L*a*b*) Lightness, Hue Angle and Chroma of technique C was computed for sites XY and ZA. Using those mathematical expressions contour curves were plotted for the different metrics. The contour lines or RSM mappings were compared to actual data points to check correlation of the data to the expression.

3 FILTER DENSITOMETRY:

Density

Figures 2 and 3 illustrate the mathematical relationship derived surface contour plots produced from the Status "T" density analysis of the ink on paper target image printed at sites XY and ZA.

Figures 4 and 5 indicate a window of acceptable maximum black percent dot area and 3 color total maximum dot area, UCA as projected from using density as a parameter. These two figures are obtained by superimposing Figure 1, on to Figures 2 and 3.

The response contours appear linear and diagonal originating from the lower left corner of the field. The data is similar from both sites XY and ZA. Table 1 details the quadratic equation and Correlation Coefficients [R^2] values derived from the density determinations for this portion of the study. The R^2 values of this parameter DENSITY are high, but a density value does not provide a color characterization.

Table 1

Site	Quadratic Equation	R^2
XY	$1.51 + 0.176\ x + 0.251\ y + 0.0406\ x^2 - .0254\ y^2$	95.8
ZA	$1.46 + 0.223x + 0.241y + 0.0689x^2 - 0.0251y^2$	94.7

Hue-Error Calculations

Figures 5 and 6 represent, RSM mathematical formula derived, contour lines produced from the Hue-Error densitometric analysis of sites XY and ZA . Both plots indicate a structure than can be described as a truncated cone with each level of the cone corresponding to a set " Status T" Hue-Error level. A flat plateau is found on top of the cone. The slope of each of the sample plots is different relating to the ink and press conditions used. The steps are incrementally separated and an indication of flat areas where no change is noted.

Table 2 indicates the RSM formula derived for both sites. Also included are the Correlation Coefficients of the formula derived to the actual data.

Table 2

Site	Quadratic Equation	R^2
XY	$16.5 + 8.01\ x + 0.86\ y + 26.6\ x^2 + 10.8\ y^2$	15.1
ZA	$7.69 + 7.57\ x - 7.88\ y + 21.5\ x^2 + 21.3\ y^2$	23.0

The RSM Hue-Error R^2 values of 15.1 and 23.0 indicate a poor fit between the plots and actual data. Such circumstances indicate the inability of the metric data to describe a mathematical representation of the data and that the best fit data and plots do not adequately describe the GCR/UCA procedure being studied.

COLORIMETRY:

Lightness Calculations:

Table 3 lists the Regression Formula produced by the data from both sites and the correlation coefficients of this data.

Table 3

Site	Quadratic Equation	R^2
XY	$21.4 - 5.20\ x - 6.87\ y - 0.799\ x^2 + 1.46\ y^2$	94.6
ZA	$22.2 - 6.82\ x - 7.11\ y - 1.41\ x^2 + 1.35\ y^2$	92.8

The RSM Lightness (L*) R^2 values of both participants indicate an excellent fit between the plots and actual data. Such evidence indicates the ability of the derived RSM mathematical representation of the data to describe the representation.

Figure 7 represents the contour plots generated by the quadratic equation for site XY. The plots of site ZA, Figure 8, are similar to those of site XY. These can be compared to the density plots from the same sites Figure 2 and 3. The shape of the L* contour and the Density contour as well as the resultant R^2 values are very similar. This is to be expected since the ANSI/ ISO PH 2.18 specification detail the black or visual filter of a densitometer be equal to the visual response. L* is a measure of the visual or photometric response.

The small increment between each of the Lightness response lines indicates the rapid colorimetric [Standard Observer based] changes between each of the steps. Early GCR work had been commercially rejected because of "it's not looking right". The use of UCA corrected that issue. Perhaps UCA levels based on Lightness might be a better indicator of how a person sees the GCR/UCA image.

Hue Angle Calculations

Table 4 lists the Regression Formula produced by the data from both sites and the correlation coefficients of this data. The RSM Hue-Angle R^2 values of both participants indicate an excellent fit between the plots and actual data. Such circumstances indicate the ability of the metric data to describe a mathematical representation of the data and that the best fit data and plots do indeed adequately describe the GCR/UCA procedure being studied.

Table 4

Site	Quadratic Equation	R^2
XY	$106 + 4.49\ x + 2.87\ y + 19.2\ x^2 + 19.3\ y^2$	71.7
ZA	$103 + 3.86\ x -9.47\ y + 28.2\ x^2 + 27.8\ y^2$	80.8

Figures 9 and 10 represent contour plots of the resultant CIE L*a*b* Hue Angle values produced from the RSM mathematical expression. They appear, as do the Hue-Error plots to indicate a structure than can be described as a truncated cone. Each level of the cone corresponding to a set Hue Angle level. The Hue Angle contour map of site ZA illustrates a steeper or more rapid change from that of XY. The change in shape can be due to press fingerprint or the inks and paper used. The higher Correlation Coefficient values for CIE L*a*b* Hue Angle than Density Hue-Error averages of from 78% to 15% indicate a better fit for the Hue Angle metric than the Hue-Error metric.

Chroma Calculations:

Table 5 lists the Regression Formula produced by the data from both sites and the correlation coefficients of this data. The RSM Chroma R^2 values of both participants indicate an excellent fit between the plots and actual data. Such circumstances indicate the ability of the metric data to describe a mathematical representation of the data and that the best fit data and plots adequately describe the GCR/UCA procedure being studied.

Table 5

Site	Quadratic Equation	R^2
XY	$5.83 - 1.87\ x +1.71\ y +0.561\ x^2 - 1.58\ y^2$	78.4
ZA	$6.95 - 2.58\ x +2.98\ y + 0.383\ x^2 - 2.17\ y^2$	88.6

Figure 11 and 12 represent the contour plots of the resultant CIE L*a*b* Chroma values produced from the RSM mathematical expression. Site XY plots appear as a set of diagonal linear lines at a high level of black printer dot area becoming increasingly curved as the UCA levels increase. Site ZA contours are definitely more curvealinear than site XY. The curvealinear action is observed at a Chroma level of 5.5 for site XY and 6.5 for site ZA. The rate and extent of the change is different between each of the sites. Site XY tops out at a Chroma level of 8.5 and ZA at a level of 9.2. The difference in the nature of these lines is significant.

A colorimetric assessment of these RSM graphs requires a combined evaluation of all three of these metrics and their interaction. Overlapping contour plots viewed by transmission are often used to visualize such effects. Reflection overlap graphs are difficult to assess and reproduce with reflection copy.

The CIE does not provide a single value metric for the combination of the effects of Lightness, Hue Angle, and Chroma. It does however provide delta E* as a single value combination of the differences in these attributes when comparing color appearance differences between samples.

The CIE equation for delta E* is: CIE $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$

For purposes of this evaluation a new colorimetric value, "e", was defined and implemented to obtain a contour plot of the RSM effects of CIE L*a*b* Lightness, Hue Angle and Chroma. The formula for "e" is identical to that used for CIE L*a*b* delta E but applied to an original computed rather than comparison values, where "e"= $[L^{*2} + a^{*2} + b^{*2}]^{1/2}$.

Table 6 details the mathematical expression and the correlation coefficients of the "e" data. The R^2 vales of the "e" mathematical expression are lower than the separate L*, Hue Angle, and Chroma R^2 values obtain from the separate RSM analysis of the data. This is statistically expected.

Table 6

Site	Quadratic Equation	R^2
XY	$108 + 3.40x + 1.77y + 19.0x^2 + 19.4y^2$	71.1
ZA	$106 + 21.5x - 6.38y + 2.76x^2 + 27y^2$	53.4

Figures 13 and 14 represent an "e" plot of both sites. The contours for site XY indicate a structure than can be described as a truncated cone. The structure closely corresponds to the original Hue Angle RSM contour plot. The "e" contours for site ZA appear different than the XY "e" contour. The ZA "e" plot appears to resemble a series of half rings that suggest they ultimately form a cone shape plot similar to that of site XY. The plot also indicates wider spacing between the contour levels offset from center.

Although the plots of "e" for both sites are less confusing than a composite plot of CIE L*a*b* Lightness, Hue Angle, and Chroma it is difficult to assign a causes for differences in plot shape. One must be able to pinpoint the attribute that causes a difference or change. Which metric L*, Hue Angle or C* contributed to the differences between the two sites? A study of each of the individual contour plots provides the answer. Such individual contour plots in conjunction with the "e" plot allow an indication of robustness or resistance to process or random change not provided by an "e" plot. For best process stability each of the individual responses that make an "e" must be stable or linear.

When the individual response curves are compared to each other it is easy to see that the cause of the different "e" responses is the ZA Chroma response. The curvealinear ZA Chroma response imposes a distortion on Site ZA's RSM "e" contour plot . The use of a matte paper stock at site XY is significant. Matte stocks as compared to glossy stock are known to lower Chroma, and therefore can account for much of the differences between sites. Chroma is not an independent colorimetric variable. A change in the percent dot area of the black printer can effect both Lightness and Chroma.

Figures 15 and 16 are identical to 13 and 14 except they contain the mask delineating the optimum TAC values [Figure 1] The window provided by the mask allows a series of operating points from which different combinations of GCR and UCA can be chosen.

CONCLUSIONS

1. A single RSM contour plot of the combined effects of CIE L*a*b* Lightness, Hue Angle and Chroma involved the necessity of defining a new colorimetric metric "e"
2. The shape of the RSM contours are completely different.when derived from Hue Error densitometer analysis compared to shape of composite or "e" RSM contour plots based on spectrophotometric analysis.
3. An attempted mathematical description of the HUE Error metric and its resultant R^2 confidence values indicates that this parameter is not a meaningful one for characterizing color [GCR and UCA] levels
4. The Density parameter and CIE L*a*b* Lightness parameter are related as they should be since each is measured with near the same visual response.
5. The Colorimetric values concerning GCR and UCA combinations can be mathematically described with confidence
6. RSM data indicates the responses are not simple
7. Colorimetric based RSM procedures based on CIE derived values are applicable to the measurement and adjustment of GCR and UCA values
8. The imposition of a Total Area Coverage specification mask is useful in defining the correct level of three color grey balance for a given black printer level

The CIE color system best describes color difference using a three parameters CIE L*a*b* Lightness, Hue Angle, and Chroma. The combination of all of these is needed to make conclusions.

INSIGHT

GENERAL

The GCR/UCA targets must be made to reflect the inks used at a particular printing location. This is facilitated by the use of standard ink sets e.g. SWOP, GAA Group IV and ISO. These standard ink sets must be defined colorimetrically for all colors including black. A three color grey must be defined that recognizes the change from neutrality for four color images if the specified black is not neutral.

OPTIMUM GCR LEVELS

Former papers concluded that the best GCR results would be obtained if the GCR and Conventional images looked the same [7]. Former information also concluded that GCR printing was potentially more stable throughout a press run [8, 9] since most of the information was carried by the black printer.

The RSM GCR/UCA contour diagrams indicate some quasi linear response areas within the TAC Mask as seen on a individual response and "e: contour plot. Such areas containing straight line portions that track or run parallel to each other is an indicative of process stability. Straight line responses appear to be associated for these data with of high black separation TAC. These more stable levels appear for the sites studied appear to be at black printer TAC levels of over 65%. The contention by Sayanagi [10] and others that the black printer should be set for the highest possible point for optimum GCR printing may have relevance in not only allowing the employment of the Neugabauer equations but also in establishing a more stable print process.

STANDARDIZATION

Recent papers indicate differences exist between what scanner programs produce as a particular GCR level. It is proposed that for the sake of standardization the black separation TAC value be called the GCR level and the UCA level be called the YMC TAC level.

Many have asked "how can I tell what level of GCR/UCA has been used to produce a specific set of separations? This work appears to indicate that a technique based on the TAC value from the Black Separation and a TAC value of the same position of the Y M C films might provide the answer. The use of a protocol in which the horizontal patches of the GCA/UCA were assigned letters corresponding to Black Printer TAC [or GCR level] and the vertical [YMC TAC] patches designated as single digit numerical values can provide inter and intra shop GCR communication. Already developed scanned film sets with unknown GCR/UCA levels can be read by transmission densitometry and the black printer TAC identified as well as the total YMC TAC identified.

These values can be used to identify a specific coordinate patch in the protocol format whose alpha/numeric designation identifies the GCR/ UCA properties of that film. If the Black TAC and the YMC TAC do not fall in the same box or position the system is not balanced. Film inspection reports could include these values. Departure from them indicates a change in the GCR/UCA level. With increasing film sampling a shop can analyze relative aim points based on these alphanumeric values and implement a Statistical Quality Control procedure.

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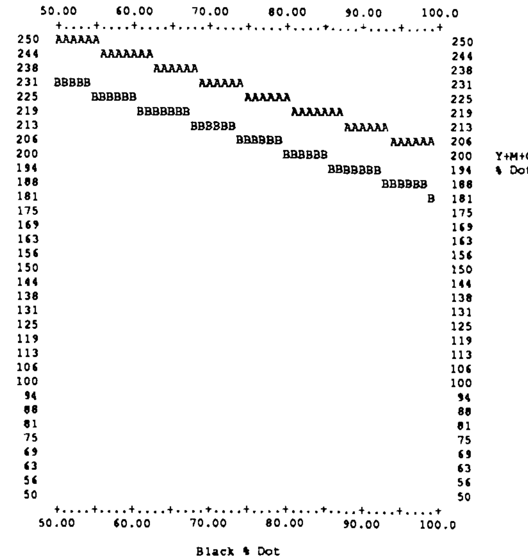
RESPONSE	REGRESSION EQUATION	R-SQUARED %
TAC	$225 + 25x + 100y$	100
SITE XY		
Density	$1.51 + 0.176x + 0.251y + 0.0406x^2 - .0254y^2$	95.8
HE	$16.5 + 8.01x + 0.86y + 26.6x^2 + 10.8y^2$	15.1
L*	$21.4 - 5.20x - 6.87y - 0.799x^2 + 1.46y^2$	94.6
h_{ab}	$106 + 4.49x + 2.87y + 19.2x^2 + 19.3y^2$	71.7
C*	$5.83 - 1.87x + 1.71y + 0.561x^2 - 1.58y^2$	78.4
"e"	$108 + 3.40x + 1.77y + 19.0x^2 + 19.4y^2$	71.1
SITE ZA		
Density	$1.46 + 0.223x + 0.241y + 0.0689x^2 - 0.0251y^2$	94.7
HE	$7.69 + 7.57x - 7.88y + 21.5x^2 + 21.3y^2$	23.0
L*	$22.2 - 6.82x - 7.11y - 1.41x^2 + 1.35y^2$	92.8
h_{ab}	$103 + 3.86x - 9.47y + 28.2x^2 + 27.8y^2$	80.8
C*	$6.95 - 2.58x + 2.98y + 0.383x^2 - 2.17y^2$	88.6
"e"	$106 + 21.5x - 6.38y + 2.76x^2 + 27y^2$	53.4

Summary of Regression Equations and Correlation Coefficients

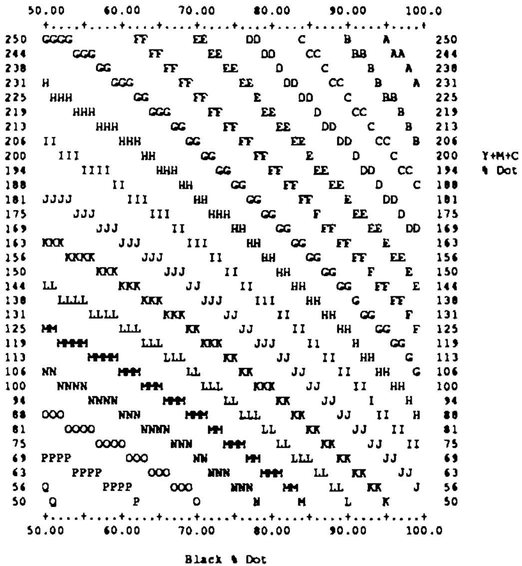
RESPONSE SURFACE - TAC



VALUES OF CONTOUR LINES:
A = 300.0000 B = 280.0000

Total Area Coverage Mask 280-300%
Figure 1

RESPONSE SURFACE - DENSITY
SITE XY

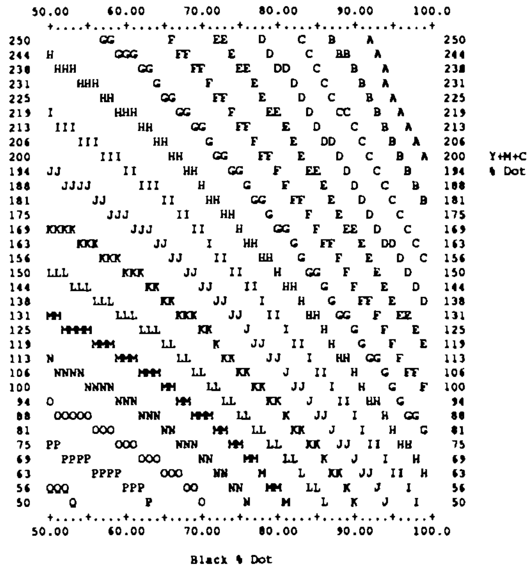


VALUES OF CONTOUR LINES:

A =	1.9000	B =	1.8500	C =	1.8000	D =	1.7500
E =	1.7000	F =	1.6500	G =	1.6000	H =	1.5500
I =	1.5000	J =	1.4500	K =	1.4000	L =	1.3500
M =	1.3000	N =	1.2500	O =	1.2000	P =	1.1500
Q =	1.1000	R =	1.0500	S =	1.0000		

Status "T" Density Response, Site XY
Figure 2

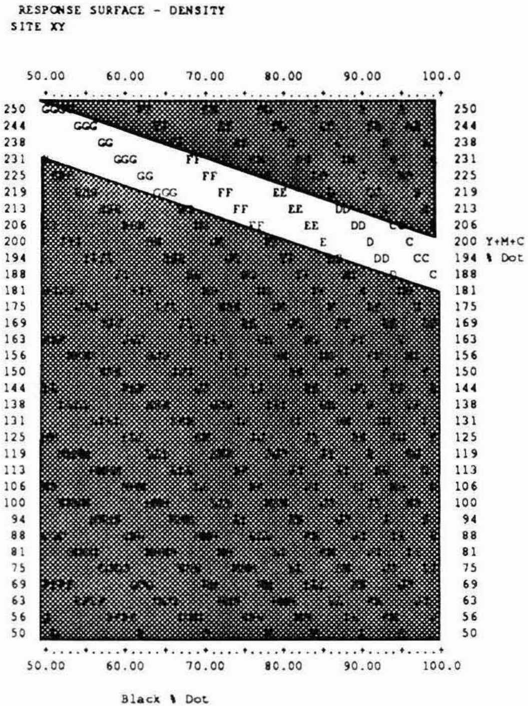
RESPONSE SURFACE - DENSITY
SITE ZA



VALUES OF CONTOUR LINES:

A =	1.8500	B =	1.8000	C =	1.7500	D =	1.7000
E =	1.6500	F =	1.6000	G =	1.5500	H =	1.5000
I =	1.4500	J =	1.4000	K =	1.3500	L =	1.3000
M =	1.2500	N =	1.2000	O =	1.1500	P =	1.1000
Q =	1.0500	R =	1.0000	S =	0.9500	T =	0.9000

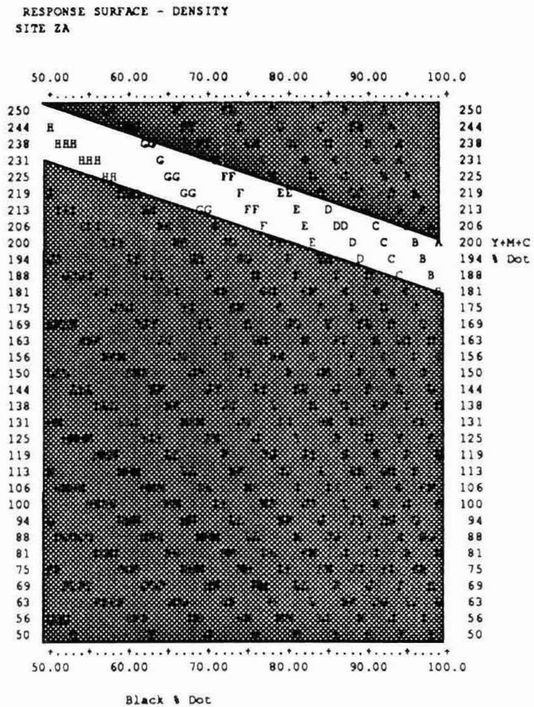
Status "T" Density Response, Site ZA
Figure 3



VALUES OF CONTOUR LINES:

A =	1.9000	B =	1.8500	C =	1.8000	D =	1.7500
E =	1.7000	F =	1.6500	G =	1.6000	H =	1.5500
I =	1.5000	J =	1.4500	K =	1.4000	L =	1.3500
M =	1.3000	N =	1.2500	O =	1.2000	P =	1.1500
Q =	1.1000	R =	1.0500	S =	1.0000		

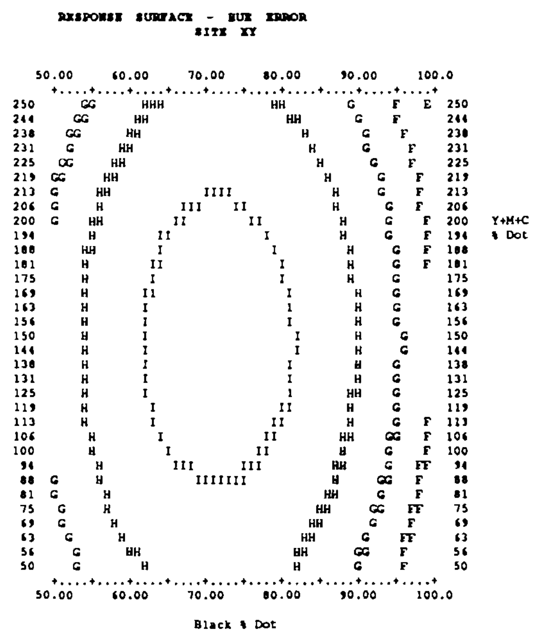
Status "T" Density Response with TAC Mask, Site XY
Figure 4



VALUES OF CONTOUR LINES:

A =	1.8500	B =	1.8000	C =	1.7500	D =	1.7000
E =	1.6500	F =	1.6000	G =	1.5500	H =	1.5000
I =	1.4500	J =	1.4000	K =	1.3500	L =	1.3000
M =	1.2500	N =	1.2000	O =	1.1500	P =	1.1000
Q =	1.0500	R =	1.0000	S =	0.9500	T =	0.9000

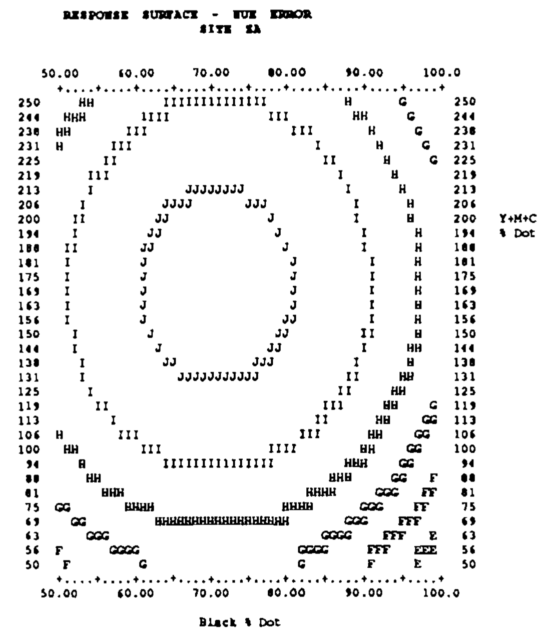
Status "T" Density Response with TAC Mask, Site ZA
Figure 5



VALUES OF CONTOUR LINES:

A =	100.0000	B =	90.0000	C =	80.0000	D =	70.0000
E =	60.0000	F =	50.0000	G =	40.0000	H =	30.0000
I =	20.0000	J =	10.0000				

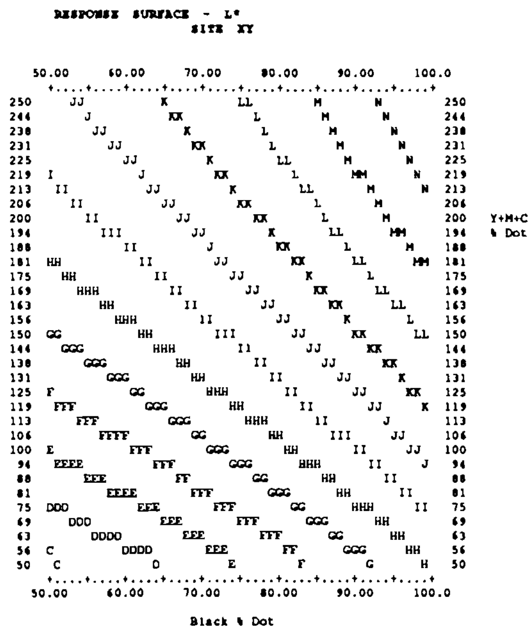
Status "T" Hue Error Response, Site XY
Figure 6



VALUES OF CONTOUR LINES:

A =	100.0000	B =	90.0000	C =	80.0000	D =	70.0000
E =	60.0000	F =	50.0000	G =	40.0000	H =	30.0000
I =	20.0000	J =	10.0000				

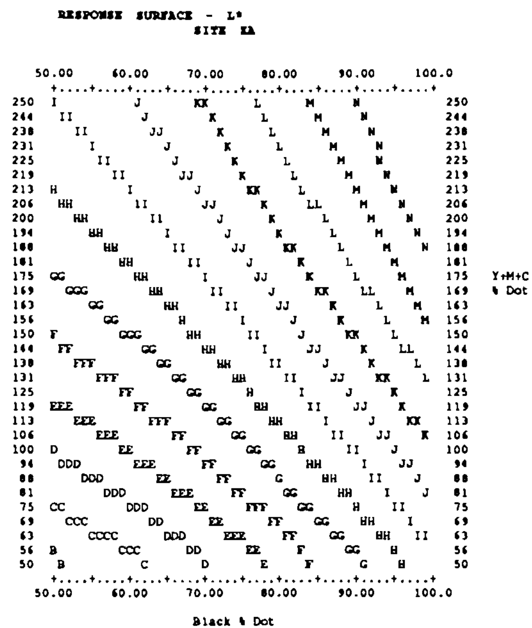
Status "T" Hue Error Response, Site ZA
Figure 7



VALUES OF CONTOUR LINES:

A =	38.0000	B =	36.0000	C =	34.0000	D =	32.0000
E =	30.0000	F =	28.0000	G =	26.0000	H =	24.0000
I =	22.0000	J =	20.0000	K =	18.0000	L =	16.0000
M =	14.0000	N =	12.0000				

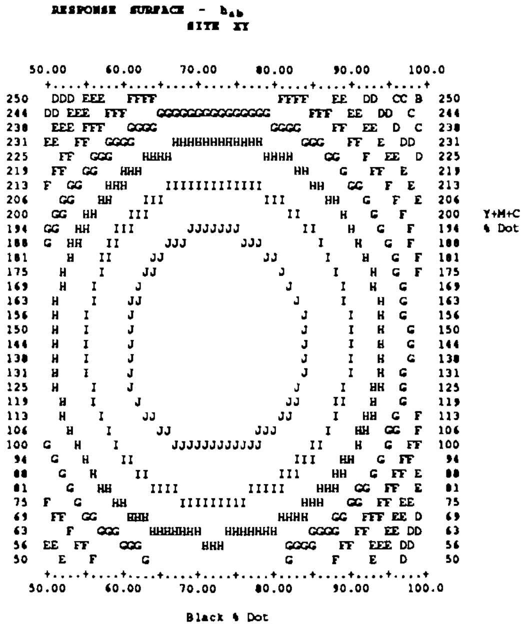
CIE L*a*b* L* Response Site XY
Figure 8



VALUES OF CONTOUR LINES:

A =	38.0000	B =	36.0000	C =	34.0000	D =	32.0000
E =	30.0000	F =	28.0000	G =	26.0000	H =	24.0000
I =	22.0000	J =	20.0000	K =	18.0000	L =	16.0000
M =	14.0000	N =	12.0000				

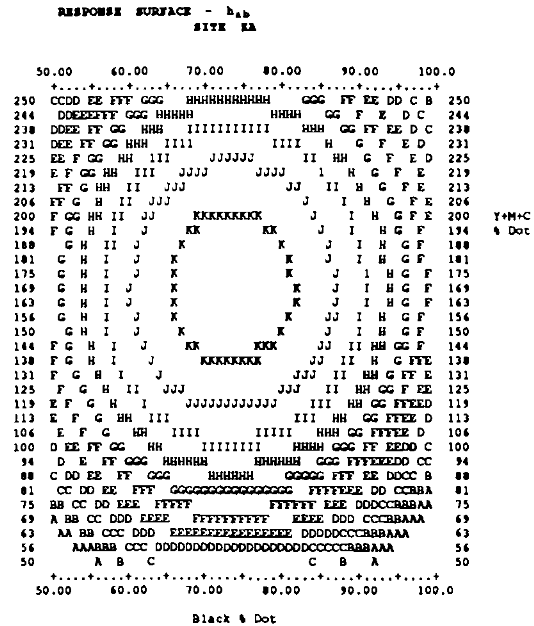
CIE L*a*b* L* Response Site ZA
Figure 9



VALUES OF CONTOUR LINES:

A =	155.0000	B =	150.0000	C =	145.0000	D =	140.0000
E =	135.0000	F =	130.0000	G =	125.0000	H =	120.0000
I =	115.0000	J =	110.0000	K =	105.0000	L =	100.0000
M =	95.0000						

CIE L*a*b* Hue Angle Response, Site XY
Figure 10

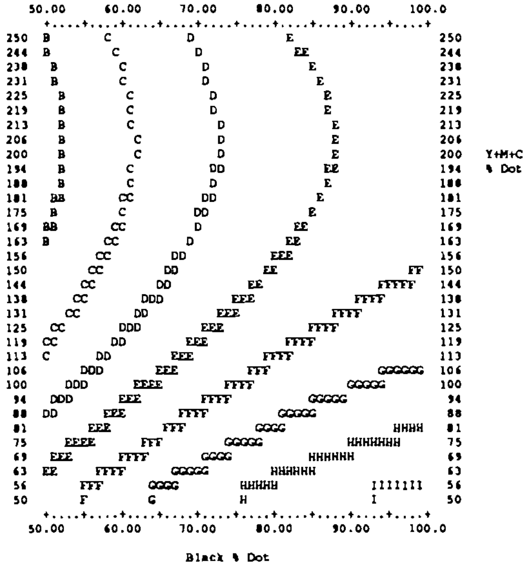


VALUES OF CONTOUR LINES:

A =	155.0000	B =	150.0000	C =	145.0000	D =	140.0000
E =	135.0000	F =	130.0000	G =	125.0000	H =	120.0000
I =	115.0000	J =	110.0000	K =	105.0000	L =	100.0000
M =	95.0000						

CIE L*a*b* Hue Angle Response, Site ZA
Figure 11

RESPONSE SURFACE - C*
SITE XY

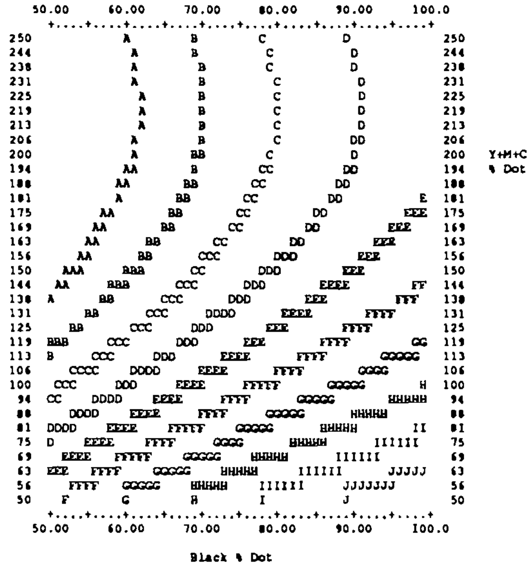


VALUES OF CONTOUR LINES:

A =	9.5000	B =	8.5000	C =	7.5000	D =	6.5000
E =	5.5000	F =	4.5000	G =	3.5000	H =	2.5000
I =	1.5000	J =	0.5000				

CIE L*a*b* C* Response, Site XY
Figure 12

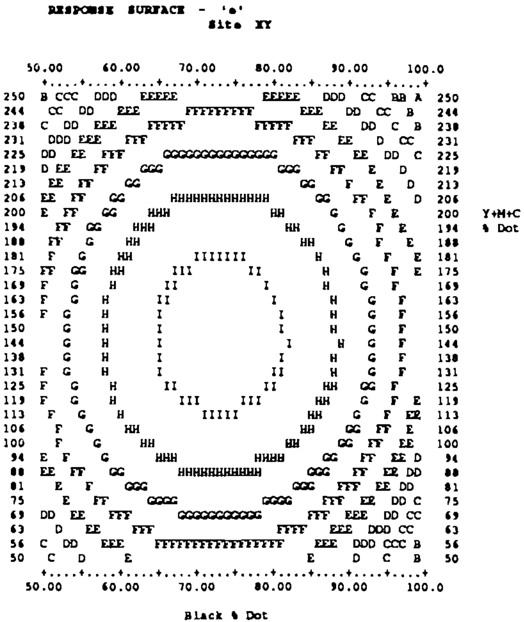
RESPONSE SURFACE - C*
SITE ZA



VALUES OF CONTOUR LINES:

A =	9.5000	B =	8.5000	C =	7.5000	D =	6.5000
E =	5.5000	F =	4.5000	G =	3.5000	H =	2.5000
I =	1.5000	J =	0.5000				

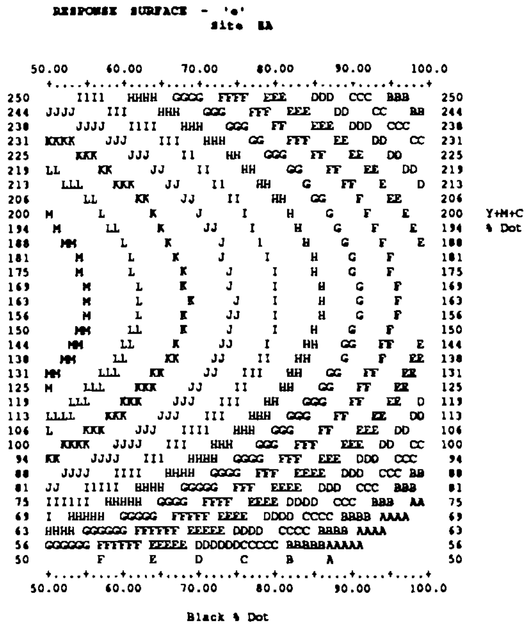
CIE L*a*b* C* Response, Site ZA
Figure 13



VALUES OF CONTOUR LINES:

A =	150.0000	B =	145.0000	C =	140.0000	D =	135.0000
E =	130.0000	F =	125.0000	G =	120.0000	H =	115.0000
I =	110.0000	J =	105.0000	K =	100.0000		

Colorimetric "e" Response, Site XY
Figure 14

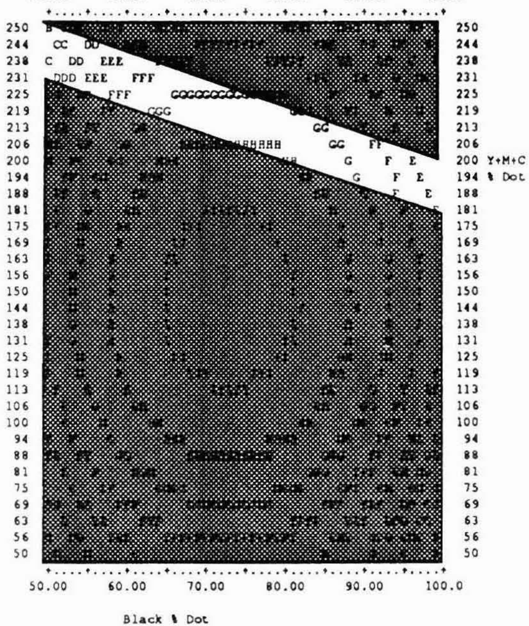


VALUES OF CONTOUR LINES:

A =	150.0000	B =	145.0000	C =	140.0000	D =	135.0000
E =	130.0000	F =	125.0000	G =	120.0000	H =	115.0000
I =	110.0000	J =	105.0000	K =	100.0000	L =	95.0000
M =	90.0000	N =	85.0000	O =	80.0000		

Colorimetric "e" Response, Site ZA
Figure 15

RESPONSE SURFACE - 'e'
Site XY

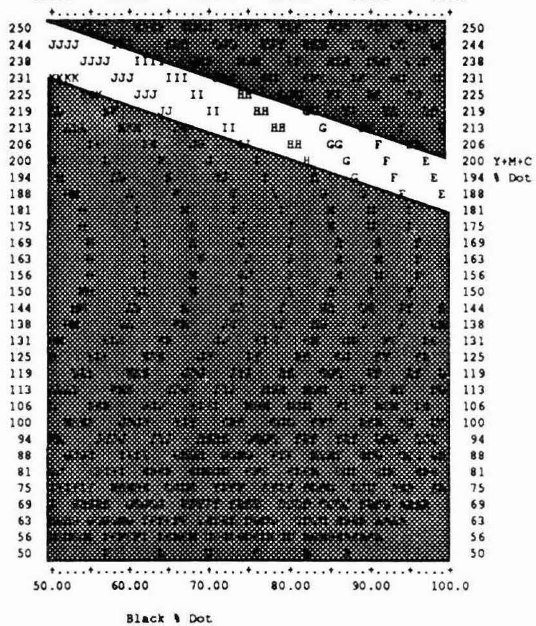


VALUES OF CONTOUR LINES:

A =	150.0000	B =	145.0000	C =	140.0000	D =	135.0000
E =	130.0000	F =	125.0000	G =	120.0000	H =	115.0000
I =	110.0000	J =	105.0000	K =	100.0000		

Colorimetric "e" Response with TAC Mask, Site XY
Figure 16

RESPONSE SURFACE - 'e'
Site ZA



VALUES OF CONTOUR LINES:

A =	150.0000	B =	145.0000	C =	140.0000	D =	135.0000
E =	130.0000	F =	125.0000	G =	120.0000	H =	115.0000
I =	110.0000	J =	105.0000	K =	100.0000	L =	95.0000
M =	90.0000	N =	85.0000	O =	80.0000		

Colorimetric "e" Response with TAC Mask, Site ZA
Figure 17